CHARACTERIZATION OF RANGELAND RESOURCES AND DYNAMICS OF THE PASTORAL PRODUCTION SYSTEMS IN THE SOMALI REGION OF EASTERN ETHIOPIA

BY

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DEDICATION

This thesis is dedicated to all the pastoralists of Ethiopia, who lived for generations in a harsh environment and who managed to maintain productivity in the arid rangelands of Ethiopia and supporting the national economy of the nation through their traditional livestock production systems.

DECLARATION

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

Amaha Kassahun Gezahegn

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DEPARTMENT: Animal, Wildlife and Grassland Sciences
DEGREE: Doctor of Philosophy

ABSTRACT

Additional index words: Biodiversity, degradation gradient, drought simulation feeding, rangeland condition, grazing behaviour, grazing/browsing capacity, key fodder species, soil characteristics, soil degradation, pastoral perceptions

The study was conducted in the Somali region of eastern Ethiopia, with an arid to semi-arid climate. The study aimed at the characterization of the rangeland resources, assessing the current condition of the rangeland, understanding pastoral perceptions on rangeland degradation and developing drought feeding strategies for livestock.

Three experimental sites, representative of the three predominant vegetation types of eastern Ethiopia were selected. They were the arid Asbuli grassland (used as grazing area for large and small ruminants), the arid Aydora open savanna (bush-grassland: entirely used for grazing/browsing by all types of livestock), and the semi-arid Hurso closed savanna (bushland: selected for its importance as browsing for camels and goats).

A degradation gradient was identified in each of the three vegetation types, where the botanical composition was surveyed and the rangeland condition assessed. The perceptions of the pastoralist on rangeland degradation were also quantified. The dry matter production of both the herbaceous and woody layer was determined, while the grazing and browsing capacity calculated. Key forage species were identified and the grazing pattern of various livestock species along the degradation gradient studied. The soil seed bank regeneration potential was assessed in a greenhouse experiment and the response of cattle, sheep and goats to a simulated drought, in terms of reduced fodder, was conducted under controlled conditions.

The results of the study confirmed the existence of severe rangeland degradation that occurred since 1944 and which was aggravated after the 1974 drought. This contributed to an increase in the number of poor households. The average livestock holding per household declined from 809 Tropical Livestock Units (TLU) before 1974 to 483 TLU after 1974. Livestock holding shifted from a predominance of cattle to small ruminants, which are able to utilize the degraded rangeland more effectively. Camels are now the most important livestock species in terms of milk and meat production, mainly due to their ability to tolerate drought.

The abundance of herbaceous plants, basal cover, dry matter production and grazing capacity was found to be higher in the benchmark sites compared to the other rangeland conditions. There was also a corresponding increase in percentage bare ground, soil compaction and soil erosion along the degradation gradients. Over-grazing and over-utilization through continuous grazing of the herbaceous layer were identified as the main causes of these differences.

Rangeland condition was observed to significantly influence the grazing behaviour of livestock in terms of plant species selection, grazing intensity and intake per animal. When forage sources were adequately available, animals selected fever plant species. As forage resources declined the animals spend more time grazing and more species selected, including less palatable species. The number of bites, intake per bite and intake as a percentage of the animal's body mass also increased as the rangeland become more degraded.

Acacia nubica and *A. mellifera* were identified as aggressive encroaching species in the Aydora open savanna and Hurso close savanna. The Aydora open savanna experienced extensive encroachment by woody plants with increasing plant densities across the degradation gradient. The Hurso closed savanna experienced an opposite trend where severe deforestation and a loss of valuable browse species occurred, mainly as a results of over cutting of the woody plants for firewood, charcoal making, construction and the clearing of the land for planted crops.

The study on the soil seed bank of soil collected along the various degradation gradients showed a high abundance of plant seed present in the soil, confirming the potential of the area for rangeland restoration.

As expected the body weight losses of all livestock species in the controlled feeding trial were highly correlated with the reduction in daily dry matter feed. More than 50% of the animals showed pronounced emaciation and physical weakness and 25% of the cattle and goats collapsed and died within ten weeks after the trial started. This explained the large scale mortalities of livestock during prolonged droughts.

Drought must be accepted as part of the pastoral life and there should be an adequate early warning system regarding livestock feed availability and strategies of appropriate mitigation strategies. More realistic stocking rates is the obvious solution to the avoidance of stock losses during droughts, but in view of the well established culture of the pastoralists it is highly doubtful if they will be willing to reduce their animal numbers. In conclusion, the experimental results indicated the existence of genetic variability among the various Somali livestock breeds regarding the tolerance to feed shortages and in rates of compensatory growth. This demonstrates the opportunity for improving the genetic composition of the Somali herds through selection.

UITTREKSEL

Die studie is in die Somalie gebied, geleë in die oostelike deel van Ethiopië, uitgevoer. Die klimaat wissel van aried tot semi-aried. Die doel met die studie was die karakterisering van die natuurlike hulpbronne, die vasstelling van die huidige veldtoestand, die ontleding van die persepsies van die veeboere teenoor weiveldagteruitgang en die ontwikkeling van 'n droogte strategie vir vee.

Drie studiepersele is geïdentifiseer wat die plantegroei van die oostelike deel van Ethiopië verteenwoordig. Hierdie persele het die grasveld van die ariede Asbuli (word gebruik as weiding deur beide groot- en kleinvee), die oop savanna plantegroei van die ariede Aydora (bos-grasgemeenskap wat uitsluitlik gebruik word deur alle grasbenutters en struikvreters), en die geslote savanna plantegroei van die semi-ariede Hurso gebied (bosveld: waarop die keuse geval het as belangrikste struikbenuttergebied deur veral kamele en bokke) ingesluit.

'n Degradasiegradiënt is vir elk van hierdie plantegroeitipes geïdentifiseer, waar die botaniese samesteling en weidingkapasiteit vasgestel is. Die persepsies van die veeboere jeens weivelddegradasie is ook gekwantifiseer. Die droë materiaalproduksie van beide die graslaag en boomkomponent is vasgestel, terwyl die weidingkapasiteit van beide die kruid- en boomlaag gemonitor is. Sleutel voerplantspesies is oor die degradasiegradiënte gekwantifiseer, terwyl die beweidingspatrone van verskeie veesoorte ook ondersoek is. Die ontkiemingsvermoë van saad in die grond is geëvalueer om die moontlikhede van veldherstel vas te stel. Die reaksie van beeste, skape en bokke onder gesimuleerde droogtetoestande is verder geëvalueer.

Die resultate ondersteun die bevindinge van grootskaalse weivelddegradasie wat waargeneem is sedert 1944 en wat verdere afmetings met die 1974 droogte aangeneem het. Dit het aanleiding gegee tot 'n toename in gesinsarmoede. Die gemiddelde rykdom van die veeboere, in terme van dieregetalle, het van 809 Tropiese Vee-eenhede (TVE) voor 1974 afgeneem tot 483 TVE na 1974. Die aanhouding van diere het verskuif van

hoofsaaklik beeste na slegs kleinvee wat die gedegradeerde weiveld beter kan benut. Kamele vorm tans die belangrikste spesie in terme van melk- en vleisproduksie, hoofsaaklik weens hulle vermoë om droogtes beter die hoof te bied.

Die voorkoms van grasse, toename in basale bedekking, droë materiaalproduksie en weidingkapasiteit was hoër in die veldverwysingspunt as in die ander veldtoestande. Die persentasie kaalgrond, grondkompaksie en gronderosie het verhoog met velddegradasie. Oorbeweiding en oorbenutting van die kruidlaag (grasse en kruide), as gevolg van aanhoudende beweiding is geïdentifeseer as die hoofrede vir hierdie verskille.

Veldtoestand is vasgestel as die faktor met die grootste invloed op dieregedrag in terme van plantseleksie, intensiteit van beweiding en die inname per dier. Wanneer die voedingsbron nie beperkend was nie, het die diere minder plantspesies geselekteer. Soos wat die voedingsbron afgeneem het, het die diere langer tye spandeer aan beweiding en ook meer spesies geselekteer, wat ook meer onsmaaklikes insluit. Die aantal happe, inname per hap en inname as ‘n persentasie van die dier se liggaamsmassa het ook toegeneem met degradasie van die weiveld.

Acacia nubica en *A. mellifera* is geïdentifiseer as aggresiewe indringerspesies in veral die Aydora oop savanna en Hurso geslote savanna gebiede. Die Aydora oop savanna gebied het ‘n geweldige toename in bosindringing ondervind, asook ‘n toename in plantdigtheid oor die degradasie gradiënte. Die Hurso geslote savanna het weer net die teenoorgestelde ondervind, naamlik ‘n verlies aan plantegroei verskeidenheid, waarskynlik weens oorontginning van die bome as vuurmaakhout, houtskool, vir konstruksie doeleindes en die uitkap daarvan vir die verbouing van akkerbougewasse.

Die saadbankstudie het ‘n hoë voorkoms van sade in die grond van verskillende veldtoestandklasse getoon, wat daarop dui dat die gebied oor die potensiaal beskik om te herstel.

Soos verwag, was die verlies in liggaamsmassa by al die veetipes hoogs gekorreleerd met die afname in daaglikse droëmateriaal inname. Meer as 50% van die diere het ‘n konstante agteruitgang en fisiese swakheid getoon, terwyl 25% van die beeste en bokke, tien dae na aanvang van die proef, totaal ingegee en gevrek het. Hierdie bevinding beklemtoon die grootskaalse vrektes wat weens langdurige droogtes in hierdie gebied voorkom.

Droogte moet as deel van die veeboer se leefwyse en beplanning beskou word en daarom moet daar vroegtydige waarskuwingsdienste ingestel word ten einde voerskaarstes te identifiseer, sodat versagtingstrategië vir droogtes geïmplementeer kan word. Meer realistiese veebeladings is die belangrikste oplossing tot voorkoming van veevrektes gedurende droogtes. Weens die goedgevestigde kultuur van die veeboere in hierdie gebied, is dit onwaarskynlik dat hulle hul diere om hierdie rede sal verminder. Die resultate toon onteenseglik dat daar wel genetiese variasie in die Somaliese diere bestaan wat betref hulle weerstand teen voerskaarste en groeitempo tydens veldherstel. Hierdie bevinding demonstreer die geleentheid wat wel bestaan, deur met die regte seleksie, die verbetering van die genetiese samestelling van die Somaliese kudde bewerkstellig kan word.

CHAPTER 1

INTRODUCTION

1.1 PASTORALISM IN ETHIOPIA

Ethiopia is a tropical African country, located between 3^{o}E and 18^{o}N, with a total land area of approximately 1.1 million km^2. It is strategically located in the Horn of Africa and borders Eritrea in the north and northeast, the Sudan in the northwest and southwest, the Somali and Djibouti republics in the east and the Kenya republic in the south. The topography ranges from 100 m.b.s.l in the northeast of the country known as Dalol depression, where the great African Rift vlley starts and then continues to Lake Victoria. The maximum altitude is recorded at the Ras Dashen mountain with 4 300 m.a.s.l (EMSA, 2004), which is registered as a world heritage site by the United Nations. Ras Dashen further bridges the Central Highlands that stretch up to the eastern lowlands of the country.

The agro-ecology of Ethiopia is quite diverse and varies from arid tropics, where the annual precipitation is below 200 mm in the lowlands and above 1 400 mm in the humid tropics. Likewise, the drylands of Ethiopia are mainly characterized by arid, semi-arid and dry humid agro-ecologies. According to MOA (1996), the aridity index includes A1.1-A1.7 (dry hot to warm), A2.1 to A2.7 (tepid to cool arid), M1.1 to M1.7 (hot to warm moist), SA1.1 to SA2.2 (hot to warm semi-arid) and SM1.1 to SM1.7 (hot to warm sub-moist) and SM2.1 to SM2.7 (tepid to cool sub-moist) (Figure 1.1 and Appendix 1.1).

Pastoral production systems (pastoralism) represent the largest land use system of the agricultural sector (Solomon Desta, 1993; Amaha, 2003), and are based on mobile rangeland livestock production systems (Helland, 1977; Samuel, 2003). Accordingly, the rangelands of Ethiopia are mainly located within the arid and semi-arid agro-ecological regions below 1 500 m.a.s.l, covering about 62% (682 000 km^2) of the total land area of Ethiopia (EARO, 2002).

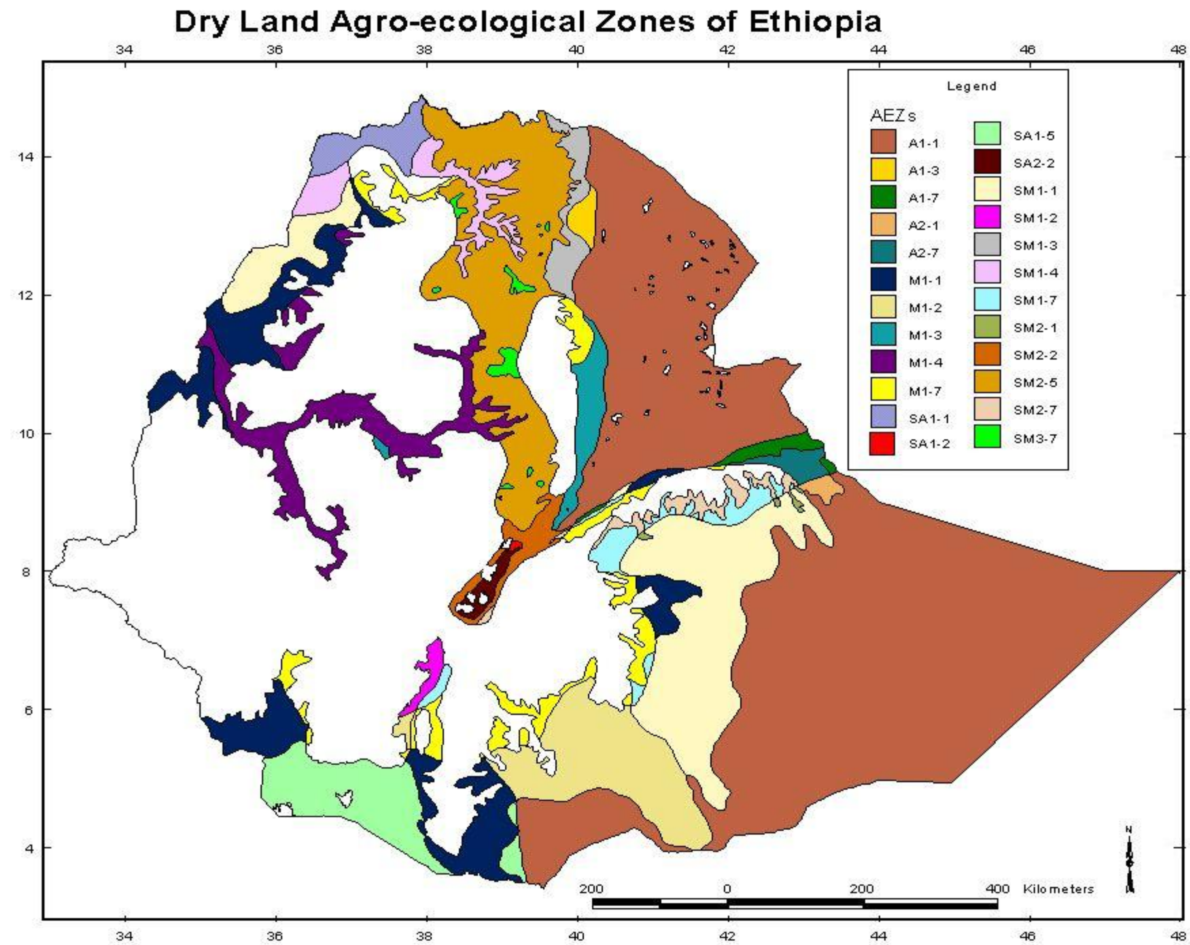

Figure 1.1 The classification of the dryland agro-ecological zones of Ethiopia (EMSA, 2004). The legend is presented in Appendix 1.1.

According to EARO (2002) the drylands of Ethiopia are dominated by rangeland based livestock production systems known as pastoralism and agro-pastoralism (partly involved in opportunistic cropping) and represent a significant sector of the national agriculture in the country. For example, pastoralists represent approximately 37% (26.6 million) of the national population that include an estimated 12.24 million (17%) mobile pastoralists and 14.4 million (20%) agro-pastoralists. Mobile pastoralism is dominant in the arid and semi-arid areas in the eastern, northeastern and southeastern parts of the country, while agro-pastoralism represents an increasing practice in the semi-arid areas in the northwestern, southern and eastern parts of the country. In general, they represent the major pastoral constituency in the Horn of Africa (Amaha, 2002).

The pastoral and agro-pastoral production system also represent approximately 45-55% of the cattle, 75% of the small ruminants, 20% of the equines and 100% of the camels of the total national livestock population. Accordingly, they contribute about 50% to the national agricultural Gross Domestic Product (GDP) and 90% of the annual hard currency earnings from live animal exports (EARO, 2002). The main mobile pastoralists in Ethiopia are the Somalis (Somali region) in the east, the Afars (Afar region) in the northeast, the Oromos (Oromiya region) in the south and south-east and the Southern Omo people (Southern region) in the south and partly in the Gambela and Benshangul regions and around the Dire Dawa Administration (Figure 1.2).

Despite the large size of the regional livestock population, its economic contribution to the regional and national economy is not significant, mostly due to natural and human limitations. The latter include the impacts of environmental and rangeland degradation (Gemedo-Dalle *et al*., 2006), increasing aridity and the occurrence of recurrent droughts at shorter intervals of every third year, causing feed and water shortages. As a result, there are high livestock mortalities in most pastoral areas (Amaha, 2003). Simultaneous outbreaks of livestock diseases are also common and spread along the drought fronts, aggravating the number of animal mortalities. Therefore, pastoralists in general and the livestock in particular are vulnerable to ecological disturbances and macro climatic variability, often resulting in food insecurities and feed shortages in the pastoral regions (SoRPARI, 2005a). Furthermore, production of grains in those pastoral regions is inadequate to supply the increasing demand by the existing population. Generally, crop yields per hectare are low (0.5-1.0 t ha^{-1}), while fertilizer usage and irrigation practices are not yet established. The pastoral regions are therefore, classified as structurally food insecure areas in Ethiopia.

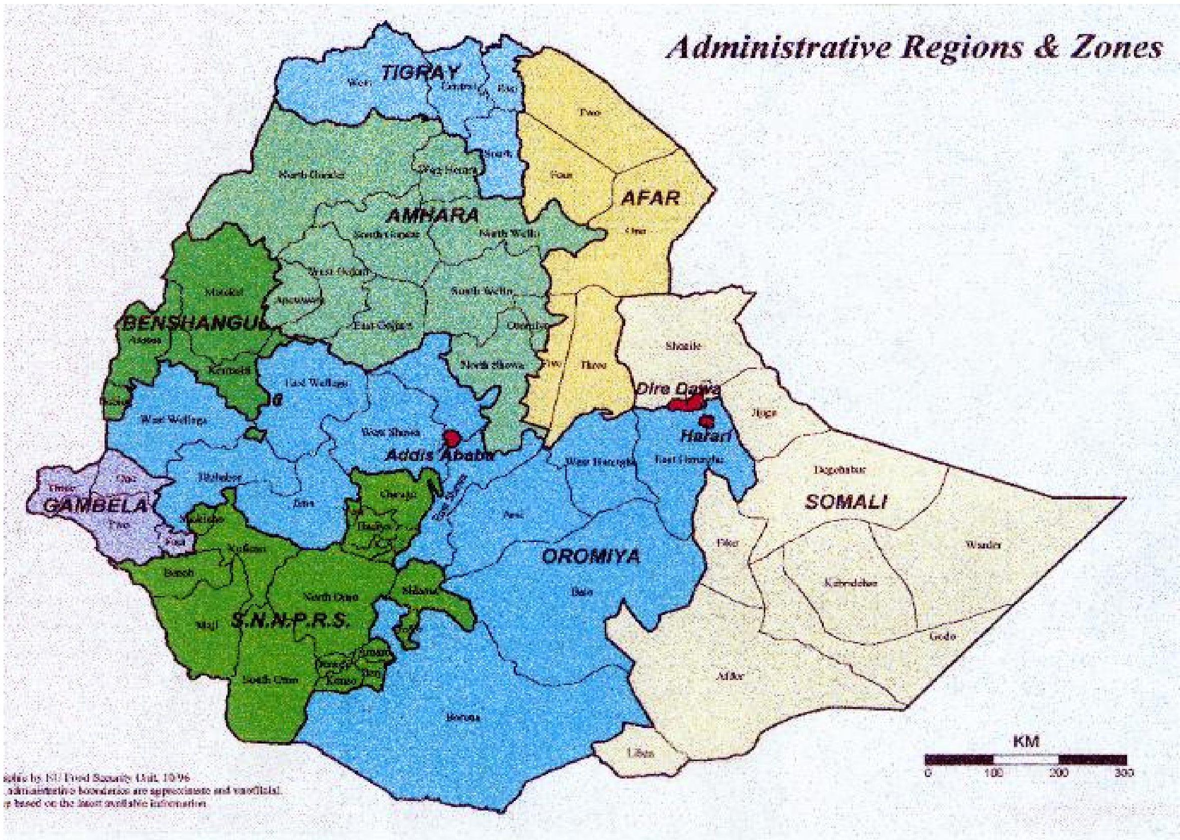

Figure 1.2 Map of Ethiopia showing the nine administrative regions and zones (EMSA, 2004).

The population of Ethiopia is estimated at approximately 72 million with a demographic distribution of 49% men and 51% women (CSAE, 2004). Agriculture is the main occupation and employs more than 80% of the population, with pastoralism as the main traditional livestock production system in the country. In relation to the latter, the main pastoral areas are: Somali, Afar, Southern Oromiya and Southern Nations and Nationalities (SNNPRS) and partly Gambela, Benshangul and Dire Dawa.

On top of inappropriate policies, both at Federal and Regional levels, rangeland degradation and recurrent droughts in the region have become obvious constraints, causing deaths of livestock and deterioration of the pastoral production system. The latter is expressed in terms of increasing poverty, famine, destitution and social destabilization of most pastoralists. This is being aggregated by the fact that livestock is not only a means of livelihood, but also of social security (Vetter *et al.*, 2006).

As a result of the variations in topography and agro-ecological zones, Ethiopia is endowed with the highest livestock population in Africa and tenth in the world. Accordingly, the estimated number of livestock population includes about 40 million cattle, 28 million sheep, 20 million goats, 4 million camels, 4 million equines and 52 million chickens. In terms of economic contribution, livestock contributes approximately 40% to the annual Gross Domestic Product (GDP) and nearly 20% to the national GDP (MOA, 1996; CSAE, 2004).

Livestock provides milk, meat, skins and hides and serves as means of employment, live assets (living banks), source of income, agro-industrial investment, source of draught power and organic manure (Amaha, 2003). To pastoralists in the Horn of Africa, livestock further serves the purpose of wealth accumulation, social prestige, social security, drought bridging mechanism, for marriage gifts and debt payment. The prevailing gaps in knowledge and challenges in the context of the pastoral production system and the pastoral communities in Ethiopia include:

(i) absence of appropriate, researched information systems, both at national and regional levels,

(ii) lack of appreciation for indigenous knowledge and participatory development planning,

(iii) lack of knowledge of rangeland resources, which include vegetation types and their uses, current health status of the rangeland and the soil seed banks,

(iv) lack of information on the grazing and browsing capacities of the different rangelands and appropriate restoration techniques,

(v) lack of documented data on the potential vegetation resources (biodiversity) and local/industrial values (ethno-botany),

(vi) lack of knowledge on the state of deterioration of the floras and faunas of the rangelands,

(vii) lack of commitment and research systems to rehabilitate or restore degraded rangelands,

(vii) poor management of livestock populations and rangeland resources,

(viii) unimproved and non market-orientated livestock production systems,

(ix) absence of a systematic and dependable market for livestock,

(x) prevalence of different animal diseases and lack of adequate health service systems,

(xi) poor pre/post drought livestock contingency strategies, and

(xii) lack of rangeland and livestock integrated research systems which can reverse the threat of famine and ensure the sustainability of pastoral production systems.

1.2 MOTIVATION FOR THE RANGELAND STUDY IN EASTERN ETHIOPIA

Despite a general understanding of the importance of pastoralism and agro-pastoralism, in terms of land coverage and resource base in Ethiopia, there has been little or no attempt to solve the problems of the pastoral areas. To this end, the pastoral production systems in Ethiopia have remained neglected until as recently as 1995 (Amaha, 2003). However, since 1995 some attention was given to the pastoral production systems, both at federal and regional levels.

Based on past trends in environmental degradation and current issues of rangeland degradation, there is clearly a need for integrated research and development interventions in those marginalized pastoral and agro-pastoral areas of the country (Gemedo-Dalle *et al.*, 2006). Similarly, reports by governmental and non-governmental institutions and other international lobby groups, emphasized the urgent need for the design and application of holistic research and development (EARO, 2002).

The Ethiopian Agricultural Research Organization (EARO, 2002), has taken the initiative and institutionalized the 'National Pastoral and Agro-Pastoral Research Program' during 1999, specifically aimed at addressing pastoral issues, problems and technologies related to the rangelands of Ethiopia (EARO, 2002). Furthermore, the Somali Regional State has also taken similar action in 2002 and established a research institute known as the

"Somali Region Pastoral and Agro-pastoral Research Institute (SoRPARI, 2006)", while other regions like the Afar, Oromiya and Southern Nations and Nationalities Regional States have taken similar actions (SRDPPB, 2004). The Gambela and Benshangul Regional States are currently making efforts to institutionalize pastoral research activities.

At the federal level the Ethiopian Government has established a Ministry of Federal Affairs, with the main task of addressing development programs in pastoral areas. As a consequence, the pastoral production system in general, and the rangelands of eastern Ethiopia in particular, have now officially been prioritized in the national research agenda for the following reasons:

(i) neglection of the pastoral areas by the national agricultural research and development systems in the recent past,

(ii) an increase in the intensity and magnitude of degradation of the rangeland vegetation in terms of negative changes in vegetation patterns and ecological niches,

(iii) an increase and expansion of encroachment by non-palatable and undesirable (noxious) endemic woody plants and exotic weeds,

(iv) the intrusion, expansion and intensification of problems related to sand sheets and dunes mainly from the eastern side to the western direction of the country, increasing wastage of useful and potential rangelands,

(v) increased rainfall runoff losses, wind and soil erosion and expansion of extensive gullies that have left valuable rangelands wasted and beyond recovery,

(vi) intensification and expansion of deforestation due to over cutting of trees for fuel wood, charcoal and construction purposes induced by poverty, unemployment, lack of awareness and lack of land use and conservation policies,

(vii) an increase in human and livestock population, causing rangeland deterioration through overstocking and overgrazing,

(viii) loss of biodiversity of valuable plants with social and economic values, due to absence of appropriate policies and conservation strategies,

(ix) deterioration in livestock production from high value (cattle) to low value (small ruminants) animals due to disturbances of rangeland ecological niches by human induced impacts and droughts,

(x) outbreak of contagious and non-contagious livestock diseases and absence of prevention and treatment mechanisms and the weakening of traditional ethno-veterinary practices,

(xi) lack of understanding by policy makers, development planners and scientists of the pastoral and agro-pastoral production systems, socio-economic settings and perceptions of the pastoralists, and

(xii) increases in the problems of feed and water shortages, due to biotic and abiotic influences, as well as lack of appropriate technologies and strategies to control or remedy the situation.

General observations indicate that in Ethiopia, degradation of the rangeland vegetation is increasing. As a result, there is a shift from mobile pastoralism to an agro-pastoral production system, with a continuing loss of bio-diversity. Recurrent droughts and livestock mortalities are increasingly destabilizing pastoralists, both socially and economically. Despite this reality, however, lack of documented information might have contributed to bias and phobias in the process of research and development planning.

Within this context, it is therefore possible to state that the sustainability of pastoral livelihood at household level, and their capacity to contribute to the regional and national economy, will depend on the health and status of the rangelands. This statement should, however, be supported with adequate and reliable information that can only be obtained through research.

1.3 GLOBAL OBJECTIVES OF THE STUDY

The global objectives of this particular study are:

(i) to understand the perceptions of the Somali pastoralists of eastern Ethiopia regarding rangeland resources, environmental degradation and socio-economic sustainability,

(ii) to conduct a broad assessment of the botanical resources (bio diversity) of the rangelands of the Somali region of eastern Ethiopia,

(iii) to assess the condition of the herbaceous layers of the rangelands of the Somali region of eastern Ethiopia in relation to their ecological potential,

(iv) to determine the botanical composition and productivity of the woody vegetation, with emphasis on browse production, indigenous ethno botanical uses and ecological significance of woody plants in the various rangeland vegetation types,

(v) to quantify the prevailing soil seed bank and seedling regeneration capacity under different ecological conditions in arid and semi-arid areas of the Somali rangelands of eastern Ethiopia,

(vi) to investigate simulated feeding systems for livestock as a possible drought escaping mechanism, and

(vii) to make appropriate recommendations and compile guidelines for future management of the rangelands of eastern Ethiopia.

CHAPTER 2

STUDY AREA AND EXPERIMENTAL SITES

2.1 INTRODUCTION

The study was done in the Somali Regional State located in eastern Ethiopia, which is divided into nine sub-regional administrative zones that include the Shinile, Jigjiga, Fike, Dege-Habur, Warder, Korahe, Gode, Afder and Liben zones. The Shinile zone, comprising an area of about 85 000 km^2, located in the northern part of the Somali Regional State (Figure 2.1) was found most suitable for the study. Due to the remote nature of the Shinile zone, it was realized that a structured approach was required in selecting and demarcating the specific study area in general and the specific experimental sites within the selected study area in particular, which were subsequently described.

2.2 CRITERIA FOR SELECTING THE STUDY AREA AND EXPERIMENTAL SITES

Following the recommendations of Mannetje and Jones (2000), which stated that the selection of a study area and experimental sites is subject to and dependent on the objective of the scientific study, the following criteria were used to select the study area and experimental sites for this study included:

(i) the dominant arid and semi-arid ecological zones in eastern Ethiopia must be represented,

(ii) the three predominant vegetation types of eastern Ethiopia, viz. grassland, open savanna (bush-grassland) and closed savanna (bushland), must be adequately represented,

(iii) components of the indigenous and endemic vegetation, representative of the original biodiversity of the region, must still be present,

(iv) areas representative of varying degrees of degradation as a result of biotic or abiotic determinants, suitable for the description of degradation gradients, must be readily available,

(v) all documented forms of rangeland degradation such as the effects of drought, bush encroachment, soil erosion, gully formation and sand expansion, must be represented,

(vi) suitable protected areas that can serve as reference sites (benchmarks) for the evaluation of the biological and ecological potential of the regions' rangeland resources must be available,

(viii) the soil and topography must be relatively uniform and comparable,

(ix) roads for access and transportation of research equipment must be available,

(x) restrictions on access due to military activities and undetected land mines must be absent, and

(xi) the area should not fall within a national park, but used for livestock grazing and/browsing in accordance to the traditional management systems, typical of the rangeland-livestock based pastoral production systems of eastern Ethiopia.

2.3 SELECTION OF THE STUDY AREA

2.3.1 Community based participatory approach

A community based participatory approach was applied based on methods described by Walters-Bayer and Bayer (2000). A multi-disciplinary team was formed, involving community members and knowledgeable rangeland managers and scientists for the selection of the study area in the Shinile zone of the Somali region. The team consisted of local pastoralists (clan chiefs and elders), women representatives, livestock herders, governmental and non-governmental development workers of wereda, botanists and soil scientists from the Department of Plant Sciences of the Alemaya University, rangeland managers from the Somali Region Pastoral and Agro-Pastoral Research Institute,

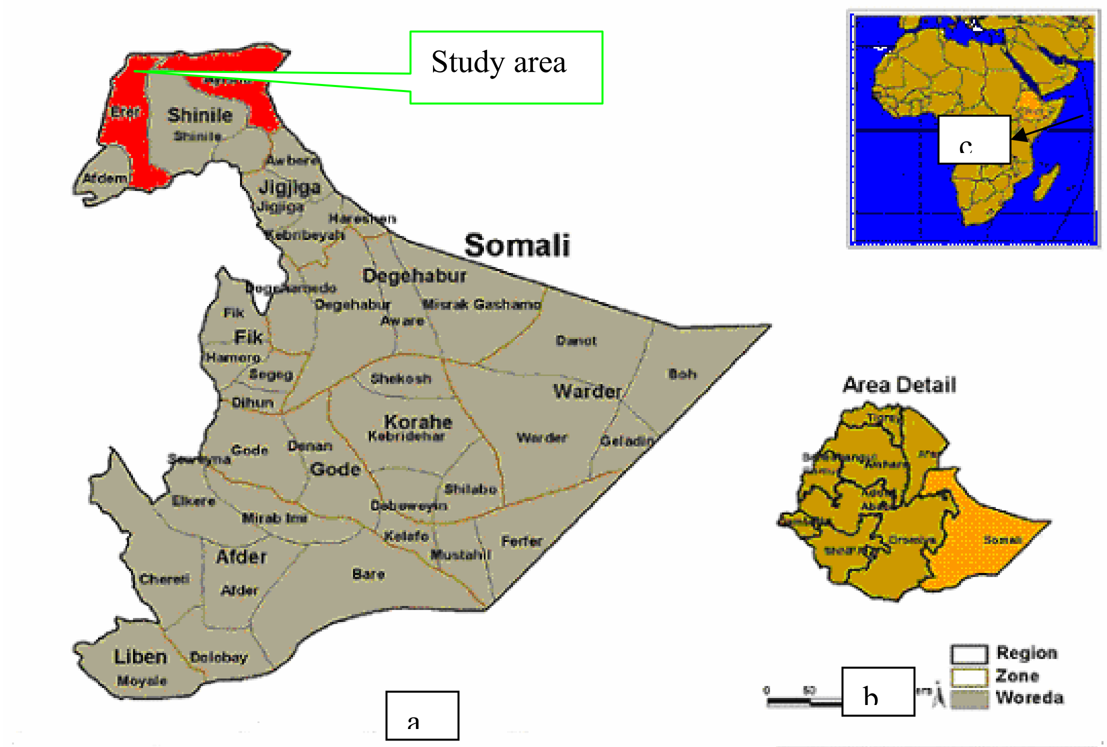

Figure 2.1 The study area (in red color), administrative zones of Somali region (a), location of Somali region in Ethiopia (b) and map of Ethiopia in the Horn of Africa (c).

rangeland experts in the region and local administrators from Erer wereda and the Shinile zone administration offices. Further assistance was obtained from the indigenous knowledge of the pastoralists, scientific publications, primary and secondary data (where reference was available), physical observations and field group discussions. A double cabin pick-up was used for all field trips. For field trips a Geographic Positioning System (GPS), binoculars and a map of Ethiopia (1:250 000 scale) were also used.

2.3.2 Reconnaissance field survey

A reconnaissance field trip was conducted, covering 3 000 km^2, with the purpose of assessing, identifying and selecting the most appropriate rangeland types in the Shinile zone, representing the typical vegetation of the Somali region and eastern Ethiopia. This was done along the main roads from Dire Dawa to the border of Ethio-Djibouti Republic and in the western Gode zone (Figure 2.1). The survey covered grasslands, open savannas (bush-grasslands) and closed savannas (bushlands), where the assessment of the rangelands in terms of their conditions were selected by combining both objective rangeland assessment techniques described by Hardy *et al*. (1999) and subjective systems as described by Van Zyl (1986). For the assessment of the vegetation of the different rangeland types, a checklist was developed in accordance to the criteria set out in section 2.2.

Not all criteria were met during the first field trip and hence a second trip was conducted, whereby nearly 100% of the set criteria were met. As a result the most appropriate rangeland sites for the study located at Erer wereda of Shinile zone of Somali region, eastern Ethiopia were selected (Figure 2.1).

2.4 SELECTION OF EXPERIMENTAL SITES WITHIN THE STUDY AREA

Three experimental sites, that represent the grassland, open savanna (bush-grassland) and closed savanna (bushland) vegetation types of eastern Ethiopia, respectively were selected within Erer wereda. Likewise, the experimental sites were systematically selected using objective and subjective approaches. Knowledgeable and experienced rangeland experts and pastoralists were consulted, whereas closer observation was done through visual inspection of potential areas. All potential sites were listed and among them those sites which met all the pre determined criteria (100%), were selected in agreement with members of the multi-disciplinary team.

According to their local names the three selected experimental sites are known as: (i) the arid Asbuli grassland, which was used as grazing area for large and small ruminants, (ii) the arid Aydora open savanna (bushgrassland), which was used for grazing/browsing by all types of livestock, and (iii) the semi-arid Hurso closed savanna (bushland), which was important for browsing animals (camels and goats) with some under canopy grazing materials. The coordinates were recorded with a Geographical Positioning System (GPS) and plotted on an Ethiopian map by the GIS Section of the Ethiopian Agricultural Research Organization, using GIS techniques.

2.5 BROAD DESCRIPTION OF THE STUDY AREA

2.5.1 Geographical location

The Somali regional state of Ethiopia is located between 4-11^{o}N and 40-48^{o}E, within the eastern and southeastern lowlands of Ethiopia. It borders the Republic of Djibouti in the north, the Somali republic in the east, the Oromiya region from south to northwest, and the Afar region in the north and northeast of the country. The total land area is about 327 000 km^{2}, equivalent to 30% of the national land area.

The Shinile zone of the Somali region of eastern Ethiopia is a pastoral area, located in the northeast of the region, with a total area of about 85 000 km^{2}. It is sub-divided into six sub-zonal administrative areas, locally called 'weredas'. The specific study area is located in the Erer wereda, which is bordered by Dire Dawa district in the south, Afdem wereda in the southwest, Afar region in the northwest, the Djibouti Republic in the northeast, Shinile wereda in the south-east and Ayisha wereda in northeast (Figure 2.1). The three experimental sites are located at distances of 25, 120 and 160 km from Dire Dawa town, which is about 520 km east of Addis Ababa, the capital city of Ethiopia, respectively. The experimental sites are located between 9^{o}-10^{o} N and 41^{o} and 42^{o} E, with altitudes ranging between 700 and 1 200 m.a.s.l.

The grassland site was located between 04 - 06^{o}N and 40 - 42^{o}E, and extended 150 km northwest and 170 km northeast from Dire Dawa, with a total land area of 25 500 km^{2}, representing about 30% of the Shinile zone. The open savanna (bush-grassland) being located between 8 - 10^{o}N and 40 - 41^{o}E extended 200 km northwest and 150 km northeast of Dire Dawa with a total of 30 000 km^{2} total land area, which is about 35.3% of the Shinile zone. The closed savanna (bushland) was located between 8 - 10^{o}N and

40 - 41°E extending 200 km north and 180 km east of Dire Dawa covering about 36 000 km^2, which is about 34.5% of the Shinile zone.

2.5.2 Climate

According to the Shinile zonal Bureau of Agriculture (2002), the agro-ecology of the study area (Erer) includes arid (60%), semi-arid (30%) and semi-desert and rocky (10%) areas. It falls within the main plateau of the Rift Valley plains, which stretches from the Danakil plateau in the northwest of the Afar region, to the bottom lands of the Chercher highlands in the Oromiya region, with an altitude ranging between 450 and 1 200 m.a.s.l.

The area is known for its harsh climate and as a result plant growth periods are short, ranging between 40 and 65 days, which is inadequate to support crop agriculture without supplementary irrigation. Hence, the growth and maturity of annual and semi-annual grasses and browses are favored (ADPO, 2004). The rainfall is bimodal which include the short rainy season from April to March (2 months) and the main rainy season from June to August (3 months). For the period 1985 to 2004, the mean annual minimum and maximum rainfall were 200 and 330 mm, respectively. Temperatures vary between 27 ^{O}C and 42 ^{O}C and the potential evapotranspiration ranges from 1 750 to 2 000 mm per annum.

2.5.3 Soil

According to the FAO/UNDP (1984) classification of Ethiopian soil, the soil of the grasslands is classified as vertisols (heavy clay in areas of pronounced dry areas), mainly dark pellic vertisol and chromic vertisols and fluvisols (young soils developed in recent alluvial deposits). The soil classification for the open savannas also includes vertisols (mainly chromic vertisols) and fluvisols. The soil of the closed savannas includes nitosols (clayey red soils with argillic B horizon) and regosols without profile development and with loose soil material. According to SERP (1990), the soil texture for the rangelands of the Shinile zone range between 4 and 60% clay, 10 and 50% silt and 40 and 60% sandy loam. The soil depth varied between 1.5 and 2 m for the clay soil of the grasslands, 1 to 1.5 m for the clay loam soil of the open savannas (bush-grasslands) and 0.5 to 1 m for the sandy loam clay soil of the closed savannas (bushlands).

2.5.4 Vegetation

The vegetation of the rangelands in the study area are dominated by herbaceous and woody plants. The herbaceous layer consisted of grass species of the genera *Eragrostis, Panicum, Echinochloa, Dactyloctenium, Cenchrus, Sorghum, Sporobolus, Eleucine* and *Leptochloa.* The woody vegetation included species of the genera *Acacia, Clotolaria, Cadaba, Cissus, Commiphora, Crotolaria, Gompho, Grewia* and *Ziziphus*. Forbs and shrubs were also present, while non-palatable woody plants such as *Acacia nubica* and *A. mellifera* and weeds such as *Xanthium abyssinica, Parthenium hystherophorus* and species of the *Malvaceae* were observed encroaching in the different plant communities of the various rangeland types. Encroachment of undesirable plants is indeed considered a major threat to the rangelands of Erer wereda (EARO, 2003a).

2.5.5 Human and livestock population

The Shinile zone has a total human population of about 358 703, of which 95% are mobile pastoralists, 4% agro-pastoralists and 1% urban dwellers. The livestock population is estimated at 2.75 million, including about 0.9 million sheep, 0.8 million goats, 0.8 million cattle, 0.2 million camels and 46 000 donkeys (IPS, 2000). The Gorgora and Issa pastoralists, in order of dominance, are the only known Somali pastoral clans in the study area. The calculated population density for the zone is 6.2 persons and 47.4 heads of livestock per km^2, respectively. The latter is equivalent to 18 Tropical Livestock Units (TLU), where 1 TLU is equivalent to a live weight of 250 kg or 13 Large Stock Units (LSU) (1 LSU equals 450 kg live weight). This is similar to the arid and semi-arid agro-ecological areas of the sub-Saharan Africa countries described by Jahnke (1982).

Erer wereda has a human population of about 80 000 with a distribution of 52% men and 48% women. More than 85% are mobile pastoralists living in the remote rural areas where feed and water for their animals is available, while less than 10% are agro-pastoralists that practice both livestock rearing and irrigated crop production. About 5% are settlers with a limited number of traders and daily laborers living in small towns. The main settlement towns where livestock is marketed are Hurso, Erer, Aydora and Asbuli, respectively. The total livestock population of Erer wereda is estimated at approximately 600 000. These include approximately 200 000 cattle (33.3%), 180 000 sheep (30.0%), 150 000 goats (25.0%), 65 000 camels (10.83%) and 5 000 equines (0.83%). However, as a result of recurrent droughts there is a trend towards increased numbers of small ruminants (mainly browsers) and camels, with a corresponding decline in cattle numbers (Erer Bureau of Agriculture, 2002).

2.5.6 Water resources

The Erer wereda is known for its underground and surface water resources, where the minimum discharge rate is estimated to be 80 liters per hour (EWAB, 2004). According to the Bureau for Water Development of Shinile zone (BWDSZ, 2003), the underground water reserves are untapped and mostly unutilized due to the inability to access the water by means of boreholes. As a result there are water shortages in the remote areas, where grazing and browsing potentials are high, but surface water sources are lacking. This problem is thus one of the causes for livestock mortality, even when feed (grazing and browsing) is abundant, during the long dry season (ADPO, 2004). The Erer wereda has three main permanent rivers known as Hurso, Gota and Erer. These rivers lead to the emergence of agro-pastoralism in those peripheral areas and serve as a source of drinking water for the pastoral households, their livestock and wild ungulates in the arid grasslands and savannas. As a result, water for livestock is not a problem in areas close to the rivers.

2.6 SPECIFIC DESCRIPTION OF THE EXPERIMENTAL SITES

2.6.1 The Asbuli grassland

This site is representative of the open grasslands of eastern Ethiopia (Figure 2.2) where the land-use is dominated by sheep, cattle and camel production. The grassland is located on a plateau and forms part of the Greater East African Rift Valley. It is located between 10°E and 41°N. The altitude ranges between 500 and 700 m.a.s.l. Annual temperatures range from 27°C during the rainy seasons to 42°C during the long dry season. Average annual rainfall is between 300 and 350 mm. The landscape consists of a flat plateau with soil types as described in section 2.5.3. The landmass extends 200 km in a northern direction and 180 km in northeastern direction, representing an area of 36 000 km^2, or 42.3% of the larger Shinile zone (BWDSZ, 2003).

Figure 2.2 View of the Asbuli grassland. The trees in the distance are *Clotropus procera* .

2.6.2 The Aydora open savanna (bush-grassland)

This site is representative of the open savannas (bush-grasslands) of eastern Ethiopia (Figure 2.3), where the land-use is dominated by cattle, camel and sheep production. Antelopes such as dik-dik are common in the area. The Aydora open savanna is also part of the Great East African Rift Valley, with the topography ranging from plains to undulating landscapes. It is located between 07 - 08^{o}N and 40 - 41^{o}E. The altitude ranges from 600 to 850 m.a.s.l. Annual temperatures range from 25^{o}C during the rainy seasons to 40^{o}C during the long dry season. The average annual rainfall ranges between 300 and 350 mm. The landmass extends 150 km in a northern direction and 170 km in a northeastern direction, representing a total area of 25 500 km^2, or about 30.0% of the larger Shinile zone (BWDSZ, 2003).

Figure 2.3 View of the Aydora open savanna. The dwarf green bushes are dominated by the woody plant *Cadaba glandulosa*.

2.6.3 The Hurso closed savanna (bushland)

This site is representative of the closed savanna (bushlands) of eastern Ethiopia (Figure 2.4), with a land-use dominated by the production of small ruminants (goats and sheep) and camels, while antelopes and wild carnivores are still common in the area. It is also part of the Great East African Rift Valley with a landscape, which is undulated to rugged with stony hills and gently sloping mountains. It is located between 40^o - 43^oE and 07^o - 09^oN. The altitude ranges from 700 to 1 200 m.a.s.l. The average annual temperatures range from 27^oC during the rainy seasons to 43^oC during the long dry season. The mean annual rainfall is between 300 and 450 mm. The landmass extends 149 km in a northern and northwestern direction and 185 km in a northeastern direction, with a total area of 27 700 km^2 or about 27.7% of the larger Shinile zone (BWDSZ, 2003).

Figure 2.4 View of the Hurso closed savanna with its typical woody plants.

2.7 LAYOUT OF EXPERIMENTAL SITES

The experimental layouts for each site were classified into four types of rangeland conditions that include excellent (benchmark), good (under grazed/browsed), fair (moderately grazed/browsed) and poor (heavily grazed/browsed) conditions using methods developed by Stuart *et al*. (1991) and Hardy *et al.* (1999). Techniques described by Gabriel and Talbot (1984) for similarities in soils, topography and causes of degradation were also applied. The indigenous knowledge of the local pastoralists and rangeland managers was also used as additional tools for determining the degradation levels and causes. Accordingly, the grassland and open savanna degradation levels were determined in reference to natural and over stocking and that of the closed savanna in terms of artificial degradation (over cutting of woody plants). The experimental layouts are explained as follows.

2.7.1 Excellent condition (benchmark)

The site agrees with the definition by Tainton (1981) for a benchmark as a veld in optimum condition for sustainable livestock production and the descriptions by Wilson (1984) and Hardy *et al*. (1999) of veld with a potential basal cover serving as reference in evaluating past and current grazing capacity. The latter however, refers to intensive livestock production and pasture management as opposed to extensive pastoral livestock production and communal rangeland management practices. Accordingly, the definition for a benchmark site in terms of the pastoral context refers to a portion of a rangeland, protected by the community for dry period grazing or traditional taboos or government protection. The indicators used include maximum basal/canopy cover with little or no open spaces or bare ground (approximately 95-100% cover), with no trampling and undisturbed with maximum biodiversity of the vegetation and absence of encroachment by undesirable plant species.

2.7.2 Good condition (under grazed/browsed)

This particular layout agrees with definitions by Kothman (1974) and Tainton (1981) that imply a specific site in a veld, where the herbaceous/canopy layers are under utilized. This refers to rangeland conditions under intensive management but in accordance to traditional pastoral rangeland management practices. According to pastoral perceptions, in good condition is so called, because it is often used for milking, suckling and pregnant (breeding) animals and in many cases prohibited for others. Hence the site is underutilized due to understocking. Subjective indicators include optimal basal/canopy cover (approximately 9%), slightly disturbed due to trampling and grazing/browsing by animals, having optimum biodiversity of the vegetation and with little or no encroachment by non-palatable plants.

2.7.3 Moderate condition (moderately over grazed/browsed)

A rangeland is said to be in a moderate condition when there is a reduction in sustainable productivity in relation to the system of land use and beyond the bounds of resilience (Abel and Blaike, 1990). It is a phenomenon in arid, semi-arid and dry humid areas caused by abuse of the environment through ignorance, mismanagement and climatic variability. Moderate condition is therefore, a rangeland degradation status characterized by the formation of smaller areas of patches, which expand or join together to form large bare and denuded areas in the long-term (Kellner and Bosch, 1992). In accordance to pastoral perceptions, moderate condition refers to rangeland whose degradation status could be explained by certain indicators. These include a basal/canopy cover ranging between 5 and 7%, where the bare ground is clearly visible. Palatable grass species are diminished while desirable browse plants are threatened due to excessive cutting for fuel wood, charcoal making and expansion of croplands. Erosion becomes evident and problematic, sand sheets start to form and there is moderate encroachment by unpalatable grasses, weeds, herbs and other woody plants. Grazing capacity of the rangeland is reduced in time and sustainable forage production is not dependable any more.

2.7.4 Poor condition (severe over grazed/browsed)

Tainton (1981) described a poor condition rangeland as highly utilized veld in terms of grazing land management. The impact of heavy grazing causes a shift in species composition (Fusco *et al*. 1995), where more palatable and high producing grass species are removed from the range (Hart *et al*. 1988). Grasses of lower palatability, and unpalatable weeds and shrubs usually form the sod and replace the desirable ones (Johnson, 1956; Mortimore and Turner, 2005). Poor rangelands are result due to heavy grazing pressure and damage the most palatable species (Dyksterhuis, 1949; Cottam and Evans, 1945) and reduce their abundance (Johnson, 1956). Therefore, severe changes in successional trends in plant communities occur under heavy grazing (Ellison, 1960). The pastoralists agree with the gist of the scientific explanation. The subjective perceptions of the pastoralists lead to further indicators of degraded or poor condition rangeland. These include (i) basal/canopy cover reduced below 50% while the proportion of bare ground increase (ii) water and wind erosion and rate of runoff increases (iii) sand expansion increases and form sand dunes (iv) encroachment of harmful plants increase and (v) the population of dwarf woody plants become dominant and trees disappear.

CHAPTER 3

IMPACT OF RANGELAND DEGRADATION ON PERCEPTIONS OF THE SOMALI PASTORALISTS IN EASTERN ETHIOPIA

3.1 INTRODUCTION

The Horn of Africa is known for its traditional mobile pastoral livestock production systems. Livestock not only constitutes the main livelihood of the pastoralists, but also represents the main component of the gross domestic product (GDP) of the economy of the countries located in the Horn. These countries include Djibouti, Eritrea, Ethiopia and Somalia, with Ethiopia contributing 62%, 84% and 65% of the land area, human and livestock populations of the Horn, respectively. According to the Inter Governmental Authority Development (IGAD, 2004), the total land area of the Horn is estimated at 2 million km^2, with a population of 86 million people and 185 million livestock. It links Africa to the Middle East and serves as a gateway to the Gulf oil resources. It is also rich in natural oil, gold and other mineral resources with a rich and diverse fauna and flora, which can make an economic difference if properly developed. The pastoral zones within the Horn are illustrated in Figure 3.1.

The agro-ecology of the Horn includes 69.2% arid (1.384 million km^2), 16.2% semi-arid (0.324 million km^2), 2.0% sub-humid (0.04 million km^2) and 12.6% highland (0.24 million km^2) areas (EARO, 2003b). However, the highlands are not considered pastoral areas. The drylands of the Horn, with a total land area of 1.7 million km^2 (85.4%), can be sub-divided into a further five broad agro-ecological zones, which include: (i) grassland (40%, 0.72 million km^2), (ii) open savanna (30%, 0.6 million km^2) , (iii) closed savanna (5.0%, 0.1 million km^2), (iv) crop cultivated land (15%, 0.3 million km^2) and (v) semi-desert (10%, 0.2 million km^2). Based on a report (IGAD, 2004), about 56.5%, 23.8%, 16.2% and 3.5% of the human population live in the highlands, arid, semi-arid and sub-humid agro-ecological areas, respectively. The livestock populations in the Horn are estimated at 114.2 million sheep and goats, 43 million cattle and 5.4 million camels. All of the small ruminants, 72.5% of the cattle and 45% of the camels are found in the arid and semi-arid zones.

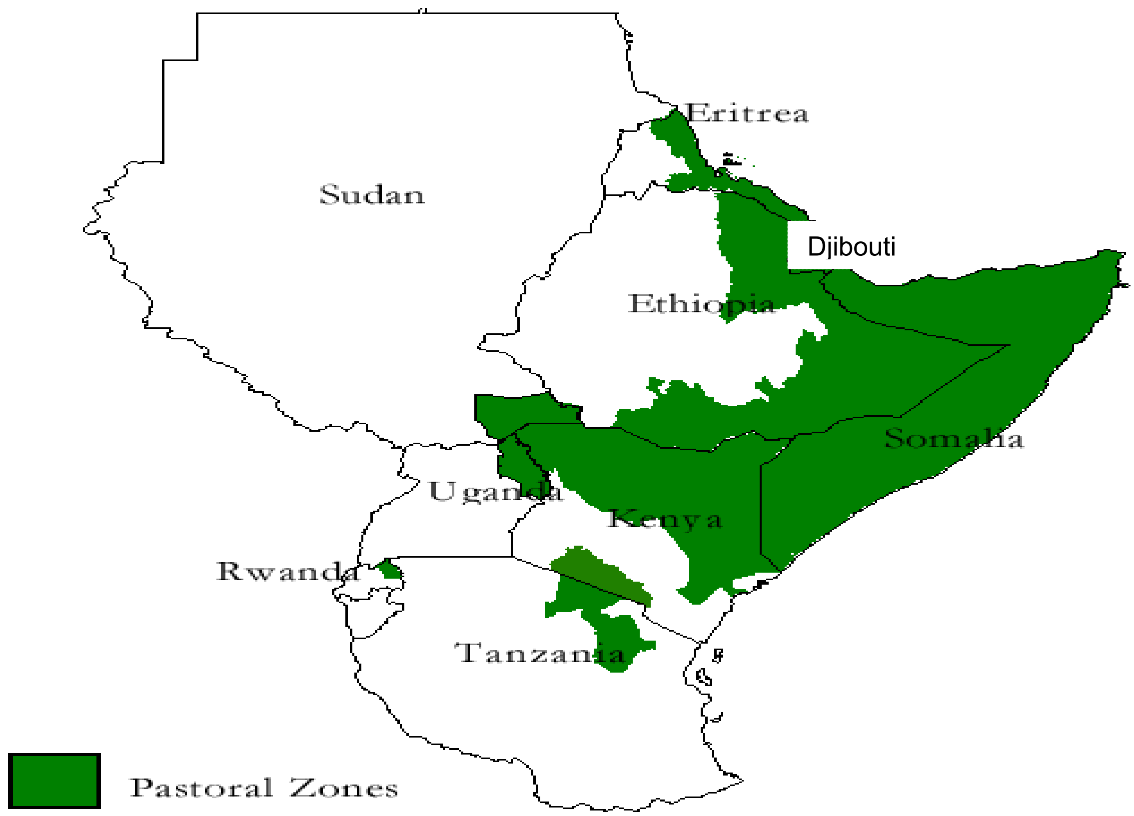

Figure 3.1 Geographical location of the countries in the Horn of Africa with their respective pastoral production system zones.

Due to the harsh climate of the drylands, where conventional crop agriculture is difficult without supplementary irrigation, mobile pastoralism has evolved as a means to convert the rangeland forage resources into milk, meat, hides and skins through livestock production (EARO, 2003b). In time, however, this form of agriculture has come under increasing pressure from the influence of droughts and environmental degradation.

Mobile pastoralists, with the second largest population in the Horn, occupy the largest area. Agro-pastoralists, with the third largest population, occupy the second largest area.

Crop agriculturalists, with the highest population, occupy the third largest land area. The smallholder agriculturalists are fourth both in landholding and population density. Livestock production in the Horn contributes about 65% of the agricultural gross domestic product (AGDP), 30% of the national GDP, 90% of the hard currency from export of live animals and employs about 70% of the population of the Horn (IGAD, 2004).

3.1.1 The view on environmental degradation

Livestock production in pastoral areas is affected by numerous problems of which environmental degradation features prominently. The problem is often better understood by the pastoralists than policy makers, development planners and researchers of the countries in the Horn of Africa. Environmental degradation, often confused with desertification, is a world scenario and pastoralists are often held responsible. The issue of environmental degradation was discussed by the United Nations (UN) during conferences held at Nairobi (1977), Rio de Janeiro (1992) and Johannesburg (2000), but consensus on scientific indicators of environmental changes, policy and development action plans were not reached (Mortimore, 2005). Current indicators are still inadequate to assess relationships between climate, vegetation and livestock, preventing the establishment of development oriented policies that must reverse the unabated process of rangeland degradation (Raynaut *et al*., 1997; Gemedo-Dalle, 2004; Vetter *et al*., 2006). The lack of understanding of the relationship between the environment and pastoralists and ignorance regarding the perception of the pastoralists may also contribute to the misunderstanding of the pastoral production system and the priority needs of the pastoralists (EARO, 2002; Amaha, 2003; SoRPARI, 2005b; Gemedo-Dalle *et al*., 2006).

In addressing the problem of rangeland degradation, the primary focus used to be on biodiversity, rainfall and soil erosion without due concern for the pastoralists (Mortimore, 2005; Gemedo-Dalle, 2004) or their perception of the problem (Sandford, 1983; Ellis and Swift, 1988; Gemedo-Dalle *et al*., 2006). This approach was mainly due to the biased perception of western intellectuals that pastoral production systems are fundamentally ecologically unsustainable (Lamprey, 1983; Sinclair and Fryxell, 1985). Besides, reports on the status of Borana rangelands in southern Ethiopia for example seem contradictory. Ayana Angassa and Baars (2002) and Ayana Angassa (2002) concluded that Borana rangelands were in good condition. On the other hand, results from the same area showed that the Borana system of production was on decline since the early 1990s (Oba and Kotile, 2001; Oba *et al.*, 2000). A root cause of this biased view is that environmental changes, rangeland degradation and pastoral perceptions of the problem are not fully understood and documented (Taffese Mesfin, 2001; Gemedo-Dalle *et al.*, 2006). These contradicting reports will have a negative impact on the planning and implementation of development projects in Ethiopia specific. Therefore, further study that might lead to better understanding of the current status of rangelands in the Borana lowlands was imperative.

3.1.2 Some facts about the Somali region of Ethiopia

The Somali region of Ethiopia is predominantly a pastoral area and located in the heart of the Horn of Africa. As with most pastoral areas it is affected by environmental changes and rangeland degradation, mainly due to increased population pressure (CSAE, 2004; NMSAE, 2004), overstocking, overgrazing and deforestation (EARO, 2003b). These factors have facilitated the disturbance of the rangeland ecosystem and enhanced the effect of droughts in the region (SoRPARI, 2005c). Droughts normally impact negatively on plants and animals (Holecheck *et al.*, 1999) by directly affecting the productivity of rangeland vegetation due to water stress and unavailability of nutrients from the soil (Fourie *et al.*, 1985; Barnes *et al.*, 1991; Vetter *et al.*, 2006), resulting in feed shortages and causing livestock deaths, food insecurity and destitution of pastoralists (Amaha, 2003; SoRPARI, 2005a).

The Ethiopian Relief and Rehabilitation Commission (ERRC, 1985) reported that climatological droughts have occurred in eastern Ethiopia during the years 1910/12, 1921/22, 1931/32, 1938/39, 1943/44, 1948/49, 1951/52, 1959/60, 1968/69, 1973/74, 1976/77, 1981/82 and 1983/84. From this it is apparent that, on average, climatological droughts were occurring once in every ten years between 1910 and 1931, but thereafter more frequently (EMSAFS, 2004).

In the pastoral areas of Ethiopia, droughts invariably resulted in livestock deaths. Accordingly, the Somali Region Disaster Prevention and Preparedness Commission (SoRDPPC, 2003c) reported a total loss of more than 4.6 million livestock during the 2001/3 drought. This represented 25%, 70% and 5% of the total cattle, small ruminant and camel livestock populations, respectively. It also left more than 40% of the pastoral households with food insecurities and destitute. In addition, environmental degradation in general and droughts in particular, seem to erode the traditional coping mechanisms of the pastoralists. However, there still exists a lack of understanding of the intensity and magnitude of environmental degradation and its impact on the overall livelihood and perceptions of the Somali pastoralists (Taffese Mesfin, 2001; Gemedo-Dalle, 2004). Although many investigations have been performed in the Borana lowlands, there was no record of any comparative study of the different functional land use units (Gemedo-Dalle *et al.*, 2006).

The objectives of this study were therefore to: (i) synthesize information on the status of the pastoral production system of the Somali region of Ethiopia under changing environmental conditions, (ii) gain a better understanding of the indicators of environmental degradation of the rangelands, (iii) study the major changes of the pastoral livelihoods and perception of the Somali pastoralists, and (iv) make relevant recommendations based on these findings.

3.2 PROCEDURE

3.2.1 Selection of villages in the study areas

Of the seven weredas in the Shinile zone (described in Chapter 2), Erer wereda that borders the Afar Regional State in the north and Aysha wereda, which borders the Djibouti Republic in the east, (Figure 2.1 of Chapter 2) were selected for the study. The fundamental criteria for their selection were the representation of different rangeland vegetation types, animal production systems, livestock herd structures as well as availability of sufficient numbers of elder pastoralists for interviewing and access to transportation. The household leaders of these weredas are mobile pastoralists belonging to the Issa tribe of the Somali clans. Within each wereda, three villages were randomly selected to conduct the survey through the participation of elder pastoralists. The nature and demography of each village are described below:

3.2.1.1 Villages from Erer wereda

(i) Megali-Adi: The village is located about 27 km north of Dire Dawa. The vegetation consists mainly of closed savanna and the area is known for its sheep, goat and camel production. The human population is estimated at 2 000 people.

(ii) Aydora: A village located about 120 km north of Dire Dawa, consisting of both open and closed savanna, dominated by sheep, goats, cattle and camel production. The human population is estimated at 3 000 people.

(iii) Asbuli: The village is located about 160 km north of Dire Dawa, and is characterized by open grasslands, dominated by cattle, sheep and camel production. The human population is estimated at 4 000 people.

3.2.1.2 Villages from Aysha wereda

(i) Arbukalle: The village is located some 45 km east of Dire Dawa. The vegetation is characteristic of open savanna and dominated by cattle, sheep, camel and goat production. The human population is estimated at 2 000 people.

(ii) Durie: The village is located about 85 km east of Dire Dawa. The vegetation is characteristic of both open and closed savanna, dominated by sheep, goats, camels and cattle production. The human population is estimated at 3 000 people.

(iii) Biedaalay: The village is about 95 km east of Dire Dawa. The vegetation is characteristic of open savanna and open grasslands, dominated by cattle, sheep, goat and camel production. The human population is estimated at 3 000 people.

3.2.2 Survey methods

3.2.2.1 Selection of households and elder pastoralists

For each village, a list of household owners, were obtained from the local administrative offices. Households with elderly pastoralists (70-75 years old) were identified and a total of 300 willing elders from six villages (50 elders per village) were selected randomly. Of the selected elders, 210 (70%) were men en 90 (30%) were women. The age group of 70-75 years was chosen in order to use their indigenous knowledge acquired through experience as a reference to assess and analyze the nature and magnitude of changes perceived to have occurred in their environment within a 60 years period between 1944 and 2004.

3.2.2.2 Interviewing

Formal and informal surveys were conducted to assess the relevant areas of information required. Then structured questionnaires and formal discussions were used during interviews with the key informants. This was done in a relaxed environment to allow maximum information flow without being restricted by the questionnaires. For the survey, 15 enumerators for completing the questionnaires and 5 field assistants for interpreting the Somali language were trained.

3.2.2.3 Time scale for impact assessment

The impact of environmental degradation over a 60 year time period was assessed by identifying the year 1974 as a reference to split the 60 year period in two equal periods of 30 years for comparison purposes: before 1974 (1944-1974) and after 1974 (1974-2004). The reference year (1974) was noted as a severe drought period in the Sahel of sub-Saharan Africa as described by Mortimore and Turner (2005), which also affected eastern Africa. It was also a year when pastoralists of the northern parts of the Somali region lost most of their livestock.

3.2.2.4 Wealth ranking of pastoralists

The wealth ranking of participating pastoralists was based on the number of livestock they owned. Rankings ranged from wealthy to medium, below medium, poor and very poor households. A minimum number of 60 small ruminants, 5 milking cows with 3 heifers and 2 bulls, 4 dairy and 2 bull camels and 3 donkeys are required to meet the nutritional and cash income requirements of a pastoral household (EARO, 2003b; Gemedo-Dalle *et al*., 2006). Accordingly, a number of 2, 3 and 4 times above this minimum represent the wealth ranking of below medium, medium and wealthy, respectively. On the other hand, households with less livestock, down to 50% of the minimum, represents a poor ranking, while holdings below 50% of the minimum represents a ranking of very poor.

3.2.2.5 Tropical Livestock Units (TLU)

The comparisons between livestock holding per household were conducted from 1944 to 1974 and 1974 to 2004, by calculating the equivalent number of Tropical Livestock Units (TLU) using the methods of Jahnke (1986). One TLU is taken as an animal of 250 kg live body mass, with a camel, cow, small ruminant and donkey equal to 1.25, 0.75, 0.1 and 0.7 TLU's, respectively.

3.2.2.6 Determination of dry matter feed requirements of livestock

The difference in total annual dry matter feed required for the livestock holdings, before and after 1974, was compared based on the assumption that one TLU requires 6.25 kg dry matter feed per day. Changes in species composition patterns were determined for households in numbers of cattle, sheep, goats, camels and donkeys over time, as well as the shift in livestock owning, rearing and herding. The number of live animals for all ranked households was converted into TLUs to calculate the total dry matter feed requirement before 1974 and after 1974, to understand the pastoral indigenous wisdom in overcoming feed shortages during crisis periods.

3.2.3 Data collection

The data collection was conducted from October 2004 to January 2005 and included the following:

(i) preference and planning of livestock holding by pastoralists,
(ii) pastoral perceptions on environmental degradation (holistic),
(iii) pastoral perceptions on rangeland degradation (particular),
(iv) changes in livestock holding and species patterns over time,
(v) indigenous rangeland management practices.
(vi) water resources and the management of water resources for livestock, and
(vii) major constraints of the pastoral production system.

3.2.4 Data analysis

The data were analyzed using descriptive statistics such as percentages, means and standard deviations, which were calculated using the Statistical Package for Social Sciences (SPSS,1996). Friedman's test (Steel and Torrie, 1980) was used for ranked data analysis. When the analysis revealed the existence of significant variation, analysis of variance (ANOVA) was performed.

3.3 RESULTS AND DISCUSSION

3.3.1 Preference and planning index for livestock holding by pastoralists

The most important reasons, as given by the elder pastoralists, for keeping different livestock species such as cattle, sheep, goats, camels and donkeys in their production systems, are presented in Table 3.1. A further discussion was held to determine: (i) which livestock species meets all requirements for livestock holding, and (ii) the planning index for keeping livestock species in their specific order of priority. A planning index is defined as the contextual framework according to which pastoralists decide to keep only a specific species or a combination of species of livestock within their herd structure.

Table 3.1 Reasons for keeping livestock and the planning index based on the ratings by elder pastoralists (n=300)

No	Reasons for livestock keeping	Respondent's preference (%)					Planning Index
		Cattle	Sheep	Goats	Camel	Donkey	
1	Milk production	90	10	60	100	0	84.0^{c}
2	Meat production	80	90	90	70	0	82.0^{c}
3	Milk and meat production	50	0	70	75	0	50.0^{f}
4	Animal breeding (reproduction)	100	100	100	100	50	100.0^{a}
5	Cash income from sales	40	100	100	20	40	65.0^{de}
6	Social security	70	50	70	100	20	72.0^{d}
7	Personal or family prestige	40	20	30	50	10	25.0^{h}
8	New bride households to start	50	100	100	30	50	70.0^{d}
9	Transportation	0	0	0	10	100	40.0^{g}
10	A drought coping mechanism	50	100	100	100	20	90.0^{ab}
11	Due to changes in aridity	20	75	100	100	40	85.0^{b}
	Average Planning index for species	59^{b}	64.5^{b}	73.5^{a}	75.5^{a}	33^{c}	

Means with different superscripts are significantly different at P<0.05, but with similar superscripts are not different at P>0.05.

From the results, camels prove to be the most preferred livestock species. According to the pastoralists, camels meet 75.5% of the requirements for keeping livestock, closely followed by goats, which achieved a score of 73.5%. These preferences correspond with those of the Somali pastoralists in western Gode zone as reported by Ahmed Shek Mohamed (2000a), but differ from the preferences of the Borana pastoralists in the Oromiya region, who preferred cattle (Coppock, 1992; Alemayehu Reda, 1998). The strong preference for goats also corresponds with those of pastoralists in southern Ethiopia (Solomon Desta, 1999; Solomon *et al.*, 2006a). However, the planning index for keeping camels and goats did not differ significantly (P>0.05), but the latter differed significantly (P<0.05) from the other livestock species. This may be due to the fact that camels and goats depend on a wider range of browse vegetation and are able to survive drought periods better than the grazers (cattle and sheep). They are also able to provide milk, meat and cash income during periods of feed shortages, especially during long dry periods.

Sheep was highly preferred, but with a planning index of 64.5%, compared to the 59% of cattle, the reasons for keeping sheep and cattle did not differ significantly (P>0.05). It did, however, differ significantly (P<0.05) from the reasons for keeping camels, goats and donkeys. The higher preference for sheep (Black-head Somali sheep), compared to cattle, was due to their better resistance to feed shortages, while all the cattle breeds are considered more sensitive to feed shortages. This finding corresponds with those of Ahmed Shek Mohamed (2000b), who compared both species for tolerance to feed shortages in the Shinile zone. The preference for holding donkeys was ranked significantly (P<0.05) lower than the other species.

Pastoralists plan for 100 and 90% of the time to have a nucleus breeding stock for reproductive purposes and have a contingency plan for drought coping, which was not statistically significant (P>0.05). The latter refers to the keeping of minimum numbers of stock for post drought reproduction, with the assumption that most animals may die due to drought. As a result, the planning index, which reflects the preference for the size and type of livestock species, is based on the ability of breeding animals to cope with feed shortages during droughts and their ability to utilize the existing rangeland vegetation. Consequently, camels, goats, sheep, cattle and donkeys are preferred in that order. This was also confirmed by findings in the Shinile zone of the Somali region (Catholic Relief Society, 2001). In addition, the encroachment of grasslands by woody vegetation has also contributed to the fact that livestock species that are able to browse are favoured above grazers.

The planning index for milk production (dairy animals) of 84% and for only meat type animals of 82%, are given a primary and a secondary focus, respectively. However, the planning index based on preferences for milk and meat production did not differ significantly (P>0.05). The planning index of 50% for dual purpose animals (that is milk and meat production) has decreased significantly (P<0.05) over time, while the planning index for milk or meat, exclusively, has increased (P<0.05) with camels as most preferred animals for both purposes. These findings correspond with those reported by SoRPARI (2005a), especially in terms of the ways in which households meet their food requirements in the form of milk and meat. Livestock also serve as means of social security. The planning index therefore, includes considerations such as savings in the form of live animals (72%), new brides to start married life (70%) and cash income to meet household necessities and expenditure (65%). In relation to the latter considerations sheep and goats are mainly kept as a source of cash income and meat, while camels and cattle are kept for milk and/or meat production with cash income as a secondary option.

The planning index of 40% for donkeys in terms of preference for their use as transport was lower ($P<0.05$), due to the increasing importance of male camels for the same purpose. However, for poor households donkeys are useful in transporting fuel wood and charcoal from the forests to market places. Poor pastoral households invest in donkeys rather than camels, whose initial investment cost is very high. As a result, donkeys are considered the poor man's animal.

The planning index of 25% for keeping excess animals for personal or family prestige has declined significantly ($P<0.05$) in all pastoral households. However, keeping extra animals is still common as contingency measure for post-drought restocking. This is also a coping mechanism, because neither the regional nor the national governments and non-governmental organizations assist the pastoralists in restocking during the post drought period.

The respondents reported that keeping animals for prestige has diminished with time, mainly due to droughts and environmental changes. This was in agreement with reports by Sandford (1983) and Ellis and Swift (1988). It also shows that the school of thought advocated by Hardin (1968) and Lamprey (1983), that pastoralists are responsible for ecological degradation because they keep excess animals for personal prestige was contradictory to the perceptions of the pastoralists. Accordingly, this view seems to be an oversimplification and need to be revised within the context of the perceptions of the pastoralists. Cossins (1985) also arrived at similar conclusions regarding the Borana pastoralists in southern Ethiopia, while Letty *et al.* (2003) demonstrated the potential of traditional livestock owners in the communal rangelands of KwaZulu-Natal, South Africa.

3.3.2 Pastoral perceptions on environmental degradations

Based on indigenous knowledge, the pastoralists use about 55 indicators of environmental degradation and classify them into seven categories such as eco-physical, climate, vegetation, livestock, animal disease, insects and reptiles and socially related (Table 3.2). Accordingly, 13 indicators or 23.6% were related to vegetation, 10 indicators or 18.2% to livestock, 8 indicators or 14.6% eco-physical, 7 indicators or 12.7% to climate, 6 indicators or 10.9% to animal disease, 6 indicators or 10.9% to social aspects and 5 indicators or 9.1% to the ecology of insects. Based on the study, the dynamics in vegetation ecology seem to influence the livestock species composition, which may serve as critical indicator of environmental degradation. Overstocking and overgrazing/overbrowsing, encroachment by weeds and undesirable woody plants and over harvesting of woody plants may have also resulted in changes in rangeland vegetation ecology. This could further contribute to the vicious drought cycle in the study area of Somali region.

The encroachment by undesirable species of plants was described by Behnke and Scoones (1993) as a sub-climax in the succession sequence due to environmental degradation, but failed to show the causative agents and their interaction. Besides Abule *et al.*, (2005a) for the Awash Rift Valley of Ethiopia, Herrmann and Hutchinson, (2005) for the Sahelian belt of Africa, Twine (2005) for South Africa, Gemedo-Dalle *et al.* (2006) and Solomon *et al.* (2006a) for the Borana zone of Southern Ethiopia reported changes in vegetation dynamics due to overstocking, drought and encroachment by undesirable plants.

The eco-physical and climatological changes have interactive effects on livestock in the form of declining productivity and the encouragement of animal diseases and insects, which negatively affect the health of the livestock and the productivity of the rangeland vegetation. Pastoralists strongly associate eco-physical indicators with inadequate and erratic rainfall, unavailability of water sources and inaccessibility to portable water for human and livestock. They further associate it with deforestation, soil erosion (due to water and wind) and encroachment of sand sheets and dunes, which may affect the

Table 3.2 Perception indicators identified by elder pastoralists for environmental degradation.

No	Perception indicators	Perception indicators
	A. Eco-physical related indicators	**D. Livestock related indicators**
1	Permanent rivers diminish in water flow or dry up	1) Camels become leading arid animals
2	Underground water discharge reduces significantly	2) Production of small ruminants increases
3	Shallow water holes dry up and water tables get deeper	3) Cattle production declines
4	Water tastes more salty and unfit for tap water	4) Animals spend more time in shade
5	Soil becomes compacted and crusted	5) Animal productivity and growth decline
6	Soil wind erosion is highly prevalent with dust devils	6) Stunted animals become a common problem
7	Sand sheets and dunes appear with frequent sand storms	7) High calf mortality and weaning takes longer
8	High run-off and flooding occur after rains	8) Longer interval between calving/kidding
		9) Reduced supply of cattle at livestock market
		10) Higher supply of camel milk than cow milk
	B. Climate related indicators	
1	Drought increases in frequency to every three years	**E. Animal disease indicators**
2	Drought lasts more than one year if once occurred	1) Contagious animal diseases are common
3	Temperature increases above normal	2) Disease outbreaks increase sporadically
4	Soil temperature is high and burning bare feet	3) Ticks and tick-born diseases increase
5	More thirst is felt and dehydration increases	4) Higher internal parasite problems
6	More shading and less grazing/browsing of animals	5) Skin diseases become a common problem
7	Incidence of predators increase with time	6) Respiratory diseases are often chronic
	C. Vegetation related indicators	**F. Insect and reptile related indicators**
1	Rainfall indicator plants do not flower	1) Termite problems increase
2	Thorny shrubs and forbs increase	2) Mice and rats increase in population
3	Dwarf bushes and trees overtake vigorous woody plants	3) Snake population and problems increase
4	Growth of woody plants is stunted	4) Locusts can occur sporadically
5	Woody plants tend to have more thorns and small leaves	5) Beetles and cattle biting flies increase
6	Edible tuberous root plants are more abundant	
7	Fruit bearing plants die or reduce in population	**G. Social indicators**
8	Encroachment of non-palatable bush species increases	1) Population pressure on land increases
9	Poisonous plants are more abundant	2) Poverty increases
10	Palatable grasses and woody plants diminish/disappear	3) More dependence on food aid
11	Feed sources grow scarce and become poor in quality	4) More migration of households takes place
12	Encroachment of dwarf spiny *Opuntia spp* increases	5) Rich households face problems
13	Encroachment of noxious weeds, which flourish after rains	6) Medium households grow poor/fragile

macroclimate as discussed by Mortimore *et al.*, (2005) in relation to the Sahelian countries. This phenomenon can be explained in terms of environmental degradation, whose impacts include recurrent droughts, increases in aridity, decrease in vegetation cover, feed shortages and poverty. Drought has become a common occurrence, which is further aggravated by a lack of commitment by the national and regional governments to intervene by means of strategies such as rangeland rehabilitation and livestock development initiatives in pastoral areas. As a result, no or little attempt was made during the past 30 years to restore the rangelands, improve the livestock production system or to minimize livestock deaths in Somali region. For all practical reasons veterinary services and drug supplies have diminished to a non-existent level.

The current situation has influenced the Somali pastoralists to such an extend that they associate environmental degradation with a reduction in livestock production and the increased incidence and outbreaks of animal diseases. This is supported by evidences of livestock mortalities that increased from 20% during the period 1930-1970, to 40% during the period 1980-1990 (SERP, 1990). During the period from 1990-2000 it rose to 60% and from 2001-2002/3 it was above 80% (SoRPARI, 2005c). These mortalities were the result of droughts, outbreaks of diseases, reductions in rangeland vegetation, increases in aridity and lack of veterinary services.

The social indicators are often associated with increased pressure on land resources due to population growth and poverty. In addition to climatic and biophysical variables, Blaikie and Brookfield (1987) reported that social impacts could serve as reflections of land degradation, resulting in the decline of pastoral production system and increases in food insecurity. As a result pastoralists are forced to depend on external food sources for survival. Hence, the problem calls for massive environmental rehabilitation programs through the collaboration of governmental, non-governmental and traditional community organizations.

3.3.3 Pastoral perceptions on rangeland degradation

The pastoralists of the Somali region perceive environmental degradation as a holistic phenomenon of which rangeland degradation is an integral part. Subsequently, based on their indigenous knowledge, they identified some 41 indicators of rangeland degradation. These indicators can be subdivided into five categories of which 16 (39.0%) are rangeland condition/health indicators, 10 (23.4%) water related indicators, 6 (16.6%) soil related indicators, 5 (12.2%) animal performance related indicators and 4 (10.8%) social related indicators. Pastoralists showed more qualitative perceptions on rangeland degradation in terms of trends in change such as increasing, decreasing, no change and unknown during the past 60 years covering 1944 to 2004. The results are presented in Table 3.3.

The rangeland condition related indicators include 10 indicators (62.5%) related to vegetation type, status and trends, 5 indicators (31.2%) related to grazing capacity and soil cover (low basal cover) and 1 indicator (6.3%) related to the status of the soil seed bank. Although unquantified, the indicators are in line with existing scientific knowledge on rangeland degradation. The majority (64.5%) of the respondents agreed that the condition of the rangeland has deteriorated, while 22.5% were of the opinion that rangeland condition increased, but 85% thought that woody plants (mainly *Acacia nubica, A. mellifera and Prosopis juliflora*) encroached and 0% thought that weeds (mainly *Xanthium abyssinicum, Parthenium hysterophorus* and *Malvaceae spp*) increased.

There was also a unanimous agreement that the occurrence of bare ground had increased, perceived to be caused by drought, overgrazing/browsing and over use of woody plants. A small percentage of pastoralists (3.3%) were of the opinion that there was no change in species composition and decreases in grazing capacity, while 9.7% were uncertain. Despite evidence of the degradation of the rangelands, about 50% of the respondents reported that the status of the soil seed banks was unknown to them.

Regarding water issues, 7 indicators (70%) were related to a lack of portable water, while 3 indicators (30%) were associated with a reduction of the water tables and discharge capacity. In general, 78.9% responded that the availability and access to water has

Table 3.3 Perception by elder Somali pastoralists on rangeland degradation indicators (n = 300).

Perception indicators on rangeland degradation		Respondents (%)			
		Decreased	Increased	No change	Unknown
No	**A. Soil erosion related indicators**				
1	Gully formation and expansion	0.0	95.0	0.0	5.0
2	Encroachment of sand, dust and dunes	0.0	50.0	15.0	35.0
3	Soil erosion by run-off	0.0	95.0	0.0	5.0
4	Soil crusting and expansion	0.0	90.0	5.0	5.0
5	Salinity and sodicity	0.0	70.0	20.0	10.0
6	Exposure of B and C horizons of soil profile	0.0	75.0	10.0	15.0
	Average percentage	**0.0**	**79.2**	**8.3**	**12.5**
	B. Water related indicators				
1	Adequacy and dependability of rainfall	100.0	0.0	0.0	0.0
2	Availability of surface water	80.0	0.0	7.0	13.0
3	Evapotranspiration	90	0.0	0.0	10.0
4	Access to shallow and deep water wells	75.0	0.0	10.0	15.0
5	Availability of water from deep wells	100.0	0.0	0.0	0.0
6	Depth of water table for digging wells	80.0	0.0	0.0	20.0
7	Access to drinking water for livestock	90.0	0.0	0.0	10.0
8	Access to drinking water for humans	84.0	7.0	9.0	0.0
9	Water quality for drinking	75.0	0.0	25.0	0.0
10	Divergence of river courses of rangelands	15.0.0	65.0	0.0	20.0
	Average percentage	**78.9**	**7.2**	**5.1**	**8.8**
	C. Rangeland condition indicators				
1	Basal cover of herbaceous layers	70.0	0.0	18.0	12.0
2	Canopy cover of woody plants	95.0	0.0	0.0	5.0
3	Perennial to annual grass ratio with time	80.0	0.0	10.0	10.0
4	Trend of palatable grass/browse species	90.0	0.0	0.0	10.0
5	Trend of unpalatable grass/browse species	0.0	95.0	0.0	5.0
6	Extent of bare ground	0.0	80.0	0.0	20.0
7	Productivity of the land over time	100.0	0.0	0.0	0.0
8	Grazing capacity of the rangelands	100.0	0.0	0.0	0.0
9	Invasion by weed species	100.0	0.0	0.0	0.0
10	Encroachment by unpalatable woody plants	0.0	85.0	5.0	10.0
11	Sustainability of the dry grazing system	100.0	0.0	0.0	0.0
12	Status of the vegetation biodiversity	97.0	0.0	0.0	3.0
13	Status of overgrazing/browsing	0.0	95.0	0.0	5.0
14	Tree to shrub ratio over time	75.0	0.0	10.0	15.0
15	Tree and shrub composition	75.0	5.0	10.0	10.0
16	Status of soil seed bank	50.0	0.0	0.0	50.0
	Average percentage	**64.5**	**22.5**	**3.3**	**9.7**
	D. Animal performance				
1	Animal growth up to maturity	100.0	0.0	0.0	0.0
2	Body confirmation of all animals	60.0	12.0	20.0	8.0
3	Milk yield by milking animals	100.0	0.0	0.0	0.0
4	Deterioration of body condition	80.0	0.0	0.0	20.0
5	Sensitivity to all kinds of animal diseases	0.0	100.0	0.0	0.0
	Average percentage	**68.0**	**22.4.0**	**4.0**	**5.6**
	E. Social indicators				
1	Conflict for resources among pastoral clans	20	60.0	15.0	5.0
2	Poverty at community level	0.0	100.0	0.0	0.0
3	Possession of animals per household	100.0	0.0	0.0	0.0
4	Failure of traditional coping mechanisms	100.0	0.0	0.0	0.0
	Average percentage	**55.0**	**40.0**	**3.7**	**1.3**

decreased, while 7.2% reported an increase in divergence of river courses. A small percentage (5.1%) of the respondents did not know, while 8.8% were of the opinion that no changes took place.

The problems related to soil includes the formation and expansion of gullies (16.7%), expansion of sand sheets (16.7%), water and wind erosion (33.2%), soil compaction (16.7%) and an increase in soil salinity or sodicity (16.7%). Accordingly, 79.2% of the pastoralists reported that soil erosion and compaction were increasing, whereas nearly 100% agreed that the herbaceous layer was unable to produce adequate forages because of decreased soil fertility as a result of erosion of the topsoil. In addition, the expansion of gullies has become a serious problem throughout the Shinile zone. Despite this a total of 8.3% of the respondents were of the opinion that no changes took place, while a further 12.5% were uncertain (did not know).

Animal performance indicators were perceived in terms of animal productivity (40%), live body condition (like excellent, good, fair and poor) (40%) and resistance to disease (20%). Accordingly, 68% of the respondents were of the opinion that animal performance has decreased, while 22.4% reported that animal diseases have increased. About 4.0% reported no change, while 5.6% did not know.

Regarding social indicators, about 100% of the respondents were of the opinion that the number of livestock per household and the capacity of traditional coping mechanisms had decreased, while 40% reported that conflicts related to poverty and grazing land shortages increased. Approximately 3.7% reported no change, while 1.3% did not know. To this effect, Abule *et al.* (2005a) and Solomon *et al.* (2006a) reported an increased resource conflict among the Somali and Afar in the northeast and between the Oromo and Somali pastoralists in the southeast of Ethiopia.

3.3.4 Changes in livestock holding and species patterns with time

Degradation has influenced the vegetation ecology of rangelands in the Somali region with obvious changes in livestock species patterns and livestock holdings of households over time (SoRPARI, 2005b). The findings of this study also agree with same conclusions. The results are presented in Table 3.4. In terms of livelihood, the Somali region pastoralists were economically well-off for 30 years up to 1974, due to the then healthy rangeland conditions and availability of adequate grazing/browsing materials to feed their livestock.

Table 3.4 Changes in wealth ranking of Somali pastoral households according to livestock holding over a 60 year period (1944-2004).

No	Wealth ranks over time	Cattle	Sheep	Goats	Camels	Donkey	Total	(%)
	i) 30 year period before 1974							
1	Wealthy households	400	200	250	50	20	920	56.6
2	Medium households	200	100	150	20	10	480	29.5
3	Below medium households	80	50	80	10	5	225	13.9
	Mean (± SD).	**227±162**	**117±76**	**160±85**	**27±21**	**12±8**	**541±352**	-
	Total TLU	-	-	-	-	-	**809**	-
	DM per year in tons	-	-	-	-	-	**32.11**	-
	ii) 30 year period after 1974	-	-	-	-	-	-	-
1	Wealthy households	100	350	500	120	10	1070	63.3
2	Medium households	50	150	300	60	5	565	33,6
3	Poor households	3	10	22	1	2	38	2.2
4	Very poor households	0	5	12	0	1	18	1.1
	Mean (±SD)	**38±47**	**129±162**	**209±236**	**45±57**	**4.5±4**	**423±500**	-
	Total TLU	-	-	-	-	-	**483.4**	-
	DM per year in tons	-	-	-	-	-	**11.03**	-
	iii) Changes over 60 years	-	-	-	-	-	-	-
	Decrease /Increase	**-527**	**+165**	**+354**	**+101**	**-17**	**+66**	-
	Percent change +/-	**-77.5**	**+47.1**	**+73.7**	**+126.2**	**-48.6**	**+4.0**	-
	Total feed reduction	-	-	-	-	-	**21.08**	**65.65**
	iv) Summary	-	-	-	-	-	-	-
	Holding in TLU (±SD)	-	-	-	-	-	**646±230**	-
	Feed Requirement (±SD)	-	-	-	-	-	**22±15**	-

The ranking of households based on wealth included the following: “wealthy” (total livestock holding of 920), “medium wealthy” (total livestock holding of 480) and “below medium wealthy” (total livestock holding of 225), with few or no poor households in the region. The average livestock composition per household was 41.8% cattle, 21.5% sheep, 29.5% goats, 4.9% camels and 2.3% donkeys. The abundance of feed during 1944-1974 was also favorable for cattle breeding, specifically for milk production. Nevertheless, the average (±SD) livestock holding of households of all wealth classes was 541 (±352), while the numbers for the different livestock species were 227 (±162), 117 (±76), 160 (±85), 27 (±21) and 12 (±8) for cattle, sheep, goats, camels and donkeys, respectively.

During the 30 year period after 1974 environmental and rangeland degradation resulted in substantial changes in eastern Ethiopia in general and the Somali region in particular. Droughts became a common occurrence initially every 5 years and currently every three years or less, resulting in a loss of more than 70% of the households' livestock in the study area (SZAB, 2003). The grasslands have shrunken and the encroachment by woody plants increased, resulting in changes in the original species composition of livestock in favour of camels and small ruminants. The species composition of livestock holding per household changed with camels increasing in numbers by 126.2%, goats by 73.7% and sheep by 47.1%, whereas the numbers of cattle and donkeys declined by 77.5% and 48.6%, respectively. Subsequently, the roles of dairy cattle and donkeys have now been taken by camels, which are drought tolerant, a good dairy animal for milk production as well as a good pack animal for transportation.

Rangeland degradation has also changed the overall wealth status of the pastoralists by eliminating below medium wealthy households and by creating poor and very poor households. The gap between livestock holding of the wealthy, medium wealthy, poor and very poor households also widened, which on the average was 1 070, 565, 38 and 18 heads of livestock, respectively. There was also a drastic change in species pattern, where the composition for an average household changed to 0.6% donkeys, 9% cattle, 10.7% camels, 30.4% sheep and 49.3% goats. This indicates that the numbers of small ruminants escalated with approximately 80%. The average (±SD) number of livestock holding for all four wealth ranks was 423 (±500), while the number of livestock per household by species was 38 (±47), 129 (±162), 209 (±236), 47 (±57) and 4.5 (±4) for cattle, sheep, goats, camels and donkeys, respectively. During a period of 30 years after 1974, the number of livestock per household decreased, the importance of small ruminants and camels increased and poverty increased. Accordingly, the total average livestock holding for all economic classes of households for example, decreased from 809 Tropical Livestock Unit (TLU) to about 483.4 TLU, which is a reduction of 40.3%. This is blamed mainly on rangeland degradation and droughts. However, livestock population is expected to increase due to increase in number of households in time.

The study also showed that pastoral management systems increased in efficiency and flexibility in coping with the diminished natural feed resources. Accordingly, the total estimated annual dry matter feed requirement of 32.11 tons per household during the 30 year period prior to 1974, was reduced to a total of 11.03 tons of annual dry matter feed after 1974. The difference between 1944 and 2004 (60 year period) was calculated to be 646 (±230) in TLU's for the total livestock holding and 22 (±15) tons dry feed required by all wealth classes, respectively. This implies that, during the 30 year period following 1974, there was a total reduction in TLU of approximately 60% with a corresponding reduction of 11.03 tons (65.65% less) in DM feed required per year. This shows that pastoralists have the wisdom of making proper use of the rangeland vegetation resources, as well as are capable of coping with changes in feed shortages by shifting from large to small ruminants and camel production or from grazing to browsing animals. As a result they have developed a strategy to cope with the most available feed resources and by reducing the high annual feed requirement for forages. Despite their efforts and wisdom, the continuity of drought in their areas, have increasingly weakened their coping mechanisms, with the result that poverty is expanding. These findings support the IGAD/FAO (2004) report that poverty has increased more than 40% in those pastoral zones in the Horn of Africa.

3.3.5 Indigenous pastoral rangeland management practices

The pastoralists in general depend on natural feed resources available in different rangeland vegetation types (open grasslands, open savannas, closed savannas and forest areas) to feed their livestock. The potential productivity of the rangelands to provide adequate feed and the availability of the desirable plant species is influenced by the erratic and inadequate rainfall in pastoral areas of Ethiopia, which creates feed shortages. However, pastoralists have developed traditional grazing/browsing land use systems to mitigate feed shortages and make better use of the available feed resources. In general, there are two types of grazing and browsing management practices, known as wet and dry period grazing/browsing. The wet season grazing/browsing is used during the short rainy season of April to May and the long rainy period between June and September. The wet season system is used as transitional to post drought/long dry period grazing/browsing system and capitalizes on the herbaceous and canopy covers at lash stage or at immaturity. The productivity and nutritive values of the plant species during the wet season are inadequate in meeting the animal nutrient requirements. According to the traditional grazing management, all animals are allowed to communally graze/browse with no discrimination between livestock species, age of the animal's, physiological condition such as pregnancy and productivity like milking and dry cows. Hay making and conservation during the wet season for supplementing the animals is not a common practice.

Traditionally, the Somali pastoralists use three types of protected areas for dry period grazing/browsing. These include: (i) part of the rangeland protected by the full agreement of the communities under traditional bylaws, (ii) water logged parts of a rangeland (moist areas) subject to breeding of mosquitoes and cattle biting insects, and (iii) parts of the closed savannas protected for reasons of religion and often available for use during dry or drought periods only. The protected areas are used through rotational grazing systems, but with priority for weaned calves, heifers, lactating or pregnant cows, breeding bulls, ewes and rams. Male calves other than those selected for breeding purpose, are slaughtered to avoid competition for feed with lactating and breeding animals.

Pastoralists also migrate to better feed resource areas for grazing and water as a strategy to mitigate feed and water shortages during droughts and long dry periods. The response by elder pastoralists on frequency of migration during the dry season was: once a week (3%), every 2 weeks (2%), every 3 weeks (5%), every month (20%), every 2 months (10%), every 3 months (25%), every 4 months (20%), every 6 months or twice a year (5%), once a year (8%) and no migration (2%). During the wet season, migration is less, but varies between villages depending on the condition of the available rangelands and water sources. Therefore, the average result on wet season migration was: only once (25%), twice (15%), three times (10%) and no migration (50%).

The results show that mobility in general is higher during the long dry periods and at times of droughts. Availability of labour within a family structure also plays a role in determining the size of the herd per family. Because of this, Somali pastoralists plan for a larger family size with the intention of herding larger livestock numbers. Males of younger age groups are the most engaged in livestock herding and responsible for fetching feed and water for the animals, while older people (men and women), as well as young children remain in the villages. Young animals are kept close to the village premises and taken care of by young boys, girls and women. For the livestock herders, the period away from their villages depend on the nature of the season, especially with regards to the availability of feed and water. Subsequently, in the opinion of the respondents, the average time spent on migration away from villages were: one or two months (5%), 3 months (30%), 4 months (20%), 5 months (10%), 6 months (15%), 7 months (10%), and 8 and 9 months (5%) each. This confirms an increase in mobility during dry periods and a decrease in mobility during wet seasons.

3.3.6 Water resources and management

3.3.6.1 Water resources

Water is the single most limiting element in the arid and semi-arid rangelands and the pastoral area in eastern Ethiopia is no exception. The erratic and inadequate rainfall, recurrent droughts, uneven distribution of water sources (rivers) and a lack of development of an efficient water distribution infrastructure are the main causes for shortage of water, both for human and livestock consumption. More detailed information is presented in Table 3.5. As a result, pastoralists utilize 14 alternative water sources, but this is not sufficient to prevent them from experiencing sporadic water supply problems, especially during the long dry period when water levels in the rivers decline or dry up completely. With regard to water supply, pastoralists have developed 7 indicators (70%) related to the availability and access to water, while 3 indicators (30%) are related to a reduction in the level of the water tables and failures to discharge enough water at a time.

Somali pastoralists normally depend on natural water resources such as permanent and temporary rivers and streams, but all pastoralists do not have equal access to these resources. About 74% of the respondents have access to these water sources during rainy seasons, but with little or no availability during the dry seasons. Hand dug wells and small ponds (beerkaas) are the main water sources used during the dry period, but 88% of the respondents depend on wells and less on ponds. However, this water supply is inadequate for the full year due to high evapotranspiration rates, reduced water tables and discharges and a limited number of available wells.

Despite the desperate need for water, about 62.5% of the respondents stated that there are no dams constructed, either by the regional or the national governments. Pastoralists understand the importance of boreholes as permanent water sources and believe that such solution can solve their water problems, but there is a lack in developing alternative water resources for human and livestock watering by the local, regional and national governments, as well as non-governmental institutions.

Table 3.5 Types of water sources and their accessibility by season for drinking (n = 300).

No	Water sources and their nature	Seasonal availability	Dependability as water source	Respondant (%)
	A. Natural sources			
1	Permanent rivers	Year round, reduced in dry periods	Dependable	100
2	Temporary rivers	During rainy seasons, rare in dry periods	Partly	50
3	Natural water ponds	During rainy and partly dry seasons	Dependable	80
4	Permanent water springs	Year round, decrease in dry period	Dependable	90
5	Temporary water springs	During rainy seasons, but dry up	Partly	50
	Average access to all sources		Wet seasons	**74**
	B. Hand dug wells			
1	Beerkaa (sealed wells)	Longer period, but capacity based	Dependable	80
2	Shallow wells	Temporary, only for dry periods	Short dry period	70
3	Deep wells	Permanent, if enough ground water discharge, but with a declining trend	Dependable	88
	Average access to all sources		Partly dry period	**76.7**
	C. Ponds			
1	Traditionally made ponds	Dry period, if rainy season adequate	Partly	40
2	Improved ponds	Dry period, if rainy season adequate	Dependable	85
	Access to all sources		Partly dry period	**62.5**
	D. Bore holes			
1	Drilled bore holes	For long dry period, if available	Dependable	0.0
2	Municipal water pumps	For dry period, if available	Conditional	0.0
	Access to all sources			**0.0**
	E. Other sources			
1	Migration for water fetching	Means to alleviate dry period shortage	Dependable	50
2	Emergency water supply	During drought period, if available	Conditional	0.0
	Average access to sources			**25.0**

Only during times of drought do relief organizations attempt to deliver emergency water supplies, usually in inadequate quantities. Water shortages for livestock have caused the death of more than 80% of the livestock in the Shinile zone during 2003. Thus, water shortages often result in migration, conflict among pastoral clans and groups and mortality of livestock, which at present in the study area is becoming more of a political, rather than a rangeland problem.

3.3.6.1 Water management for livestock

As indicated in Table 3.6, the type and distribution of water sources and the season of the year influence the watering frequency, distance traveled and the duration of the trekking of the different livestock species. The pastoralists manage the different livestock species based on their inherent ability to withstand periods without water and their ability to travel in order to reach water. Accordingly, during the long dry periods (July, August and September), called “Hagaa”, camels, cattle and donkeys and small ruminants (sheep and goats), travel average (±SD) distances of 120 (±60), 70 (±40) and 55 (±71) km, respectively, to watering points. This takes them an average of 24 (±8), 15 (±3) and 10 (±2) hours, respectively.

The average (±SD) traveling distances and times are reduced during the shorter dry period (December, January and February), called “Jillal”. These distances are reduced to 100 (±45), 55 (±7.1), and 41 (±12) km for camels, cattle and donkeys and small ruminants, respectively. The traveling time is also reduced to 18 (±6), 12 (±3) and 10 (±1.5) hours, respectively. As the availability and access to water resources start to improve at the beginning of the short rainy season (October and November) the traveling distances are further reduced to 55 (±7.1), 30 (±14.1) and 15 (±7.1) km with a corresponding traveling time of 10 (±2.5), 6 (±1.5) and 5 (±0.5) hours for camel, cattle and donkeys and small ruminants, respectively. During the main rainy season (April, May, and June) the traveling distances to water are reduced to 35 (±7.1), 20 (±14.1) and 10 (±7.1) km, while the traveling time is reduced to 8 (±2), 5 (±1) and 2 (±0.3) for camels, cattle and donkeys and small ruminants, respectively. The main rainy season covers about 70% of the Somali region, while 30% of the regional land area receives short rains during March and April and the main rains during June, July and August. However, areas covered by the main rainy season relatively have lesser (but for 5 months) water shortages than the areas none covered by the main rains in the region.

From the results it is clear that camels are able to travel the longest distances to water with the longest interval between watering, while small ruminants are the most restricted in their ability to travel and requires water more frequently. Livestock often suffer from dehydration during the short dry period and face death during the long dry period. The long distances they need to travel, coupled with inadequate watering frequencies, not only deplete their energy but also reduce the time spent on grazing/browsing. At best this is reflected by reduced productivity and growth rates, while large scale mortalities often occur during extended dry periods. A further result of the limited number of watering

Table 3.6 Mean (±SD) watering frequency, distance to water point and trekking time for livestock.

No	Season and livestock species	Drinking frequency	Distance to water point in km	Trekking hours
	A. During long dry period ("Jillal")			
1	Camels	Every week	120±60	24±8
2	Cattle	Every 3 days	70±14	15±3
3	Sheep and goats	Every 2 days	55±7.1	10±2
4	Donkeys	Every 3 days	70±14	15±3
	B. During short dry period ("Dhare")			
1	Camels	Every 5 days	100±45	18±6
2	Cattle	Every 2 days	55±7.1	12±3
3	Sheep and goat	Every 1.5 days	41±12	10±1.5
4	Donkeys	Every 2 days	55±7.1	12±3
	C. During main rainy season ("Guu")			
1	Camels	Every 2 days	35±7.1	8±2
2	Cattle	Every day	20±14.1	5±1
3	Sheep and goat	Every day	10±7.1	2±0.3
4	Donkeys	Every day	20±14.1	5±1
	D. During short rainy season ("Hagga")			
1	Camels	Every 4 days	55±7.1	10±2.5
2	Cattle	Every day	30±14.1	6±1.5
3	Sheep and goats	Every day	15±7.1	5±0.5
4	Donkeys	Every day	30±14.1	6±1.5

points is that it favors the concentration of animals around the watering points, leading to increased degradation of the rangeland sites.

3.3.7 Major constraints of the pastoral production system

The elder Somali pastoralists of the Shinile zone classified their perceptions of the major constraints of the pastoral production system into seven groups. They also described these constraints in terms of 51 different types of negative impacts on the overall livelihood of the pastoral communities (Table 3.7).

Table 3.7. Pastoralists perceptions of major constraints, their description and overall impact.

No	Major constraints	Description of the problem	Overall impact of the problem
1	Drought	Became more recurrent	High livestock mortality Lower prices for livestock Higher prices for grains and flours More dependency on food aid Increased poverty and destitution Migration and social destabilization Traditional coping mechanisms weakened
2	Water shortages	Becoming more scarce	Increasing livestock mortality Increasing livestock emaciation Increasing migration and conflict Diminishing hopes on livelihood Total reduction in milk production Very poor quality of hides and skins
3	Feed shortages	Decline in quantity and quality	Increasing livestock mortality Reducing animal productivity Increasing migration for feed Increasing conflict between clans Limiting livestock diversity
4	Animal diseases	No veterinary services Lack of veterinary drug supply No early warning systems No boarder quarantine system	Cause more mortalities and risk Total failure in producing marketable animals Ban on livestock export by Arabs Total loss of hard currency earnings More cross border disease transmission Lower confidence in government
5	Market for livestock	Lack of appropriate markets Lack of market infrastructures Lack of information systems	More supply to neighbouring countries Difficulty to access markets Low/no taxation to government No attachment to national economy Cheaper price for livestock Unplanned livestock sales at loss Loss of producer benefits Increased cross border livestock trading
6	Population growth	Degradation of rangelands Increased poverty	Over stocking and over grazing Increased desertification Deforestation for income generation Encroachment of woody plants Reduction of palatable grass species Shrinkage of grazing lands Deforestation for income generation Shrinkage of browsing vegetation Loss of biodiversity and important plants Increased conflict from animal theft
7	Marginalization	Lack of adequate development interventions in pastoral concerned constraints	No/too little infrastructure and public services such as vaccination or drugs No/too little development intervention No/too little rangeland rehabilitation/ No/too little water and feed development Lack of agricultural extension services Little/no health and education services Unsustainable security and more conflict Low confidence in the national system

Of these, the pastoralists relate 10 impacts (19.6%) to human population growth, 8 impacts (17.5%) to marginalization, 8 impacts (15.7%) to livestock marketing problems, 7 impacts (13.7%) to drought, 7 impacts (13.7%) to animal disease, 6 impacts (11.8%) to water shortages and 5 impacts (9.8%) to feed shortages. In order to understand the intensity and magnitude of the implications of these constraints, they were ranked in order of importance as perceived by the elder pastoralists. According to this ranking the marginalization by national and regional governments was ranked first, followed by drought (2^{nd}), water shortages (3^{rd}), feed shortages (4^{th}), animal disease (5^{th}), problems of livestock marketing (6^{th}) and human population growth (7^{th}). The differences in perception of the problems have increased since 1974, while the same perceptions did not prevail 30 years before 1974, since 1944. This happened because rangeland degradation has significantly increased since 1974, followed by unavailability of feed resources and increases in shortage of water sources among and between the pastoral villages.

The overwhelming impacts of the different constraints upon the pastoralists seem to have created a far-reaching frustration that may lead to political instability, due to their seeming belief that they are denied their basic development rights. Accordingly, the pastoralists seem to have developed a feeling of betrayal by both the regional and national systems of governance. From their point of view, they are facing the current challenges not because of nature but due to the marginalization of their rights for development at regional and national levels. The role of non-governmental organizations is also explained as non-existing.

3.4 CONCLUSIONS AND RECOMMENDATIONS

In this study, the elder pastoralists have explained that the production system has been faced by different constraints since 1944. Environmental degradation has increased in terms of intensity (frequency) and magnitude (coverage in area). The degradation of the rangeland is influenced by environmental degradation as well as human interference. The latter is still continuing as a threat to the production system, which is driven from the increasing poverty. It is continuing also, because the pastoral areas are the most undeveloped, due to lack of commitment and efforts by all concerned governmental institutions to tackle the problems of pastoralists.

On the other hand, the pastoralists have attempted to developed different drought coping mechanisms which include: migration with their livestock in search of feed and water, diversification of livestock species, early animal sales, borrowing or lending of livestock for re-stocking, fuel wood and charcoal making for a cash income, engagement in daily labour, practicing irrigated cropping, conflict with other clans for grazing and water sources and finally dependence on food aid. However, these mechanisms are growing weaker and less viable due to severe rangeland degradation and recurrent droughts and lack of support by concerned institutions to minimize the problems in pastoral areas.

Therefore, it is concluded that rangeland degradation has become the main factor to influence the vegetation ecology and the production system as well as a threat to the sustainability of the livelihood of the Somali pastoral households. As a result, environmental rehabilitation and conservation of natural resources need to be given priority attention at regional and national levels. In this regard the Pastoral Areas Development Project of the Ministry of Federal Affairs of Ethiopia, must plan to drastically improve water development, veterinary services, drought mitigation strategies for livestock, animal marketing and infrastructure development. These efforts should also be supported by continued research on the problems facing the rangelands of Ethiopia.

The level and intensity of poverty among pastoralists have increased in the 30 year period since 1974. The wealth ranking of households as measured according to their traditional standards has diminished and new wealth classes such as poor and very poor have established at an alarming rate. The issue of poverty must receive the highest priority from the Federal and Regional governments' development strategies in general and the strategy of the millennium poverty reduction goals of Ethiopia that are planned by the Ethiopian government as a component of the global poverty reduction strategy of the United Nations up to 2025.

It was found that the preference and planning for livestock keeping by pastoralists are intelligent and flexible with the purpose of mitigating environmental changes and rangeland degradation. Development planners and policy makers need to incorporate the indigenous knowledge and strategies of pastoralists in development interventions through community participation. The current livestock population showed a definite shift towards small ruminants and camels at the cost of cattle. Measures to prevent the possible loss of valuable indigenous cattle breeds are thus essential.

The pastoralists have acquired extensive knowledge on environmental and rangeland degradation and have developed specific indicators. Most of these indicators were based on their impacts on the production system and on the livelihood of the pastoral communities. Hence they are almost relevant to the knowledge developed by the scientific community, which is attempting to understand the dynamics and functions of the rangeland ecosystems. With due consideration to environmental and rangeland degradation, future development interventions have to integrate the characteristics of the soils, water, livestock and the pastoral communities in order to achieve sustainable solutions. Measures to restore the rangelands have to be employed and suitable evaluation and monitoring systems must be established to measure the success of these measures.

The main constraints of the pastoral production system in eastern Ethiopia in general and the Somali region in particular, have become critical and all concerned institutions such as regional and federal governments and non-governmental organizations should become involved in finding solutions. In context to the constraints facing the rangelands, the following areas of intervention are recommended:

(i) The feeling of marginalization is growing within the pastoral communities. As a result, their confidence in the national government system showed significant land degradation. This should be reversed through integrated, priority based interventions in the form of infrastructure development and service delivery by the regional and national governments and relevant non-governmental organizations. This commitment must receive high priority in order to maintain the unity of the nation.

(ii) Water shortages and a decrease in water quality have increased and is a critical problem to the pastoral communities in general. Loss of livestock due to water shortages, even during non-drought periods, is a common occurrence. To this end, more effort should be made in developing and improving access to surface and underground water sources.

(iii) Feed shortages should be reduced through the rehabilitation of degraded rangelands and the protection against over utilization of rangeland vegetation. This will require efficient restoration techniques with sufficient support of extension services.

(iv) The effects of climatological droughts must be minimized by establishing effective early warning systems and adequate preparedness. The national policies and strategies on disaster prevention and preparedness need to be amended for the pastoral areas with due consideration to livestock preservation and post-drought restocking programs.

(v) Livestock disease management in the pastoral areas must receive similar attention to the crop protection measures in the country. Adequate and efficient vaccination, treatment and drug supply programs as part of a veterinary extension service, must be thus established. The creation of a disease-free zone to promote export of livestock needs to be a national goal for the development of the livestock sector, especially in pastoral areas.

(vi) Livestock marketing infrastructures and information systems must be developed in such a way that livestock production and the national economy are positively linked. In the absence of this, any imposition on the pastoralists to prevent the sales of their animals to neighboring countries is unacceptable and may lead to political unrest.

(vii) The national and regional governments and non-governmental organizations should encourage and promote well planned, designed and facilitated settlement schemes around potential permanent river basins.

CHAPTER 4

PLANT BIODIVERSITY OF THE RANGELANDS OF THE SHINILE ZONE IN THE SOMALI REGION OF EASTERN ETHIOPIA.

4.1 INTRODUCTION

Different arid and semi-arid rangeland vegetation types, such as grasslands, open savannas (bush grassland) and closed savannas (bushland) are found in eastern Ethiopia, especially in the Somali Regional State (SoRPARI, 2005a). These rangelands are rich in botanical resources, but at present they are subjected to human and natural influences (Gemedo-Dalle *et al.*, 2006). Encroachment by weeds and undesirable woody plants has become a threat to the pastoral production systems in the Horn of Africa, especially in eastern Ethiopia (Amaha, 2003; Gemedo-Dalle *et al.*, 2006). Weedy species such as *Xanthium* and *Parthenium*, woody species like *Prosopis juliflora, Acacia mellifera*, *A. nubica* and succulents such as *Opuntia ficus-indica* are increasing and are responsible for a significant reduction in the production potential of the rangelands (SERP, 1990). The state of biodiversity in the Somali region is threatened by encroaching weeds and woody plants (EARO, 2003a), which may be related to rangeland degradation (Chapter 3). Deforestation due to human population pressure, recurrent droughts and overgrazing further contributed to the deterioration of the rangeland vegetation, resulting in a decline of the grazing and browsing capacities of the rangelands in eastern Ethiopia (SoRPARI, 2005c; Gemedo-Dalle *et al*., 2006).

Despite the threat to the biodiversity of the rangelands, there has been little or no effort made to assess the biodiversity of the rangeland vegetation in terms of floristic composition, distribution and diversity of the different rangeland types due to poor plans for conservation and development of natural resources in the Somali Regional State (EWBP, 2004). As a result, there is inadequate data on the floristic status of the rangelands to assist the application of conservation measures (Barkhadle, 1994). Current challenges in the sector of biodiversity in the country in general and the pastoral areas of the country in particular, may be generalized as lack of qualitative and quantitative information base, in order to strategically combat the problems of environmental degradation (Amaha, 2003). All effort to address the issue of biodiversity conservation and development in Ethiopia has primarily focused on food crops, with no attention to rangeland vegetation which has an equal value in terms of fodder production for livestock (Gemedo-Dalle *et al*., 2006). There is a perception that a significant part of the national biodiversity in Ethiopia has already been lost. This may be due to a lack of appreciation for the values of biodiversity as means of environmental protection, economic and esthetical values, livestock and game production and eco-tourism, which are more and above the perceptions related to the pastoral production system in place.

Given the gap in information, there is an urgent need to establish a database on the biodiversity of the rangeland vegetation resources for present and future utilization, conservation and development needs in one hand and for improving the pastoral livestock production system on the other (EARO, 2003b). Existence of information in the form of a database and full knowledge of the rangeland vegetation resources would certainly promote appropriate rangeland research interventions, conservation measures and development planning in the Somali region and other pastoral areas of the country (SORPAI, 2005b). Hence the study was conducted with the following objectives: (i) to develop a biodiversity database on the floristic composition, distribution and diversity of three rangeland vegetation types of eastern Ethiopia, (ii) to determine the extent of bush encroachment and degradation in these rangeland vegetation types, and (iii) to make relevant recommendations for future research and development planning.

4.2 MATERIALS AND METHODS

4.2.1 Approach for the rangeland vegetation assessment

Based on the purpose of the study, various botanical assessment approaches can be used (Whalley and Hardy, 2000). Accordingly, the selection criteria, community participation and reconnaissance field trips described in Chapter 2 were incorporated into this study.

Simple inventory techniques and indigenous knowledge, as described by EWBP (2004), were also used. The study was conducted during the rainy season (June to September) of 2003 and 2004, when most of the rangeland plant species regenerate and flower. Priority was given to grass and forb species, because of their shorter lifespan under arid and semi-arid conditions. The woody plants were studied over a longer period following their phenological characteristics over the seasons mainly flowering stage.

4.2.2 Stratification for vegetation sampling

A stratified sampling technique proposed by ILCA (1990) was used. Accordingly, the area between Dire Dawa and Asbuli (160 km) was divided into 32 belt transects, each with a size of 5 x 2.5 km (12.5 km^2). Based on the vegetation cover and the prescribed stratification approach, a total of 15 representative transects were selected for the study on biodiversity. Each transect was further divided into 10 sampling blocks of 1.25 km^2 each, where 50% of these transects were selected at random using techniques described by Whalley and Hardy (2000).

4.2.3 Identification of plant species

Plant collection procedures for tropical forages described by Shaw and Bryan (1976), Mott (1979), Clements and Cameron (1980), McIvor and Bray (1983), Lazier (1985) and Guarino *et al.* (1995) were extensively used. Plant samples were prepared according to the guidelines of the National Herbarium for Floras and Faunas of Ethiopia (1987). Plants of the herbaceous layers were collected by carefully uprooting the plant using a shovel, together with above-ground parts such as stems, leaves, shoots, flowers, pods or seeds. Samples were pressed between sheets of paper until they were dry and then send to the National Herbarium of Ethiopia in Addis Ababa for identification.

Scientific names of the woody plants were identified in the field by experienced botanist during the flowering period of each plant, while vernacular names of the plants was identified by the local elders and herdsmen in the study area.

4.2.4 Vegetation surveys and data analyses

4.2.4.1 Botanical composition

Determination of botanical composition of the herbaceous layers was based on the use of the step point method described by Tidmarsh and Havenga (1955). A 1.5 m stick with a sharp end was used to indicate the observation points that were spaced at 3 m intervals. Any plant within 20 mm radius from the observation point was recorded. A total of 2 000 observation points per sampling block and a total of 10 000 per rangeland type were recorded. Botanical composition for the woody layers was based on total count of the rooted woody plant species within the 15 belt transects each with a total area of 12.5 km^{-2}, laid out for the study.

Botanical composition based on species frequency as defined by Kothman (1974) and applied by Abercombie *et al.* (1980) was determined based on percentage of occurrence of individual plant species in relation to the total number of observation points. Accordingly, the abundance status of each plant genera or family was categorized as dominant (frequency of occurrence of ≥15%), common (frequency of occurrence of 6-14%), less common (frequency of occurrence of 4-5%) and uncommon or scarce (frequency of occurrence of <4%).

4.2.4.2 Plant diversity

The plant diversity was expressed as percentage of species number per plant genera or family, using methods described by Pielou (1975); Thothhill (1978); Mentis (1984); NHFFE, (1987); Scheiner (1992) and Whalley and Hardy (2000). The status in diversity on genera or family bases was evaluated in terms of perceptions of the elders of the pastoral communities and rangeland managers in the study area. Subsequently, species contributed less than 10% to the total species composition were classified as scarce, while those contributed 10-29% were classified as less common, 30-49% as common and >50% as most common (dominant), respectively.

4.3 RESULTS AND DISCUSSION

4.3.1 Vegetation of the Shinile open grasslands

4.3.1 1 Botanical composition

In the grasslands a total of 49 plant species were identified, which included 38 grass and 11 non-grass species. The 11 non-grass species include 6 forbs, 3 weeds and 2 woody plant species. The grasses made 77.5% and the non-grasses 22.5% of the total species composition for the grassland vegetation. The proportion of the non-grasses was forbs (12.2%), weeds (6.2%) and woody plants (4.1%), whereby the species composition for each category was also calculated. The detail results are given in Table 4.1. Poaceaea was the main grass family covering about 92%, followed by Cyperaceae (5%) and Arecaceae (3%). The total of 49 plant species of the herbaceous layers composed of 22 genera of grasses, 6 families of forbs, 3 families of weeds and 2 families of woody plants. In terms of the identification for life forms of the grass species, there were a total of 13 (59%) perennial grasses and 9 (41%) annual grasses. The frequency for the grasses, forbs, weeds and woody plants in the grassland were 93.1, 3.7, 2.6 and 0.6% respectively (Table 4.1).

The genera for perennial grasses included: *Panicum, Dactyloctenium, Eleucine, Cenchrus, Leptochloa, Sporobolus, Brachiaria, Cynodon, Cyperus,(Sedge), Phalaris* and *Polypogon*. The annual grasses include *Eragrostis, Echinochloa, Sorghum, Eriochloa, Frymbristylis, Hirta, Snowdonia, Setaria* and *Thebaica*. Farther, 53% of the total genera had only 1 species each, 30% of the genera were less common with 2 species each, 6.7% of genera were common with 5 species each and 1 (3.35%) genera was dominant in abundance with 6 species. There exist a higher number of perennials than the annual grasses, which imply the potential productive nature of the grassland. In contrast, the pastoral communities in the study area reported that the annual grasses are increasing and perennials decreasing by time, which might be a sign of deterioration. They also suggested that factors such as overstocking, over grazing and droughts are often responsible.

Table 4.1 Species composition based on frequency of occurrence of the herbaceous layers of Shinile zone grasslands in Somali region, eastern Ethiopia.

No	Species name	Species abundance (%)	Vernacular name (in Smali)	Family name
A	**Grasses**			
1	***Andropogon sorghum***	2.65	Terfae	*Poaceae*
2	***Brachiaria serrifolia***	2.6	Bael-belbeleiti	*Poaceae*
3	***Cenchrus cetigerus***	2.65	Earduq	*Poaceae*
4	***Cenchrus ciliaris***	2.65	Baldohoor	*Poaceae*
5	***Cyperus polystachus***	1.32	Saerdo	*Cyperaceae*
6	***Cynodon aethiopicus***	1.32	Sedeho	*Poaceae*
7	***Dactyloctenium aegyptium***	1.60	Maeda-habour	*Poaceae*
8	***Digitaria abyssinica***	2.12	Quewool	*Poaceae*
9	***Echinochloa pyramidalis***	1.10	Baera-aelay	*Poaceae*
10	***Echinochloa crus-galli***	3.05	Osuguul	*Poaceae*
11	***Echinochloa haploclada***	2.12	Mayeer	*Poaceae*
12	***Eleucine flochifolia***	2.60	Gargoor	*Poaceae*
13	***Eragrostis biflora***	1.00	Mequalihid	*Poaceae*
14	***Eragrostis cilianensis***	3.60	Harfooe	*Poaceae*
15	***Eragrostis pilosa***	1.84	Saaren	*Poaceae*
16	***Eragrostis tef***	1.00	Nefeer	*Poaceae*
17	***Eriochloa nubica***	2.95	Awis-shebel	*Poaceae*
18	***Frimbristylis keniacensis***	2.60	Saard	*Cyperaceae*
19	***Hyparrhenia hirta***	2.60	Hadaf	*Poaceae*
20	***Hypheana thebaica***	2.60	Gouoon	*Arecaceae*
21	***Leptochloa obtusiflora***	2.60	Raari-feres	*Poaceae*
22	***Panicum coloratum***	2.60	Daerdi	*Poaceae*
23	***Panicum spp.***	2.60	Baal-dori	*Poaceae*
24	***Phalaris arundinaceae***	2.60	Hinfaad	*Poaceae*
25	***Polypogon paradoxa***	2.64	Iidilbah	*Poaceae*
26	***Polypogon monspliensis***	1.84	Beraaeley	*Poaceae*
27	***Polypogon schemperianus***	2.6	Baaraadie	*Poaceae*
28	***Schenoplectus confuses***	1.32	Guurta	*Poaceae*
29	***Setaria lindenbergiana***	2.60	Raari-aad	*Poaceae*
30	***Snowdonia polystachia***	2.60	Muuja	*Poaceae*
31	***Sorghum abyssinica***	2.65	Aagaar	*Poaceae*
32	***Sorghum arundinaceum***	7.30	Mequalihdae	*Poaceae*
33	***Sporobolus africanus***	2.60	Yer-yerot	*Poaceae*
34	***Sporobolus agrostidae***	3.70	Aando-queis	*Poaceae*
35	***Sporobolus microprotus***	1.00	Yer-yerot	*Poaceae*
36	***Stylosanthus ssp***	3.70	Rari-ferus	*Poaceae*
37	***Tetrapogon cenchriformis***	1.58	Jebeen	*Poaceae*
38	***Tragus berternianus***	2.60	Merebaabis	*Poaceae*
B	**Forbs**			
1	***Cassia obovota***	0.50	Jaleelo	*Caesalpiniaceae*
2	***Croton menyhartii***	0.80	Baar-ade	*Euphorbaceae*
3	***Hibiscus asperhook***	0.50	Quedil-baah	*Malvaceae*
4	***Ocium spp.***	0.50	Rhido	*Labiataceae*
5	***Sericompsis pallidis***	0.40	Wani-aad	*Amaranthaceae*
6	***Tribulus terrestris***	1.00	Gooundo	*Zygophylaceae*
C	**Weeds**			
1	***Amaranthus spp.***	0.80	Aarem	*Amaranthaceae*
2	***Parthenium spp.***	0.60	Arema Cuba	*Parthenium*
3	***Xanthium abyssinica***	1.20	Oufi	*Xanthaceae*
D	**Woody plants**			
1	***Clotropus procera***	0.20	Booe	*Asclepiadaceae*
2	***Lanthana camara***	0.40	Esamegen	*Lanthaceae*
	Total	**100.0**		

Eragrostis was the dominant genera within the grass community with a total of 7.44%, while the genera's of *Panicum* (5.2%) and *Echinochloa* (6.2%) was also common in occurrence. *Dactyloctenium*, *Eleucine*, *Eriochloa, Cenchrus, Leptochloa, Sorghum* and *Sporobolus* each with a frequency of 5.26% showed to be less common in their occurrence. However, the following 11 genera of grass namely: *Brachiaria, Cynodon, Cyperus, Frimbristylis, Hirta, Phalaris, Polypogon, Setaria, Snowdonia, Tetrapogon* and *Thebaica* each with 2.63% in frequency seem to be scarce in their distribution (Figure 4.1). With regard to the forbs Zygophylaceae and Caesalpiniaceae, each with >15% of frequency, were dominant in occurrence. Labiataceae and Euphorbaceae, each with a frequency of 6-14%, were common in occurrence, but Amaranthaceae and Malvaceae with a frequency of <4% each, seem to be scarce in their occurrence (Figure 4.1). Among the weed families, Xanthium with a frequency of >50% was dominant, whereas, the Amaranthus with about 33% in frequency was common and Parthenium with 16.7% in frequency was less common in occurrence. According to the perception of the pastoralists, these weeds showed a marked progress in expansion since the 1980th (Figure 4.2).

According to the results, *Eragrostis, Sporobolus* and *Echinochloa* are the most common in abundance in the Shinile zone grasslands, while those common genera of grasses need an efficient utilization-based conservation measure in the near future. Those genera of grasses that are in scarce and less common status would require immediate conservation measures integrated with efficient grazing systems. The increase in annual grasses and undesirable forbs like *Tribulus* spp., may indicate an increase in degradation of the grasslands, due to overgrazing and recurrent droughts, which may call upon intervening in appropriate grazing systems and the control of the expansion of weeds and harmful forbs through community participation.

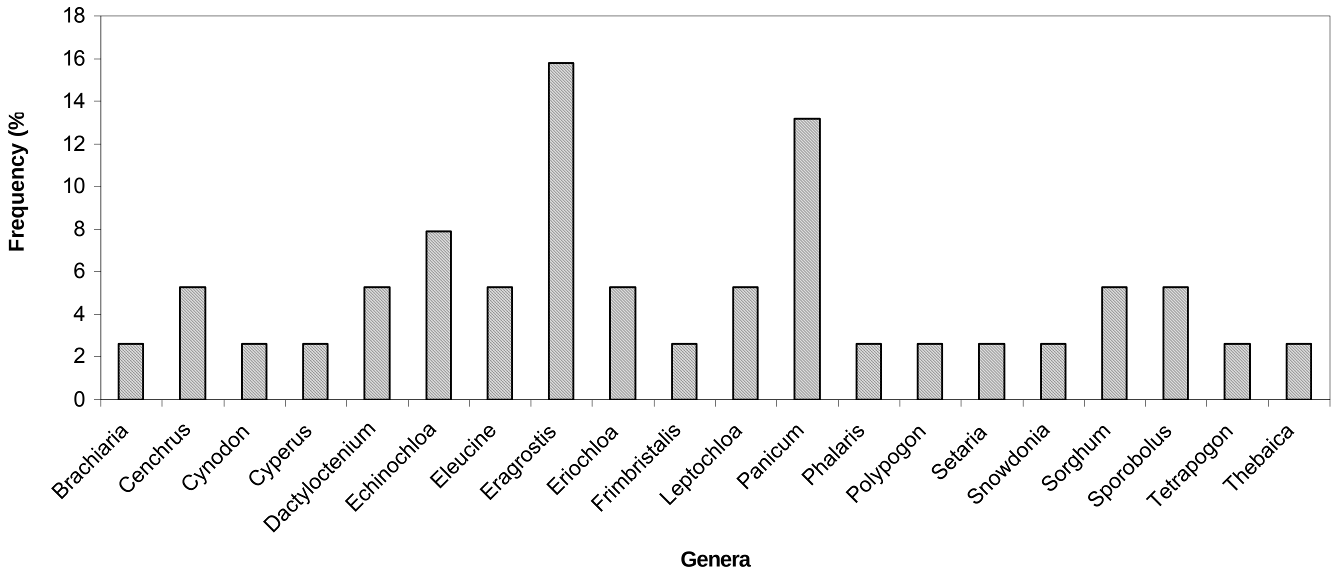

Figure 4.1 Frequency (%) for grass genera of the Shinile zone grasslands in the Somali region.

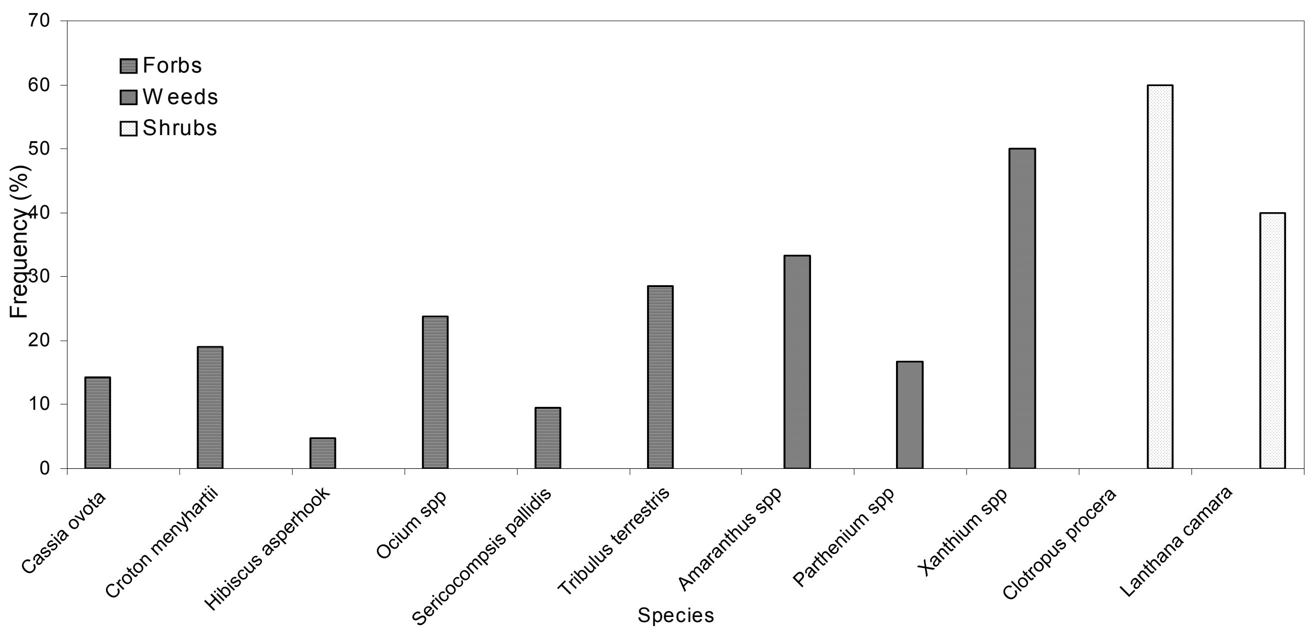

Figure 4.2 Frequency (%) as expressed as percentage of the total frequency for forbs, weeds and woody plants of the grasslands of the Shinile zone in the Somali region.

4.3.1 2 Plant diversity

The genera *Eragrostis* was most common by including four species namely: *Eragrostis cilianensis*, *E. pilosa, E. biflora* and *E. tef*. In general *S. arundinaceum* and *E. cilianensis* were common, while the other spp. were common to scarce. Accordingly, *E. pilosa* and *P. monspeliensis* were less common, whereas *E. biflora, E. tef* and *S. microprotus* were scarce. *Panicum* consisted of five species among which *P. coloratum* was the most common and *P. paradoxa* less common, however, *C. polystachus, C. aethiopicus* and *S. confusus* were observed as scarce. The diversity for the genera *Eriochloa* was consisted of three species among which *E. haploclada* was the most dominant, with *E. cruss-galli* as common and *E. nubica* as less common (Table 4.2).

Four genera of grasses such as *Cenchrus, Dactyloctenium, Sorghum* and *Tetrapogon,* with two species each, showed to be common in their diversity status, however, demanding for utilization-based conservation measures. Thirteen genera of grasses namely *Brachiaria, Cynodon, Cyperus, Eleucine, Frimbristylis, Hirita, Leptocloa, Phalaris, Polypogon, Setaria, Snowdonia*, *Sporobolus* and *Thebaica* consisted of only one species each falling in the status ranging from less common to scarce in their status for diversity, which may require greater concern for utilization-based conservation measures in the short-term.

The forbs *Croton menyhartis*, *Hibiscus asperhook*, *Ocium spp.*, *Sericompsis pallidis* and *Tribulus terrestris* were limited by one species each and at present may seem less common. However, the pastoralists in the study area reported that these species are expanding by time and space. *Tribulus terrestris*, *Xanthium* and *Parthenium* are encroaching more than 50% of the grazing lands and becoming a challenge to the pastoral production system. This indicates that the encroachment by weeds will continue as a threat to the productivity and sustainability of the Shinile grassland and need an integrated effort to control the expansion and to minimize the problem, through the participation of the pastoral communities.

Table 4.2 Species richness (%) of the herbaceous layers of the Shinile zone grasslands of the Somali region.

No.	Genera	Composition (%)	Biodiversity within genera of grasses (%)
A	**Grasses**		
1	Brachiaria	1 (2.6%)	*Brachiaria* spp. *(100%)*
2	Cenchrus	2 (5.3%)	*C .cetigerus (50%), C.ciliaris (50%)*
3	Cynodon	1 (2.6%)	*C. sertifolia, (100%)*
4	Cyperus (sedge)	1 (2.6%)	*C. berteronianus, (100%)*
5	Dactyloctenium	2 (5.3%)	*D. aegyptium (30%), D. agrostidae (70%)*
6	Echinochloa	2 (5.3%)	*E. abyssinica (60), E. haplochlada (40%)*
7	Eleucine	1 (2.6%)	*E. flochifolia (100%)*
8	Eragrostis	6 (18.4%)	*E. biflora (5%), E. cilianensis (25%), E. pilosa (10%), E. tef 5%, E. microprotus 5%, E. arundinacieum (50%)*
9	Eriochloa	3 (7.9%)	*E. crus-galli (30%), E. haploclada (50%), E. nubica (20%)*
10	Frimbristylis	1 (2.6%)	*F. keniacensis (100%)*
11	Hirta	1 (2.6%)	*H. hirta (100%)*
12	Leptochloa	1 (2.6%)	*L. obtusiflora (100%)*
13	Panicum	4 (13.2%)	*P. aethiopicus (20%), P. coloratum (50%), P. paradoxa (20%), P. confusus (10%)*
14	Cynodon	1 (2.6%	*C. polystachus (100%),*
15	Phalaris	1 (2.6%)	*P. arundinaceae (100%)*
16	Polypogon	1 (2.6%)	*P. schemperianus (90%), P. monospeliensis (10%)*
17	Setaria	1 (2.6%)	*S. lindenbergiana (50%), S. arundinacieum (50%)*
18	Snowdonia	1 (2.6%)	*S. polystachia (100%)*
19	Sorghum	3 (7.9%)	*S. abyssinica (25%), S. sorghum (25%), S. arundinoceam (50%)*
20	Sporobolus	1 (2.6%)	*S. africana (50%), S. microprotus (50%)*
21	Tetropogon	2 (5.3%)	*T. cenchriformis (100%)*
22	Thebaica	1 (2.6%)	*T. thebaica (100%)*
B	**Forbs**		
1	Caesalpiniacea	1 (23.8%)	*Cassia obovota (100%)*
2	Euphorbaceae33	1 (19.0%)	*Croton menyhartii (100%)*
3	Malvaceae	1 (4.8%)	*Hibiscus asperhook (100%)*
4	Labiatae	1 (14.3%)	*Ocium spp (100%)*
5	Amaranthaceae	1 (9.5%)	*Sericompsis pallidis (100%)*
6	Zygophylaceae	1 (28.6)	*Tribulus terrestris (100%)*
C	**Weeds**		
1	Amaranthacea	1 (33.3%)	*Amaranthus spp (100%)*
2	Parthenium	1 (16.7%)	*Parthenium hestherophorus (100%)*
3	Xanthiaceae	1 (50%)	*Xanthium abyssinica (100%)*
	Total	**3 (100%)**	
D	**Woody plants**		
1	*Asclepiadaceae*	1 (60%)	*Clotropus procera (100%)*
2	*Lanthanaceae*	1 (40%)	*Lanthana camara (100%)*

4.3.2 Vegetation of the Shinile open savannas (bush-grasslands)

4.3.2 1 Botanical composition

A total of 33 plant species were identified in the open savanna of the Shinile zone, with 20 grass and 13 non-grasses species (Table 4.3). Those non-grass species include 2 forbs and 6 weeds, while a total of 3 250 woody plants were counted consisting of 5 species. According to the taxonomic classification of the plants, there were 10 genera of grasses that consisted about 71.4% of the total composition of the herbaceous layers, 2 families of forbs (7.2%), 6 families of weeds (21.4%) and 4 families of woody plants (15.1%). The grasses consisted 90%, the forbs about 2.5% and the weeds 7.5% of the total frequency of occurrence respectively in the open savannas. In terms of life forms, 8 genera of grasses (52%) were perennials and 3 genera (48%) were annuals. The genera of perennial grasses include *Crysopogon, Dactyloctenium, Sporobolus, Panicum, Phalaris, Tetrapogon, Polypogon* and *Echinochloa.* The annual grasses include *Eragrostis*, *Tragus* and *Setaria*. The forb families include Euphorbiaceae and Zygophylaceae. The weed families consisted of Malvaceae, Rosaceae, Hebenareae, Parthenium, Amaranthaceae and Xanthaceae. The families of the woody plants include Mimosaceae, Capparaceae, Tiliaceae and Caesalpinaceae.

Eragrostis, with 35% frequency of occurrence was observed to be common, while *Dactyloctenium*, *Panicum* and *Tetrapogon* were observed as less common. This may lead to scarce among the grass communities in the absence of utilization-based conservation measures. The genera of grasses such as *Chrysopogon, Echinochloa, Sporobolus, Phalaris, Setaria* and *Tragus* were scarce under existing conditions of mismanagement such as overgrazing and overstocking or droughts. Among the forb families, Euphorbaceae was the most common, while Zygophylacea was observed to be common in the open savannas. With regard to the weed species, the frequency of occurrence for *Xanthium*, *Parthenium* and *Serra incavna* were common, *Amaranthus* and *Hebenaria* were less common and *Euphorbia* was scarce in the herbaceous layers.

However, the weeds are reported by the pastoralists as increasing in time and space, which would call upon for an integrated and adequate control measure and the participation of the communities. Of the woody plant families Capparaceae was the most common followed by Mimosaceae, which is categorized as an encroacher woody plant in the area.

Table 4.3 Species composition based on frequency of occurrence of the herbaceous layers and canopy layers of the Shinile zone open savannas in the Somali region, eastern Ethiopia.

No	Species name	Species Composition (%)	Vernacular (Somali name)	Family name
A	**Grass species**			
1	***Andropogon micans***	4.0	Rareemo	Poaceae
2	***Chrysopogon plumolusus***	4.0	Daa-raemo	Poaceae
3	***Cynodon aethiopicus***	4.0	Sedeho	Poaceae
4	***Dactyloctenium aegyptium***	4.0	Maeda-habour	Poaceae
5	***Digitaria abyssinica***	4.0	Quewool	Poaceae
6	***Eragrostis aspera***	3.5	Tigaad-aad	Poaceae
7	***Eragrostis biflora***	7.70	Mequalihid	Poaceae
8	***Eragrostis cilianensis***	8.5	Harfooe	Poaceae
9	***Eragrostis cylindriflora***	1.7	Nefir	Poaceae
10	***Eragrostis japonica***	1.7	Nefertiti	Poaceae
11	***Eragrostis papposa***	1.7	Sarren	Poaceae
12	***Panicum coloratum***	5.0	Daerdi	Poaceae
13	***Phalaris arundinaceae***	5.0	Hinfaad	Poaceae
14	***Polypogon monosplensis***	5.75	Baraeley	Poaceae
15	***Setaria lindengergiana***	5.0	Raari-aad	Poaceae
16	***Sporobolus agrostideae***	6.0	Aando-queis	Poaceae
17	***Sporobolus microprotus***	5.0	Yer-yerot	Poaceae
18	***Tetrapogon villisa***	4.0	Aya-mukarre	Poaceae
19	***Tetrapogon cenchriformis***	6.0	Haarfo	Poaceae
20	***Tragus racemosus***	5.0	Jebeen	Poaceae
B	**Forbs3**			
1	***Croton menyhartii***	1.5	Baal-aade	Euphorbiaceae
2	***Tribulus terrestris***	1.0	Guondo	Zygophyllaceae
C	**Weeds**			
1	**Large leaved plants**	1.0	Balambaal	Malvaceae
2	***Bergia suffruticosa***	1.0	Kallinole	Rosaceae
3	***Hebenaria montoliveae***	1.0	Issa megen	Hebenareae
4	***Parthenium hestherophorus***	1.5	Arema Cuba	Parthenium
5	***Serra incana cavan***	1.0	Jaalele	Amaranthaceae
6	***Xanthium abyssinica***	2.0	Oufi	Xanthaceae
	Total (a+b+c) percent	100.0		
D	**Woody plans**	Plant counts *		
1	***Acacia nubica***	1 500 (46.0%)	Gummer	Mimosaceae
2	***Acacia tortillas***	350 (10.8%)	Qqurae	Mimosaceae
3	***Cadaba glandulosa***	1 000 (30.8%)	Queleen	Capparaceae
4	***Grewea ferruginea***	250 (7.7%)	Asha-aado	Tiliaceae
5	***Cassia obovota***	150 (4.6%)	Jaleelo	Caesalpinaceae
	Total (d)	**3250 (100%)**		

***** Represents number of counted woody plants and percent frequency of occurrence (%).

Ceasalpiniaceae was less common and Tiliaceae a scarce in the open savannas. In general, the extensive encroachment by weeds and woody plants may be taken as a threat to the livestock production in the area and requires strong control measures that involve the pastoral communities in the area.

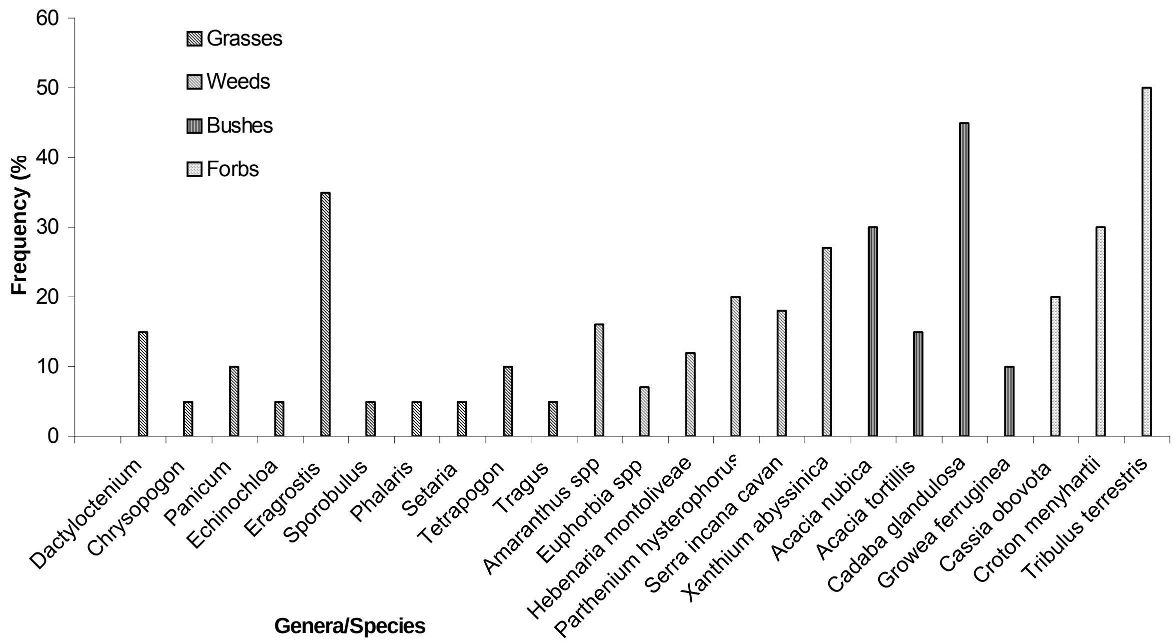

Figure 4.3 Frequency (%) of plant species of the open savanna in the Shinile zone of the Somali region

The higher composition of the perennial grasses may imply the potential productive nature of the open savannas for livestock production. The total number of grass species encountered was also lower by 50%, while annual grasses were higher by 20% in the open savanna than in the grasslands. This indicate that a process of degradation is maybe undergoing in the open savannas more than in the grasslands, most likely due to poor grazing management practices and recurrent drought in the area. Moreover, the encroachment by weeds was 10 times higher and the woody plants 15 times greater in the open savannas than in the grassland, which has reduced the ability of the rangeland to produce adequate forage for livestock feeding and simultaneously increased the threat to the pastoral production system in place. This demands due attention on integrated management for controlling the weeds and woody plants, which also require the support of appropriate rangeland vegetation monitoring and evaluation systems based on the participation of the pastoral communities.

4.3.2 2 Plant biodiversity

The biodiversity of 6 genera (60%) of grasses in the open savannas were consisted of only one species each, while 2 genera (20%) of the grasses were comprised of two species each, 1 genera (10%) of grass however made three species and another 1 genera (10%) of grass was consisting 7 species. *Eragrostis* was the most common in abundance, while *Dactyloctenium* was observed to be common in occurrence (Table 4.4). *Eragrostis* was represented by *E. cilianencis*, which was a common species in occurrence. *Eragrostis biflora* and *P. monosplensis* were less common. *Eragrostis aspera* and *E. papposa* were observed as scarce species in the field, which may be due to overgrazing and drought. *Panicum* and *Tetrapogon* were less common in status that may be due to the degradation in the open savannas. Six genera of grasses namely: *Crysopogon, Echinochloa, Sporobulus, Phalaris, Setaria* and *Tragus* were observed as scarce that require more conservation efforts in the short-term.

The encroachment by weeds such as *Xanthium abyssinica* exceeded by 50% and that of *Parthenium hysterophorus* by 20% more in the open savannas than in the grasslands. Among the woody plants, the (Mimosaceae family), *Acacia nubica* was the most common in the open savanna, while *A. tortillis* was observed to be a common species. *Acacia nubica* is reported by the pastoralists as the most undesirable woody plant which is currently categorized as an aggressive encroacher of the rangelands in the area. Accordingly, it has invaded more than 50% of land area of the open savannas. Capparaceae is the most common in abundance in the conserved areas of the rangeland, while Tillaceae is less common and Caesalpinaceae a scarce woody plant in terms of biodiversity. In general, the open savannas are under a serious threat from encroachment by unpalatable and noxious woody plants, which may be taken as an evidence of a higher level of rangeland degradation in disadvantage of the herbaceous layers, which may further lead from a partial to a total failure of the rangelands to produce enough forage for livestock, specially in the absence of adequate measures to control the encroachment.

Table 4.4 Percentage species richness of the herbaceous and canopy layers of the Shinile zone open savanna.

No.	Genera/Family	Distribution (%)	Biodiversity within genera/family (in %)
A	**Grasses**		
1	Andropogon	1 (5%)	*A. micans (100%)*
2	Crysopogon	1 (5%)	*C. plomulosus, (100%)*
3	Dactyloctenium	1 (5%)	*D. aegyptium (100%),*
4	Echinochloa	1 (5%)	*E. abyssinica (100%)*
5	Eragrostis	7 (35%)	*E. aspera (10%), E. biflora (25%), E. cilianensis (30%), E. cylindriflora (5%), E. japonica (5%), E. papposa (5%), E. monspeliensis (20%)*
6	Sorghum	1 (8%)	*S. agrostidae (100%)*
7	Sporobolus	1 (5%)	*S. microprotus (100%)*
8	Panicum	2 (10%)	*P. aethiopicus (50%), P. coloratum (50%)*
9	Phalaris	1 (5%)	*P. arundinaceae, (100%)*
10	Setaria	1 (5%)	*S. lindenbergiana (100%)*
11	Tetrapogon	2 (10%)	*T. villosa (40%), T. cenchriformis (60*
12	Tragus	1 (5%)	*T. racemosus (100%)*
	Total	**20 (100%)**	
B	**Forbs**		
1	Euphorbaceae	1 (70%)	*Croton menyharti, (100%)*
2	Zygophyllaceae	1 (30%)	*Tribulus terrestris (100%)*
	Total	**2 (100%)**	
C	**Weeds**		
1	Malvaceae	1 (10%)	Large leaved plants (100%)
2	Rosaceae	1 (15%)	*Bergia suffruticosa (100%)*
3	Hebenariae	1 (10%)	*Hebenaria montoliveae (100%)*
4	Parthenium	1 (20%)	*Parthenium hysterophorus (100%)*
5	Amaranthaceae	1 (15%)	*Serra incana cavan (100%)*
6	Xanthaceae	1 (30%)	*Xanthium abyssinica (100%)*
	Total	**6 (100%)**	
D	**Woody plants**		
1	Mimosaceae	2 (25%)	*A. nubica (60%), A. tortillis (40%)*
2	Capparaceae	1 (55%)	*D. glandulosa (100%)*
3	Caesalpinaceae	1 (10%)	*Cassia obovata (100%)*
4	Tillaceae	1 (10%)	*G. ferruginea (100%)*
	Total	**5 (100%)**	

4.3.3 Vegetation of the Shinile closed savanna (bushland)

4.3.3 1 Botanical composition

A total of 20 800 rooted woody plants were counted in the closed savanna area of the Shinile zone during the study. These consists a total of 60 woody plant species under 23 different families comprised deciduous and evergreen plants (Table 4.5). The woody plants serve as browse feed for camel and goat production, source of energy, income generation and traditional values by the pastoralists (Chapter 6).

The families of woody plants include Acanthaceae, Agavaceae, Balanitaceae, Boraginaceae, Burseraceae, Caesalpinaceae, Capparaceae, Cupreussaceae, Euphorbiaceae, Labiataceae, Liliaceae, Mimosaceae, Papilionaceae, Rhamnaceae, Rosaceae, Salvadoraceae, Solananceae, Sterculiaceae, Tamarisaceae, Tiliaceae, Viscaceae and Vitaceae. Accordingly, the family Mimosaceae was dominant in its frequency of occurrence, while Papilionaceae, Burseraceae, Liliaceae and Tiliaceae were observed to be common in occurrence. Three families of woody plants namely Capparaceae, Euphorbiaceae and Rhamnaceae were less common in their frequency of occurrence. The families of the woody plants that include Balanitaceae, Labiataceae, Salvadoraceae, Solanaceae, Vitaceae, Acanthaceae, Agavaceae, Asclepiadaceae, Boraginaceae, Caesalpiniaceae, Cupressaceae, Rosaceae, Sterculiaceae, Tamaricaceae and Viscaceae may be stated as rare due to the lowest frequency of occurrence (Table 4.5 and Figure 4.4). The under canopy herbaceous layers of the closed savannas were not observed as a result of drought that occurred during the study period. Nevertheless, future research activities would be required to undertake farther investigation.

During the study period, over-cutting of the woody plants in the closed savanna of the Shinile zone was observed. Clearing of trees for expansion of crop agriculture was dominant. The Military Training Institute of the Ministry of Defense of Ethiopia at Hurso, for example, cleared a significant area of the closed savanna for irrigated vegetable production, but not used for the intended purpose. As a result, the land was invaded with *Parthenium* spp. There is also over-use of woody plants for fire wood,

Table 4.5 Species composition based on frequency of occurrence of woody plants of the closed savannas.

No	Species name	Total plant count (no.)	Species composition (%)	Vernacular (Somali name)	Family name
1	*Acacia albida*	416.0	2.0	Garbi	Mimosaceae
2	*Acacia benadirensis*	83.0	0.4	Sarmaanyar	Mimosaceae
3	*Acacia bussei*	208.0	1.0	Galool	Mimosaceae
4	*Acacia cernua*	208.0	1.0	Aab-aab	Mimosaceae
5	*Acacia horrida*	208.0	1.0	Sarmaan	Mimosaceae
6	*Acacia mellifera*	582.0	2.8	Beei-iegn	Mimosaceae
7	*Acacia nilotica*	624.0	3.0	Maara	Mimosaceae
8	*Acacia nubica*	624.0	3.0	Guumer	Mimosaceae
9	*Acacia Senegal*	416.0	2.0	Aad-aad	Mimosaceae
10	*Acacia stenocarpa*	83.0	0.4	Damal	Mimosacea
11	*Acacia totilis*	624.0	3.0	Quer-rae	Mimosacea
12	*Acalypha fruticosa*	416.0	2.0	Dhiqrii	Euphorbiaceae
13	*Albiza harveyi*	83.0	0.4	Gisareeb	Mimosacea
14	*Aloe somaliensis*	283.0	1.36	Da-aar	Liliaceae
15	*Aloe tricosantha (white)*	141.0	0.68	Daar-biyoodi	Liliaceae
16	*Aloe tricosantha (red)*	216.0	1.02	Daar-maroodi	Liliaceae
17	*Balanites aegyptiaca*	283.0	1.36	Quud	Balanitaceae
18	*Balanites galabra*	424.0	2.04	Kiddi	Balanitaceae
19	*Blepharis edulis*	354.0	1.7	Aara-aar	Acanthaceae
20	*Boswellia sacra*	518.0	2.49	Mohor	Burseraceae
21	*Cadaba forinosa*	312.0	1.5	Dita-aab	Capparaceae
22	*Cadaba fructicosa*	312.0	1.5	Dukhaan	Capparaceae
23	*Cadaba glandulosa*	416.0	2.0	Queleen	Capparaceae
24	*Cassia obovota*	495.0	2.38	Saalemuko	Ceasalpinaceae
25	*Cissus rotundifolia*	354.0	1.7	Aarmo	Vitaceae
26	*Cissus furthi*	354.0	1.7	Aarmo-gorayo	Vitacea
27	*Crotolaria spp.*	21.0	0.1	Aasuurro	Papilionacaea
28	*Commiphora abyssinica*	518.0	2.49	Aeeqaad	Bursseraceae
29	*Commiphora erythracae*	345.0	1.66	Haa-gaar	Bursseraceae
30	*Commiphora lughensis*	173.0	0.83	Haagar-aad	Bursseraceae
31	*Commiphora ogadensis*	173.0	0.83	Haaga madow	Bursseraceae
32	*Crotolaria articulate*	416.0	2.0	Gabaldaye	Papilionacaea
33	*Crotolaria dumosa*	416.0	2.0	Eala-aas	Papilionacaea
34	*Crotolaria glandifolia*	416.0	2.0	Faarauod	Papilionacaea
35	*Debera galabra*	141.0	0.68	Gueruus	Salvadoraceae
36	*Euphorbia abyssinica*	208.0	1.0	Haadaan	Euphorbiaceae
37	*Euphorbia arobechii*	624.0	3.0	Dharkeyn	Euphorbiaceae
38	*Gomphocarpus fruticosus*	354.0	1.7	Wayla-woed	Asclepiadaceae
39	*Grewia bicolor*	345.0	1.66	Dhebi	Tiliaceae
40	*Grewia forbesii*	173.0	0.83	Kursho	Tiliaceae
41	*Grewia pencillata*	173.0	0.83	Hohob	Tiliaceae
42	*Grewia villosa*	345.0	1.66	Kobosh	Tiliaceae
43	*Grewia ferruginea*	691.0	3.32	Asha-aado	Tiliaceae
44	*Heliorabium spp.*	354.0	1.7	Habo-aad	Boraginaceae
45	*Indigifera Arabica*	21.0	0.1	Eila-aad	Papilonaceae
46	*Indigifera spinosa*	21.0	0.1	Faragorgor	Papilonaceae
47	*Juniperus procera*	354.0	1.7	Dayib	Cupressaceae
48	*Ocium tomentosum*	707.0	3.4	Idieae	Labiataceae
49	*Rubus rosifolius*	354.0	1.7	Issa megen	Rosaceae
50	*Salvadora persica*	566.0	2.72	Aadey	Salvadoraceae
51	*Sanseviera abyssinica*	354.0	1.7	Heeg	Agavaceae
52	*Solanum carinensis*	424.0	2.04	Kirrir	Solanaceae
53	*Sylvia somalensis*	283.0	1.36	Aagaarshie	Solanaceae
54	*Sterculia Africana*	354.0	1.7	Geed-jini	Sterculiaceae
55	*Tamarinusa indica*	212.0	1.02	Raqay	Caesalpinaceae
56	*Tamarix aphyla*	354.0	1.7	Dhuur	Tamarcaceae
57	*Viscum tuberculatum*	354.0	1.7	Queb-doehou	Viscaceae
58	*Ziziphus mauritiania*	520.0	2.5	Gobyar	Rhamnaceae
59	*Ziziphus mucronata*	312.0	1.5	Edi-shabeel	Rhamnaceae
60	*Ziziphus spineles Christi*	208.0	1.0	Gob	Rhamnaceae
	Total	**20 800**	**100.0**		

charcoal making and house construction by non-pastoral groups. The major factor of the observed deforestation was for income generation due to the prevailing poverty and unemployment in the area, which will continue to endanger the vegetation cover of the closed savannas in general and a threat for camel and goat production in the area in particular. Hence conservation measures and efficient utilization strategies are felt as urgent to protect the biodiversity.

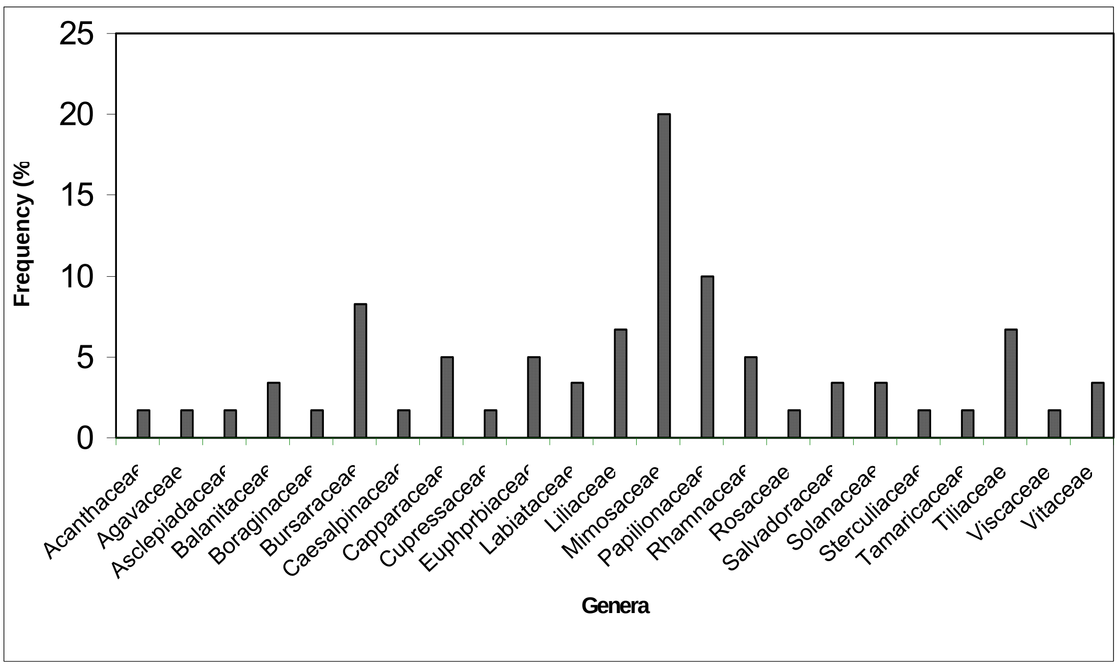

Figure 4.4 Frequency (%) of the families of woody plants of the closed savannas in the Shinile zone

4.3.3 2 Plant biodiversity

Mimosaceae was represented by 12 species and was the most common in abundance of biodiversity (Table 4.6). The latter include the less common species of *A. nilotica*, *A. nubica*, *A. tortillis*, *A. mellifera*, *A. albida* and *A. senegal*, however the remaining were observed to be rare. The pastoralists in the study area reported that *A. nubica* and *A. mellifera* are becoming aggressive encroacher woody plants in the area. Papilionaceae, Burseraceae and Tiliaceae were observed to be common in their biodiversity status. The families of Liliaceae, Capparaceae and Rhamnaceae were less common among the woody plants. However, the woody plant families of

Balanitaceae, Caesalpinaceae, Labiataceae, Liliaceae, Salvadoraceae Solanaceae and Vitaceae, Acanthaceae, Agavaceae, Asclepiadaceae, Boraginaceae, Cupressaceae,

Table 4.6 Percentage species richness of the canopy layers of Shinile zone closed savanna in the Somali region.

No.	Genera/Family	Composition %	Percentage species richness within family
1	Acanthaceae	1 (1.7%)	*B. edulis (100%)*
2	Agavaceae	1 (1.7%)	*S. abyssinica (100%)*
3	Asclepiadaceae	1 (1.7%)	*G. carpus fruticosus (100%)*
4	Balanitaceae	2 (3.4%)	*B. aegyptica (40%), B. galabra (60%)*
5	Boraginaceae	1 (1.7%)	*Heliorabium (100%)*
6	Burseraceae	5 (8.3%)	*B. sacra (30%), C. abyssinica (30%), C. erythracea (20%), C. lughensis (10%), C. ogadensis (10%)*
7	Caesalpiniaceae	2 (3.4%)	*T. indica (30%), Cassia obovata (60%)*
8	Capparaceae	3 (5%)	*C. forinosa (30%),C. fructicosa (30%), C. glandulosa (40%)*
9	Cupressacae	1 (1.7%)	*J. procera (100%)*
10	Euphorbiaceae	3 (5%)	*A. fructicosa (40%), E. abyssinica (20%), E. arobochii (40%)*
11	Labiataceae	2 (3.4%)	*Ocium tomentoium (100%)*
12	Liliaceae	2 (3.4%)	*A. somalinensis (40%), A. tricosantha w. (white) (30%), A. tricosantha (red) (20%)*
13	Mimosaceae	12 (20%)	*A. albida (10%), A, benadirensis (2%), A. busie (5%), A.cernua (5%),A.horrida (5%), A.melifera (14%), A. nilotica (15%), A. nubica (15%), A, senegal (10%),A. harveyii (2%), A. stenocarpa (2%), A. tortillis (15%)*
14	Papilionaceae	6 (10%)	*C. articulata (20%), C. dumosa (20%), C. glandifolia (20%), I. arabica (10%), I. spinosa (10%) Crotolaria* spp *(10%)*
15	Rhamnaceae	3 (5%)	*Z. mauritiana (50%), Z. mucronata (30%), Z. spineles- cristi (20%)*
16	Rosaceae	1 (1.7%)	*R. rosifolius (100%)*
17	Salvadoraceae	2 (3.4%)	*S. persica (80%), D. galabra (20%)*
18	Solanaceae	2 (3.4%)	*S. carinensi (60%), S. somalensis (40%)*
19	Sterculiaceae	1 (1.7%)	*S. africana (100%)*
20	Tamarisaceae	1 (1.7%)	*T. aphyla (100%)*
21	Tiliaceae	5 (8.3%)	*G. bicolor (20%), G. forbesii (10%), G. pencilata (10%), G. villosa (20%), G. ferruginea (40%)*
22	Viscaceae	1 (1.7%)	*V. tuberculatum (100%)*
23	Vitaceae	2 (3.4%)	*C. rotundifolia (50%), C.furthi (50%)*
	Total	60 (100%)	

Rosaceae, Sterculiaceae, Tamaricaceae and Viscaceae were observed to be scarce in their biodiversity status. Despite the abundance in biodiversity status of the family Mimosaceae, this plant family seems to be the most endangered due to over-cutting as a result of its multi-purpose uses. The over-use is thus leading to extinction in some of the most important species such as *Acacia tortilis*.

Among others also, *Acacia nubica* and *A. mellifera* have been observed not only as encroaching woody plants but ever expanding across the closed savannas. Based on the current trend, it could be anticipated that the woody plants would expand and cover most of the canopy covers of the closed savannas in Shinile zone. Both species are found to be ecologically unfriendly to the under canopy herbaceous layers, causing a tremendous decline in the productivity of important grass species. Moreover, the pastoral communities give the least value in their indigenous knowledge.

4.4 CONCLUSIONS AND RECOMMENDATIONS

The botanical composition of the grasslands and the open savannas of the Shinile zone consisted of 38 and 20 species of grasses, respectively. In comparison, the total number of the grass species was 90% higher in the grasslands than in the open savannas. In general, the species of perennial grasses were abundant in distribution, but scarce in diversity or species richness. The annual grass species were low in abundance, but high in diversity or species richness. However, the pastoralists in the study areas reported that the rangeland vegetation ecology is shifting from perennial grasses into annual grasses. This may imply that the grasslands and open savannas in Shinile zone, are showing deterioration in their grazing potential. However, the scenario need further research studies on management options and monitoring of the vegetation dynamics in time and to maintain the health of the rangelands.

The plant biodiversity for the three types of rangelands, in terms of number of species per plant genera or family, was 2 in the grasslands, less than 2 in the open savannas and 3 in the closed savannas. About 16 (53%) of the grass genera consisted of only 1 species each whereas 9 (30%) genera of grasses contained 2 species each. Each of the 2 (6.7%) genera of grasses made up 5 species, except that only 1 (3.3%) genera of grass consisted of the highest number of 7 species.

In conclusion, the biodiversity of the grasses is generally skewed towards a common to less common status. The situation may also be further threatened due to the existing mismanagement in utilization practices of the herbaceous layers. Of the latter, the current over-grazing, over-stocking and other forms of rangeland degradation are worth mentioning. Therefore, the problem calls upon implementing both short- and long-term strategies and action plans in order to promote (i) an appropriate utilization-based conservation scheme for the rangeland vegetation resources, (ii) efficient grazing/browsing systems, (iii) development of forage seed banks (iv) promotion of community-based research and development programs (v) participation of governmental and non-governmental organizations in rangeland development interventions and (vi) participation of pastoral communities and their indigenous knowledge.

The composition for forb species included six in the grasslands and two in the open savannas. *Tribulus terrestris,* which is noxious, was much more abundant in the open savannas than in the grasslands, while the weed species *Xanthium abyssinica* and *Parthenium hysterophorus* was respectively greater by 30 and 20% higher in the grasslands than in the open savannas. Weed species such as *Malvaceae spp*., *Bergia suffruticosa*, *Hebariana montoliveae* and *Serra incana cavan* were observed more in the open savannas than in the other rangelands types, while the weed of *Amaranthus spp*. was observed in the grasslands only. To the contrary, woody species such as *Acacia nubica A. tortillis*, *Cadaba glandulosa*, *Cassia obovota,* and *Grewea ferruginae* were observed only in the open savannas. Moreover, *Acacia nubica* is the most aggressive encroacher that covered about 50% of the open savannas, which is not only overtaking the herbaceous layers, but displacing *Cadaba glandulosa* which is an important camel feed. Similarly, *A. nubica* and *A. mellifera* are encroaching woody plants with a dominating trend in the Hurso closed savanna and extending to other rangelands in the Shinile zone.

In conclusion, the vegetation ecology of the rangeland types in general seem to be (i) endangered by the encroachment of weeds and undesirable woody plants, (ii) deteriorating in the capacity for optimum herbage production, (iii) degrading in their biodiversity status and (iv) suffering from lack of attention to control the expansion of encroachment. In context to the Hurso closed savanna, over-cutting of the woody plants is the most challenge due to lack of protection, while the overall deforestation is diminishing the sustainability of browse feeds and becoming a threat to goat and camel production. Therefore, the problem calls upon: (i) development of appropriate utilization-based conservation strategies and policies, (ii) promotion of awareness creation at the level of pastoral communities, (iii) development and application of appropriate extension systems supported by demonstration sites, (iv) promotion of integrated scientific and traditional control mechanisms on encroacher weeds and woody plants, (v) protection of the environmental degradation, (vi) rehabilitation and restoration of deteriorated rangeland vegetation, (vii) implementation of community participation-based rangeland vegetation monitoring and evaluation systems, (viii) undertaking further studies on biological, chemical and traditional control measures and practices and (ix) collaborative and integrated interventions by governmental, non-governmental and pastoralists' traditional institutions.

CHAPTER 5

AN ECOLOGICAL STUDY ON THE HERBACEOUS LAYER OF RANGELANDS IN THE SOMALI REGION OF EASTERN ETHIOPIA

5.1 INTRODUCTION

The majority of rangeland ecosystems are located in vegetation biomes such as grasslands, shrublands, savannas and deserts (Friedel *et al*., 2000), and these areas are often characterized by an inherent arid climate that experience large daily and seasonal temperature extremes (Williams *et al*., 1968; Vetter *et al*., 2006)). Rangeland condition is a concept encompassing the levels of specific indicators such as plant species composition, vegetation cover (basal cover), forage production (productivity), land condition (soil erosion and compaction) and management at a particular location(s) aimed at sustained livestock production (Trollope *et al.*, 1990; Friedel *et al.*, 2000). According to Mannetje, *et al*. (1976), the determination of the botanical composition of rangeland is important in understanding the fodder value of individual species and their reaction to biotic and edaphic factors, which may be explained in terms of type of species, yield, frequency of occurrence, density and basal cover. Plant dry matter yield is often directly related to animal production, while the other parameters are useful to describe and quantify the plant population and successional trends of the rangeland vegetation (Du Toit and Aucamp, 1985) and to assess the rangeland condition (Foran *et al*., 1978; Tainton, 1986; Throw *et al*., 1988; Van der Westhuizen *et al*., 1999; 2001).

Plant species composition will have an effect on forage quality, animal grazing behaviour (in terms of intake rates, number of bites, bite volume and time of bites), abundance and distribution of the species in the rangelands (O'Reagain, 1996). Knowledge of the botanical composition and trends over time are essential for management decisions (Van der Westhuizen *et al*., 1999; 2001). Increases of undesirable perennial species and decreases of desirable species are important indicators of rangeland condition (Kirkman, 1995), but changes in the abundance of pioneer plants may be misleading in view of their quick response to rainfall and rapid disappearance afterwards (Kelly and Walker, 1977; Shackleton, 1993). A decrease in palatable perennial grasses is often the result of continued selective and/or heavy grazing by livestock (Noy-Meir *et al*., 1989; Sarmento, 1992; Vetter *et al*., 2006), in which case they are normally replaced by unpalatable grasses, weeds and shrubs (Cottam and Evans, 1945; Dyksterhuis, 1949). Forage species are commonly classified into broad quality categories such as high, medium and low, whereas determinants of palatability and acceptability are poorly understood with very little quantitative data available for rangelands in general (Meissner *et al*., 1999).

Many researchers argued that heavy and continuous grazing affected herbaceous species composition very little in some communal areas and game reserves in South Africa, and that selective grazing may cause more severe degradation (Tainton, 1972; Venter *et al*., 1989; Barnes, 1992). In arid and semi-arid communal rangelands, heavy and/or continuous grazing may, however, affect the species composition negatively, often resulting in the replacement of perennial species by annuals (Heady, 1966; Kelly and Walker, 1977; O'Connor and Pickett, 1992). According to Vetter *et al*. (2006) rangeland under communal tenue had higher stocking rates, human population densities, different grass composition, lower basal cover and higher soil erosion than commercial farms. In addition to rangeland management practices (grazing regimes), climate and soil are also important determinants of rangeland condition in the semi-arid and arid rangelands (Effershank *et al*., 1978, Van der Westhizen *et al*., 2001), and the effect of grazing during any specific season is often dependent on rainfall (O'Connor, 1985; 1991). Climatic and grazing variables can limit biomass production in arid and semi-arid rangelands of Africa (Behanke *et al*., 1993; De Queiroz, 1993; Dodd, 1994).

Forage production of rangelands is important to pastoral livestock systems and animal production is in most cases directly related to the productivity (Fourie *et al*., 1985), perenniality, palatability and acceptability of the plants to the animals (Cowling *et al*., 1994). As in other rangeland ecosystems, fodder production is influenced by climate (Behanke *et al*., 1993; De Queiroz, 1993; Dodd, 1994), the condition of the soil (Effershank *et a*l., 1978), as well as the degree of degradation (McNaughton *et al*., 1983;

Schlesinger *et al*., 1990). Perennial plants add to the nutritive value of rangeland and its ability to withstand biotic stress such as trampling, fire, insect and drought damages (Roberts *et al*., 1975; Fourie, 1985). Other determinants of rangeland productivity include the form of land tenure, stocking rate, drought, burning, animal type and distribution of watering points (Danckwerts *et al*., 1996).

The percentage basal cover is a term often used to describe the ground area occupied by the bases of individual herbaceous species (Whalley *et al*., 2000). It is considered a good indicator of potential herbage production (Snyman and Van Rensburg, 1986; Thrash, 1988), but with a low abundance of desirable forage producing species a high percentage basal cover does not always imply a high forage production (Merill and Readon, 1966; Meissner *et al*., 1999; Coates and Penning, 2000). Basal cover is considered a sensitive indicator of ecosystem change and is one of the measurements used in several rangeland condition assessment techniques (Holecheck *et al*., 1989). From a rangeland management point of view, basal cover is an important parameter because it is believed that overstocking and continuous grazing will lead to a decline in total basal cover (O'Connor, 1985; Thurow *et al*., 1988; Gemeda-Dalle *et al*., 2006).

Although many investigations have been performed in the Borana lowlands, there was no record of any comparative study of the different functional land use units, and also quantitative data are missing on the density and frequency of forage species (Gemedo-Dalle *et al*., 2006). Besides, reports on the status of Borana rangelands in southern Ethiopia seem contradictory. Ayana and Baars (2000) and Ayana Angassa (2002) concluded that Borana rangelands were in good condition. On the other hand, results from the same area showed that the Borana system of production was on decline since the early 1990's (Oba and Kotile 2001, Oba *et al*., 2000). These contradicting reports will have a negative impact on the planning and implementation of development projects in the area. The arid and semi-arid rangelands of eastern Ethiopia, and in particular those in the Shinile zone of the Somali Regional State, cover large land areas and are characterized by their heterogeneity. To date very few ecological studies were conducted in this area. Consequently, the unique rangeland resources of the area, notably the vegetation and soil, are as yet unquantified, as is their potential for pastoral livestock production. This was the motivation for this study that was conducted with the following objectives:

(i) to determine and assess the botanical composition of the herbaceous layer,
(ii) to evaluate the production potential of the herbaceous layer for sustainable pastoral livestock production,
(iii) to identifying and evaluate key forage species and
(iv) to study the effect of rangeland degradation on the diet selection and grazing behaviour of various livestock species along degradation gradients.

5.2 METHODS AND MATERIALS

5.2.1 Selection of sample site and layout of transects

The study was conducted within each of the three broad vegetation types of the Shinile zone in the Somali region of eastern Ethiopia. These included the Asbuli grassland, Aydora open savanna (bush-grassland) and Hurso closed savanna (bushland) (Chapter 2, section 2.5). A degradation gradient was identified in each of the three vegetation types. Based on the observed rangeland condition a further four areas were identified along each degradation gradient, subjectively classified as excellent (named the benchmark), good, moderate and poor. At each of these four rangeland condition sites, belt transects were randomly laid out on a total area of 10 km^2 representing each site. Along the degradation gradients 10 replicated plots in the form of 1 000 x 3 m belt transects were randomly laid out.

The coordinates for each belt transect were recorded with the use of a GPS (Geographic Position Systems). In the Asbuli grassland the transect at the benchmark site was located between 09^{o}59'787"E to 41^{o}19'407"E and from 10^{o}00'964"N to 41^{o}17'381"N at an altitude ranging from 748 to 760 m.a.s.l. The transect in the good condition site was located between 09^{o}787"E to 41^{o}19'407"E and from 10^{o}59'964"N to 41^{o}17'381"N at an altitude ranging from 748 to 760 m.a.s.l. The transect site in moderate condition was located between 09°59'187"E to 41°20'288"E and 09°598'667"N to 41°20'661"N at an altitude ranging from 745 to 769 m.a.s.l. The transect site in poor condition was located between 10°00'227"E to 41°19'767"E and from 09°58'667"N to 41°20'661"N at an altitude ranging from 747 to 769 m.a.s.l (Appendix Table 2, 3 and 4).

In the Aydora open savanna (bush grassland), the transect at the benchmark site was located between 09°49'787"E to 41°20'463"E and from 10°00'964"N to 041°17'381"N at an altitude ranging from 808 to 820 m.a.s.l. The transect in the site in good condition site was located between 09°49'473"E to 41°21'407"E and from 09°59'187"N to 41°20'288"N at an altitude ranging from 754 to 826 m.a.s.l. The transect site in moderate condition was located between 09°59'187"E to 41°20'288"E and 09°47'686"N to 041°20'942"N at an altitude ranging from 825 to 846 m.a.s.l. The transect site in poor condition was located between 09°46'195"E to 41°21'516"E and from 09°47'686"N to 41°20'942"N at an altitude ranging from 825 to 863 m.a.s.l (Appendix Table 5.2).

In the Hurso closed savanna (bushland) the transect at the benchmark site was located between 09°37'131"E to 41°38'466"E and from 09°37'578"N to 041°38'431"N at an altitude ranging from 1086 to 1112 m.a.s.l. The transect in the site in good condition was located between 09°37'247"E to 41°38'333"E and from 09°37'187"N to 41°38'588"N at an altitude ranging from 1086 to 1100 m.a.s.l. The transect site in moderate condition was located between 09°37'281"E to 41°38'163"E and 09°37'383"N to 41°38'252"N at an altitude ranging from 1082 to 1095 m.a.s.l. The transect site in poor condition was located between 09°37'281"E to 041°38'163"E and from 09°37'071"N to 41°38'137"N at an altitude ranging from 846 to 1104 m.a.s.l (Appendix Table 5.3).

5.2.2 Species composition and basal cover of the herbaceous layer

The species composition of the herbaceous layer was determined based on frequency of occurrence (Kothman, 1974; Abercombie *et al.*, 1980), using the step point method (Mentis 1981) according to the nearest plant method. In addition to the nearest plant, basal cover strikes were also recorded from which the percentage basal cover and bare ground were calculated as described by Foran *et al*. (1978) and Mentis (1981). Point-observations were spaced by 3 m intervals. Surveys were done in September and October 2003 and 2004 after the main rainy season (June-August), when the rangeland vegetation was at full growth. One thousand point-observations were recorded per replicate (plot) and 10 replicates per treatment (rangeland condition site). Hence a total of 10 000 observation points were recorded for each rangeland condition site.

Herbaceous plants were identified on a species basis. Species that was difficult to identify were allocated a number and a sample collected using the guidelines of Mott (1979), McIvor and Bray (1983), Lazier (1985) and Guarino *et al*. (1995). Plant samples, including stems, leaves, branches, flowers, pods and seeds, if present, were prepared according to the guidelines of the National Herbarium for Floras and Faunas of Ethiopia (NHFEE,1987) and send to the National Herbarium of Ethiopia in Addis Ababa for identification.

5.2.3 Rangeland condition assessment

The ecological status of herbaceous plants refers among others to the grouping of species on the basis of their reaction to different levels (intensity and frequency) of grazing. All herbaceous species react differently to grazing, because they can either increase or decrease in number. This response to grazing forms part of the succession theory described by Dyksterhuis (1949) and various ecological indices were developed to describe the response of herbaceous plants to different grazing regimes (Foran, 1976; Tainton *et al*., 1980; Vorster, 1982). Subsequently, all identified herbaceous plants (grasses and forbs) were classified into the following groups: (i) Decreasers (species that are abundant in rangeland in excellent condition and which decrease in rangeland that is under or over utilized - these species are usually highly desirable), (ii) Increasers IIa (species that are rare in rangeland in excellent condition, but increases when rangeland in moderately overgrazed over the long -term, these species can still be considered desirable), (iii) Increasers IIb (species that are rare in rangeland in excellent condition, but increases when rangeland is heavily overgrazed over the long-term, these species are generally less desirable), and (iv) Increasers IIc (species that are rare in rangeland in excellent condition, but increases when veld is excessively overgrazed over the long-term, these species are generally undesirable).

Growth period as perceived by pastoralists may be explained as the period of a physiological process of herbaceous plants from germination up to seed production and ending in standing hay with a straw color in the field. This physiological process is expected to take place under conditions where rainfall (moisture) and soil temperatures are normal. Growth periods are normally measured in number of days during a year (Ethiopian Ministry of Agriculture, 2000). However, despite certain attempts with food crops in some thermal zones of Ethiopia, there is no information regarding forage crops. The application of indigenous knowledge of the pastoralists and particularly the herdsmen (Gemedo-Dalle *et al*., 2006) was used in bridging the gap of the information base. Based on the knowledge of the elder pastoralists and herdsmen all the herbaceous species were also classified as annual, semi-perennial and perennial species.

From the herbaceous species composition, a rangeland condition score were calculated for each site using the Ecological Index Method (Vorster, 1982) as widely used in South Africa. The herbaceous species, belonging to the same ecological group (increasers/decreasers), were grouped together and their combined percentages contribution to the species composition was multiplied with specific index values. These index values were: 10 (Decreasers), 7 (Increaser IIa), 4 (Increaser IIb), 1 (Increaser IIc and Invader species) (Vorster, 1982). According to this procedure the lowest possible score is 100 (very poor) and the maximum score 1 000 (excellent). The rangeland condition scores along each rangeland condition gradient were compared with that of its benchmark site as described by Tainton *et al*. (1980). Those with a score between 441-550 were classified as in excellent condition, while those with scores of 331-440, 221-330, 111-220 and <110 were classified as good, moderate, poor and very poor, respectively.

5.2.4 Assessment of soil erosion and soil compaction

In each of the tree rangeland vegetation types and in each of four rangeland condition sites along the various degradation gradients, the condition of the soil surface was evaluated. During the survey of the herbaceous species composition, using the step point method (see section 5.2.2 above), the occurrence of soil erosion and soil compaction were also recorded at each observation point (spaced at 3 m intervals). The assessment of the level of soil erosion was based on the presence of pedestals. It was assumed that the higher the pedestals the greater the loss of topsoil at that specific point. The occurrence and severity of soil erosion at each observation point were classified as: (i) no soil erosion, (ii) slight sand mulch, (iii) slope sided pedestals and (iv) pavements and gullies with severity values of 5, 4, 3, 2 and 1 respectively, as described by Baars *et al.* (1997). Soil compaction was measured by a simple penetrometer in 1 kg cm^{-2}, by taking 500 observations per rangeland condition site and was compared with cattle routes in the rangeland sites used for animal trekking to watering points.

5.2.5 Dry matter production and grazing capacity

The dry matter (DM) yield of herbaceous plants was determined in each of the Asbuli grassland and Aydora open savanna during November 2003. Unfortunately estimation of the DM yield for the Hurso closed savanna, was found to be difficult due to drought during the study periods and was therefore not done A harvest technique was employed, which provided estimates of net primary production, less possible dry matter losses due to grass mortality and utilization. Grasses and forbs were harvested in quadrants of 1 x 1 m (1 m^2) randomly placed along the belt transect at each rangeland condition site. A total of 10 quadrats (10 m^2) per rangeland condition site were harvested. Rooted herbaceous plants within each quadrate were clipped to stubble height using hand clippers. Stubble height varied from 10-30 mm, depending whether the species was tufted or not. The clipped material was dried for 24 hours at 105°C to a constant mass and weighed. In addition, all herbaceous plants were counted in the quadrats in order to determine the average plant density per m^2.

Estimates of the grazing capacity were made from the grass DM yields, using methods described by Minson and McDonald (1987) and the formula proposed by Moore *et al.* (1985):

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

where y = grazing capacity (ha AU^{-1} or ha TLU^{-1}) (AU = animal unit: animal of 450 kg live weight, and TLU = tropical livestock unit: animal of 250 kg live weight)
d = number of days in a year (365)
DM = total herbaceous DM yield ha^{-1}
f = utilization factor and
r = daily grass DM required per AU/TLU ((10 kg AU^{-1} and 6.5 kg TLU^{-1}).

The utilization factor ranges between 20 to 50%, but for the purpose of this study an average utilization factor of 35% (f = 0.35), was used for calculating the grazing capacity as explained by Boudet and Riviere (1968).

5.2.6 Identification of key forage species and their phytomass production

Key forage species for purposes of this study refer to those species that, under the arid and semi-arid conditions of the rangelands, are perceived by the pastoralists to be the most valuable fodder species that have a high production potential, are climax species and which are preferred by livestock. The pastoral elders, herdsmen and rangeland experts in the study area were asked to name the key forage species and a list of species was compiled. The typical habitat of each species was identified and representative sites selected. A homogeneous stand for each species was harvested in quadrates of 1 x 1 m (1 m^2) when they were in a 50% flowering stage. A total of 10 quadrats (10 m^2) per species were harvested. Rooted herbaceous plants within each quadrate were clipped to stubble height using hand clippers. Stubble height varied from 10-30 mm, depending whether the species was tufted or not. The clipped material was dried for 24 hours at 105^{o}C to a constant mass and weighed. Each block selected for harvesting was protected from livestock and human interference by using the participation of the communities in the area. The main purpose was to prevent grazing and trampling.

5.2.7 Diet selection preferences and grazing behaviour of livestock species

Camels, cattle, sheep and goats were used in a study for their diet selection preferences and grazing behaviour. Six animals from each livestock species were randomly selected from a herd, marked for identification with an ear tag and their live body weight determined using a heart girth meter or a scale. In the study of the diet selection, each experimental animal was allowed to graze the herbaceous layer for 12 hours per day (between 06:00 and 12:00 and again between 14:00 and 18:00). Each animal grazed for a period of four days in a rangeland condition site and a total of 16 days in four rangeland condition sites (excellent, good, moderate and poor) per rangeland vegetation type. Each animal was also studied for a period of 7 days (a week) on grazing for grazing behaviour and in order to record the grazing intensity in number of bites and time spent on grazing in each rangeland condition site.

The diet selection and grazing behaviour of each animal was observed with the aid of a binocular from a distance of approximately five meters. Data recorded include the grass species grazed, number of bites and time spent on grazing. The trial was conducted between September and October 2003 when the forage species were in full bloom. Each animal was systematically under observation for a total of four hours a day, 2 hrs before noon and 2 hrs after noon. This was done in order to accommodate the heat and high temperature in the study area. One trained assistant was assigned to follow one animal per day and a total of 24 technicians were deployed for the study.

In view of the limited duration of the actual diet selection trial the indigenous knowledge of the pastoralist were used to reinforce the data of the field trial. Based on the extensive knowledge and experience of the pastoralists, all herbaceous species were ranked according to the diet selection preference of livestock. Accordingly, each species of the herbaceous layer was ranked as first, second, third and fourth in terms of the preference by either of the four classes of livestock (cattle, sheep, goat and camel).

5.2.8 Estimation of dry matter feed intake of different livestock species

A total of 24 male animals, consisting of 6 cattle, 6 sheep, 6 goats and 6 camels were used for the grazing trial. These animals were also used for the feed intake trial. The average live weight of the cattle, sheep, goats and camels were 200, 35, 30 and 220 kg, respectively. The experiment was conducted in the Camel Experiment Station, located at about 70 km from the town Jigjiga (capital city of the Somali Regional State).

All animals were transported form the Asbuli grassland where the grazing trial was done. Accordingly, the cattle and camels were each given 1 kg of *Panicum coloratum* hay, while the sheep and goats each received 200 g of hay, five times a day for 21 days (3 weeks). The number of bites and time taken to consume the feed offered to each experimental animal was recorded. The average number of bites per minute and feed intake (g) per bite were calculated and used through extrapolation to estimate the average intake per animal during grazing. Accordingly, the daily forage intake per animal per day was calculated as: total minutes in grazing per day per animal, multiplied by the number of bites per minute, multiplied by the forage intake per bite per animal.

5.2.9 Data analysis

The data was analyzed using descriptive statistics such as percentages, means and standard deviations, which were calculated using the Statistical Package for Social Sciences (1996). Friedmans test (Steel and Torrie, 1980) was used for ranked data analysis. When the analysis revealed the existence of significant variation, the analysis of variance (ANOVA) was performed. Pearson's correlation coefficient analysis (Hintze, 1998) was used to signify the relationship between rangeland condition classes of the rangeland types and different productivity parameters, where necessary.

5.3 RESULTS AND DISCUSSION

5.3.1 Species composition and basal cover of the herbaceous layers

5.3.1.1 Species composition

In both rangeland vegetation types, a total of 45 species of grass and non-grass species were identified (Table 5.1) (Asbuli grassland and Aydora open savanna). The Asbuli grassland contributed 24 species (51% of the total number of species), while the Aydora open savanna contributed 23 species (49%). It was difficult to assess the composition of the under canopy herbaceous layers of the Hurso closed savanna, due to the prevailing drought. Some species were unique to the grassland and the open savanna.

Accordingly, 12 species (52.2% of total) were common only in the Asbuli grassland and the Aydora open savanna, while 11 species (47.8%) were unique to the grassland. These include: *Andropogon sorghum, Brachiaria deflexa, Colotropus procera, Croton menyharti, Cyperus polystachia, Sericompsis palidis, Sorghum abyssinica, S. arundinaceae, Sporobolus africana, Tetrapogon cenchriformis, Tragus berteronianus* and *Parthenium hysterophorus*. Eleven species (50%) were unique to the open savanna. These include: *Andropogon micans, Chrysopogon aethiopicus, C. monspliensis, Eragrostis papposa, E. cylindriflora, E. joponica, E. papposa, Phalaris aruninaceae, Sera incana cavan, Sporobolus microprotus* and *Tetrapogon villosus* (Table 5.1).

The species composition of the herbaceous layer of the Asbuli grassland included 9 annual species and 15 perennial species. The dominance of perennial grasses may indicate that the herbaceous layer is in good condition. According to the pastoralists, however, the trend in the annual grasses has been increasing over the past two decades and some useful perennial grasses have decreased in abundance (Table 5.2).

Table 5.1 List of common and unique herbaceous species recorded in the Asbuli grassland and Aydora open savanna of the Shinile zone of the Somali region

No	Asbuli grassland	Aydora open savanna	Species unique to only one of the rangeland type
1	*Andropogon sorghum*	*Andropogon micans*	*Andropogon micans*
2	*Brachiaria deflexa*	*Chrysopogon aethiopicus*	*Andropogon sorghum*
3	*Colotropus procera*	*Chrysopogon monosplensis*	*Brachiara deflexa*
4	*Croton menyharti*	*Chrysopogon plumolosus*	*Colotropus procera*
5	*Cyperus polystachia*	*Cynodon aethiopicus*	*Croton menyharti*
6	*Dactyloctenium aegyptium*	*Dactyloctenium aegyptium*	*Chrysopogon aethiopicus*
7	*Digitaria abyssinica*	*Digitaria abyssinica*	*Chrysopogon monsplensis*
8	*Eragrostis biflora*	*Eragrostis aspera*	*Eragrostis aspera*
9	*Eragrostis cilianensis*	*Eragrostis biflora*	*Eragrostis cylindriflora*
10	*Eragrostis pillosa*	*Eragrostis cylindriflora*	*Eragrostis joponica*
11	*Hyphenea thebaica*	*Eragrostis cilianensis*	*Eragrostis papposa*
12	*Panicum coloratum*	*Eragrostis joponica*	*Phalaris arundinaceae*
13	*Polypogon monspliensis*	*Eragrostis papposa*	*Sericompsis pallidis*
14	*Sericompsis palidis*	*Panicum coloratum*	*Sera incana cavan*
15	*Setaria lindenbergiana*	*Phalaris arundinaceae*	*Sorghum abyssinica*
16	*Sorghum abyssinica*	*Polypogon monspliensis*	*Sorghum arundinaceae*
17	*Sorghum arundinaceae*	*Sera incana cavan*	*Sporobolus africana*
18	*Sporobolus africanus*	*Setaria lindenbergiana*	*Sporobolus microprotus*
19	*Sporobolus agrostideae*	*Sporobolus agrostideae*	*Tetrapogon cenchriformis*
20	*Tetrapogon cenchriformis*	*Sporobolus microprotus*	*Tragus berteronianus*
21	*Tragus berteronianus*	*Tetrapogon viliosus*	*Tetrapogon viliosus*
22	*Tribulus terrestris*	*Tribulus terrestris*	*Parthenium hystherophores*
23	*Parthenium hystherophores*	*Xanthium abyssinica*	
24	*Xanthium abyssinicum*		

Based on the indigenous knowledge of the pastoralists, for the grassland and open savanna, the length of the growing period for all species was found to vary from 2.5 months up to 6 months. No information was available on *Clotropus procera*. In the Aydora open savanna, of the total of 17 annual species, 2 species (11.76%), 9 species (52.94%) and 6 species (35.30%) are perceived to have growth periods of about 2.5, 3.0 and 3.5 months, respectively. In both the grassland and open savanna, there were a total of 21 species of perennial grasses, of which the pastoralists reported that 11 species (52.39%) having a 4 months growth period each, while 7 species (33.33%) have a growth period of 5 months and 2 species (9.52%) 6 months of growth.

Table 5.2 Botanical composition related parameters of the Asbuli grassland and Aydora open savanna of the Shinile zone of the Somali region

No	Plant species	Different plant parameters			
		Life form	Length of growth period (months)	Ecological grouping	Palatability
1	*Andropogon micans*	Annual	3.5 months	Decreaser	HP
2	*Andropogon sorghum*	Annual	3.5 months	Decreaser	HP
3	*Brachiaria deflex*	Perennial	5 months	Decreaser	HP
4	*Colotropus procera (shrub)*	Perennial	NA	Invader	UP
5	*Croton menyharti*	Annual	2.5 months	Increaser IIc	LP
6	*Chrysopogon aethiopicus*	Perennial	4 months	Decreaser	HP
7	*Chrysopogon monosplensis*	Perennial	4 months	Decreaser	HP
8	*Chrysopogon plumolosus*	Perennial	4 months	Decreaser	HP
9	*Cynodan aethiopicus*	Perennial	4 months	Increaser IIa	IP
10	*Cyperus polystachia*	Perennial	4 months	Increaser IIc	LP
11	*Cyperus rotandus*	Perennial	6 months	Increaser IIc	LP
12	*Dactyloctenium aegyptium*	Annual	2.5 months	Increaser IIc	IP
13	*Digitaria abyssinica*	Perennial	4 months	Increaser IIa	HP
14	*Eragrostis aspera*	Annual	3 months	Decreaser	HP
15	*Eragrostis biflora*	Annual	3 months	Decreaser	HP
16	*Eragrostis cilianensis*	Annual	3 months	Increaser IIb	P
17	*Eragrostis cylindriflora*	Annual	3 months	Increaser IIa	P
18	*Eragrostis japonica*	Annual	3 months	Increaser IIa	P
19	*Eragrostis papposa*	Annual	3 months	Decreaser	HP
20	*Eragrostis pillosa*	Annual	3 months	Decreaser	HP
21	*Hyphenea thebaica*	Annual	3 months	Increaser IIa	P
22	*Panicum coloratum*	Perennial	4 months	Decreaser	HP
23	*Phalaris arundinaceae*	Perennial	4 months	Decreaser	HP
24	*Polypogon monspliensis*	Perennial	4 months	Increaser IIb	P
25	*Sericompsis palidis*	Annual	3.5 months	Increaser IIc	LP
26	*Setaria lindenbergiana*	Perennial	4 months	Increaser IIa	P
27	*Sorghum abyssinica*	Annual	3.5 months	Increaser IIb	HP
28	*Sorghum arundinaceae*	Annual	3.5 months	Increaser IIa	P
29	*Sporobolus africana*	Perennial	4 months	Increaser IIb	P
30	*Sporobolus agrostideae*	Perennial	5 months	Increaser IIb	P
31	*Sporobolus microprotus*	Perennial	5 months	Increaser IIb	P
32	*Tetrapogon cenchriformis*	Perennial	5 months	Increaser IIc	P
33	*Tetrapogon villosa*	Perennial	5 months	Increaser IIb	P
34	*Tragus berteronianus*	Perennial	5 months	Increasers IIc	P
35	*Tragus racemosus*	Annual	3.5 months	Increaser IIc	P
36	*Tribulus terrestris*	Annual	2.5 months	Increaser IIc	LP
37	*Parthenium hystherophorus*	Perennial	6 months	Invader	UP
38	*Xanthium abyssinicum*	Perennial	5 months	Invader	UP

HP= highly palatable, P= palatable (between high and intermediate), IP= intermediately palatable, LP= less palatable and UP=unpalatable, NA= data not available

According to the ecological grouping of the species, 13 of them (34.2%) are Decreasers, 6 species (15.8%) Increaser IIa, 7 species (18.4%) Increaser IIb, 9 species (23.7%) are Increaser IIc and 3 species (7.9%) are Invaders. Among the Invaders, the weed species *Parthenium hystherophoreus* and *Xanthium abyssinica* were dominated.

In terms of species palatability for the different classes of livestock, the most palatable species were Decreasers followed by Increasers IIc, while Increaser IIa and IIb were less palatable. Accordingly, 14 species (36.8%) are highly palatable, another 14 species

(36.8%) are palatable, 2 species (5.3%) intermediately palatable, 5 species (13.2%) are less palatable and 3 species (7.9%) are unpalatable (Table 5.2).

Based on frequency of occurrence the number of species in the Asbuli grassland was highest in the benchmark (19 species = 35.1% of the total), high in the good rangeland condition site (17 species = 31.5%), low in the moderate condition site (11 species = 20.4%) and lowest in the poor rangeland condition (7 species = 13%). Assuming a 100% score in the benchmark, the species abundance showed a decline in the moderate, good and poor rangeland conditions sites of 10.5, 42.10 and 63.16 %, respectively. This implies that deterioration in the rangeland condition has a direct and negative influence on the number of species (Table 5.3).

Of the total number of 19 species in the benchmark site of the grassland, the species frequency of occurrence was dominated in the following order namely: *Sorghum abyssinica*, *Andropogon sorghum*, *S. arundinaceae*, *Digitaria abyssinica*, *Tetrapogon cenchriformis*, *Sporobolus africana*, *Bracheria deflexa*, *S. agrostideae*, *Eragrostis cilianensis*, *Tragus berteronianus* and *Colotropus procera*. With regard to the good rangeland condition class, the occurrence in terms of species frequency was dominated by *S. abyssinica*, *S. arundinaceae*, *Setaria lindenbergiana*, *D. abyssinica*, *A. sorghum*, *E. cilianensis*, *S. agrostideae*, *T. berteronianus*, *T. cenchriformis* and *Panicum coloratum* in that order. The species frequency of occurrence in the moderate condition grassland site was dominated by *D. abyssinica*, *E. cilianensis*, *Tribulus terrestris*, *Sorghum abyssinica*, *S. africana*, *Polypogon monspliensis* and *S. arundinaceae* in that order. For the poor condition site, the order of species frequency was *T. terrestris*, *Xanthium abyssinicum*, *D. abyssinica*, *S, africana*, *E. cilianensis* and *C. procera*. The frequency for the weed species increased along the degradation gradient from the benchmark to the poor rangeland condition sites. Therefore, it may be possible to indicate that invader weeds have more opportunity for expansion as the rangeland condition deteriorates (Table 5.3).

Table 5.3 Species composition (%) of the herbaceous layer based on frequency of occurrence in the different rangeland condition sites of the Asbuli grassland in the Shinile zone of the Somali region

No	Plant species	Rangeland condition			
		Benchmark	Good	Moderate	Poor
1	***Andropogon sorghum***	**8.5**	**8.3**	**NA**	**NA**
2	Bare ground	**0.05**	**5.0**	**30.0**	**55.0**
3	***Brachiaria deflexa***	**6.0**	**NA**	**NA**	**NA**
4	***Colotropus procera***	**NA**	**0.8**	**2.0**	**4.9**
5	***Croton menyharti***	**NA**	**NA**	**2.9**	**NA**
6	***Cyperus polystachia***	**2.5**	**2.0**	**NA**	**NA**
7	***Dactyloctenium aegypticum***	**NA**	**3.6**	**NA**	**NA**
8	***Digitaria abyssinica***	**7.5**	**8.4**	**14.5**	**7.5**
9	***Eragrostis biflora***	**4.0**	**NA**	**NA**	**NA**
10	***Eragrostis cilianensis***	**5.0**	**7.0**	**10.5**	**6.5**
11	***Eragrostis pillosa***	**4.0**	**NA**	**NA**	**NA**
12	***Hyphenea thebaica***	**3.1**	**4.9**	**NA**	**NA**
13	***Panicum coloratum***	**4.4**	**6.2**	**NA**	**NA**
14	***Polypogon monspliensis***	**4.6**	**NA**	**6.4**	**NA**
15	***Sericompsis palidis***	**NA**	**3.6**	**NA**	**NA**
16	***Setaria lindenbergiana***	**7.0**	**9.0**	**NA**	**NA**
17	***Sorghum abyssinica***	**9.1**	**9,4**	**7.7**	**NA**
18	***Sorghum arundinaceae***	**8.0**	**9.3**	**4.8**	**NA**
19	***Sporobolus Africana***	**6.4**	**NA**	**7.0**	**6.7**
20	***Sporobolus agrostideae***	**6.0**	**6.5**	**NA**	**NA**
21	***Tetrapogon cenchriformis***	**6.8**	**6.2**	**NA**	**NA**
22	***Tragus berteronianus***	**5.0**	**6.3**	**NA**	**NA**
23	***Tribulus terrestrris***	**NA**	**NA**	**9.9**	**9.4**
24	***Parthenium hystherophores***	**1.2**	**1.5**	**1.8**	**2.2**
25	***Xanthium abyssinicum***	**0.75**	**2.0**	**2.5**	**7.8**
	Total (%)	**100.0**	**100.0**	**100.0**	**100.0**
	Total number of species	**19.0**	**17.0**	**11.0**	**7.0**

In terms of number of species the benchmark and good condition sites of the Aydora open savanna had a total number of 11 species (23.9% of the total number of plant species) each. The number of species was higher in the moderate condition and poor condition rangeland sites, each with 12 species (26.1% of the total number of plant species). Assuming a 100% score for the benchmark, the number of species was similar in the good condition site, but showed an increase by about 10% in the moderate and poor rangeland condition sites. There was an increase in invader species along the degradation gradient from the benchmark to the poor condition with higher population of *Xanthium abyssinicum* in the benchmark (Table 5.4). The weed is not so far reported in the rangelands in eastern Ethiopia.

Table 5.4 Species composition (%) of the herbaceous layer based on frequency of occurrence in the different rangeland condition sites of the Aydora open savanna in the Shinile zone of the Somali region

No	Plant species	Frequency (%)			
		Benchmark	**Good**	**Moderate**	**Poor**
1	***Andropogon micans***	5	4	3	2
2	Bareland	3	8	21	44
3	***Chrysopogon aethiopicus***	0	3	4	6
4	***Chrysopogon monosplensis***	0	30	0	1
5	***Chrysopogon plumolosus***	0	0	22	0
6	***Cynodon aethiopicus***	9	0	6	0
7	***Dactyloctenium aegyptium***	10	9	6	0
8	***Digitaria abyssinica***	9	0	0	0
9	***Eragrostis aspera***	0	0	0	3
10	***Eragrostis biflora***	0	10	9	7
11	***Eragrostis cylindriflora***	0	0	2	4
12	***Eragrostis cilianensis***	0	9	0	0
13	***Eragrostis japonica***	7	0	0	0
14	***Eragrostis papposa***	0	0	0	5
15	***Panicum coloratum***	4	2	0	2
16	***Phalaris arundinaceae***	0	0	5	0
17	***Polypogon monspliensis***	7	0	0	0
18	***Sera incana cavan***	1	1	2	0
19	***Setaria lindenbergiana***	30	15	12	9
20	***Sporobolus agrostideae***	0	10	7	11
21	***Sporobolus microprotus***	6	0	4	0
22	***Tetrapogon viliosus***	0	3	0	3
23	***Tribulus terrestris***	0	0	0	3
24	***Xanthium abyssinicum***	14	0	0	0
	Total (%)	**100**	**100**	**100**	**100**
	Total number of plant species	**11**	**11**	**12**	**12**

Of the total number of 11 species found in the benchmark site of the Aydora open savanna, the species number was dominated in the following order, namely *Setaria lindenbergiana Xanthium abyssinicum*, *Dactyloctenium aegyptium, Cynodon aethiopicus, Digitaria abyssinica*, *Eragrostis joponica*, *Polypogon monospliensis*, *Sporobolus microprotus* and *Andropogon micans.* Of the total of 11 species in the good rangeland condition class, the species was dominated by *Chrysopogon monosplensis, Setaria lindenbergiana, Eragrostis biflora, Sporobolus agrostideae, D. aegyptium* and *Eragrostis cilianensis* (Table 5.4).

With regard to the moderate rangeland condition class, the species was dominated in the following order, namely *Chrysopogon monosplensis Setaria lindenbergiana, Eragrostis biflora, Sporobolus agrostideae, Cynodon aethiopicus, Dactyloctenium aegyptium, Phalaris arundinaceae*, and *Chrypsopogon aethiopicus*. The order in which the species frequency was dominated in the poor condition class, was dominated by *Sporobolus agrostideae, Setaria lindenbergiana, Eragrostis biflora, Chrysopogon aethiopicus, Phalaris arundinaceae* and *Eragrostis papposa*.

5.3.1.2 Basal cover and bare ground

There was a negative relation between bare ground and plant basal cover along the degradation gradients of all three rangeland vegetation types. The percentage bare ground increased ($p<0.01$) and the basal cover decreased ($p<0.01$) as degradation increased from the benchmarks to the poor condition sites. Accordingly, there was a linear increase in bare ground from the good to the poor condition sites (Figure 5.1).

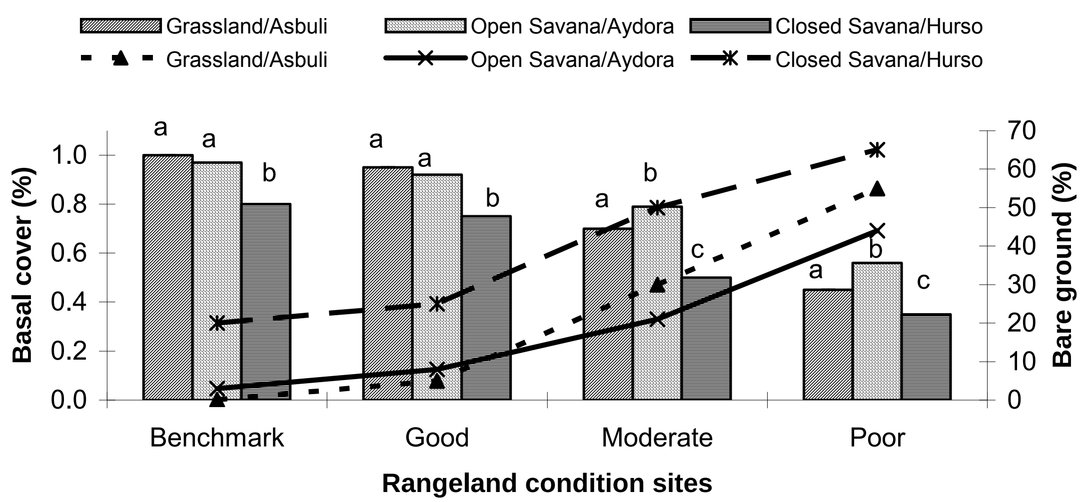

Figure 5.1 Proportion of basal cover and bare ground in relation to rangeland condition sites. (The bar graphs represent the basal cover and the line graphs the bare ground). Different letters mean there exist significant differences ($p<0.05$).

5.3.2 Rangeland condition assessment

5.3.2.1 The Asbuli grassland

Based on the Ecological Index Method (EIM), the benchmark (excellent), good, moderate and poor rangeland condition sites at the Asbuli grassland were rated as excellent, moderate, poor and very poor respectively. The same sites evaluated, based on the benchmark method, showed a difference from that of the EIM. Accordingly, the excellent, good, moderate and poor condition sites score excellent, good, moderate and poor respectively (Table 5.5).

Table 5.5 Ecological status based on EMI rangeland condition index score for the different condition sites of the Asbuli grassland in Shinile zone, Somali region

No	Plant species	Rangeland condition sites			
		Benchmark	**Good**	**Moderate**	**Poor**
1	***Andropogon sorghum***	85.0	83.0	0.0	0.0
2	***Brachiara deflexa***	60.0	0.0	0.0	0.0
3	***Colotropus procera***	0.0	0.8	2.0	4.9
4	***Croton menyharti***	0.0	0.0	2.9	0.0
5	***Cyperus polystachia***	2.5	2.0	0.0	0.0
6	***Dactyloctenium aegypticum***	0.0	3.6	0.0	0.0
7	***Digitaria abyssinica***	75.0	84.0	145.0	75.0
8	***Eragrostis biflora***	40.0	0.0	0.0	0.0
9	***Eragrostis cilianencis***	20.0	28.0	42.0	26.0
10	***Eragrostis pillosa***	40.0	0.0	0.0	0.0
11	***Hyphenea thebaica***	21.7	34.3	0.0	0.0
12	***Panicum coloratum***	40.0	62.0	0.0	0.0
13	***Polypogon monspliensis***	18.4	0.0	25.6	0.0
14	***Sericompsis palidis***	0.0	3.6	0.0	0.0
15	***Setaria lindenbergiana***	49.0	63.0	0.0	0.0
16	***Sorghum abyssinica***	36.4	37.6	30.8	0.0
17	***Sorghum arundinaceae***	56.0	65.1	33.6	0.0
18	***Sporobolus Africana***	44.8	0.0	49.0	46.9
19	***Sporobolus agrostideae***	42.0	45.5	0.0	0.0
20	***Tetrapogon cenchriformis***	6.8	6.2	0.0	0.0
21	***Tragus berteronianus***	5.0	6.3	0.0	0.0
22	***Tribulus terrestris***	0.0	0.0	9.9	9.4
23	***Parthenium hystherophores***	1.2	1.5	1.8	7.8
24	***Xanthium abyssinicum***	0.75	2.0	2.5	0.0
	Total index score	**644.55**	**528.50**	**345.10**	**172.20**
					<
	Condition class grade based on EIM	**Excellent**	**Moderate**	**Poor**	**Very poor**
	Class grades for Asbuli grassland as per assessment	**Excellent**	**Excellent**	**Moderate**	**Poor**
	Expressed based on benchmark condition	**100.0%**	**82.0%**	**53.5%**	**27%**
	Condition class grades based on benchmark	**Excellent**	**Good**	**Moderate**	**poor**

Site selection and layout of the experimental sites classified into condition classes based on subjective method was acceptable, provided an adequate knowledge and experience required.

5.3.2.2 The Aydora open savanna

According to the EMI method the benchmark, good, moderate and poor sites scored excellent, excellent, moderate and moderate respectively. Based on the benchmark method however, the excellent, good, moderate and poor condition sites of the rangeland scored as excellent, excellent, good and moderate respectively (Table 5.6).

Table 5.6 Ecological status based on rangeland condition assessment for the different condition sites of the Aydora open savanna in the Shinile zone, Somali region

No	Plant species	Rangeland condition classes			
		Benchmark	**Good**	**Moderate**	**Poor**
1	***Andropogon micans***	50	40	30	20
2	***Chrysopogon aethiopicus***	0	30	40	60
3	***Chrysopogon monosplensis***	100	200	0	10
4	***Chrysopogon plumolosus***	0	90	130	0
5	***Cynodon aethiopicus***	63	0	42	0
6	***Dactyloctenium aegyptium***	10	9	6	0
7	***Digitaria abyssinica***	90	0	0	0
8	***Eragrostis aspera***	0	0	0	10
9	***Eragrostis biflora***	20	80	90	70
10	***Eragrostis cylindriflora***	0	0	14	28
11	***Eragrostis cilianensis***	0	32	0	0
12	***Eragrostis japonica***	49	0	0	0
13	***Eragrostis papposa***	0	0	0	50
14	***Panicum coloratum***	40	20	0	20
15	***Phalaris arundinaceae***	0	0	50	0
16	***Polypogon monspliensis***	28	0	0	0
17	***Sera incana cavan***	4	4	8	0
18	***Setaria lindenbergiana***	210	105	84	63
19	***Sporobolus agrostideae***	0	40	28	44
20	***Sporobolus microprotus***	24	0	16	0
21	***Tetrapogon viliosus***	0	12	0	12
22	***Tribulus terrestris***	0	0	0	3
23	***Xanthium abyssinicum***	14	0	0	0
	Total index score	**702.0**	**662.0**	**538**	**390** <
	Condition class grade	**Excellent**	**Moderate**	**Poor**	**Very poor**
	Class grades for Aydora open savanna assessment	**Excellent**	**Excellent**	**Moderate**	**Moderate**
	Expressed based on benchmark condition	**100.0%**	**94.3%**	**76.6%**	**55.5%**
	Condition class grades based on benchmark	**Excellent**	**Excellent**	**Good**	**Moderate**

The findings in the Aydora open savanna were still support that selection of the rangeland sites and classification into their relevant condition site by using the subjective method was a reliable technique, provided that a good knowledge and experience may be required. However, the results also support the argument that the EMI method need to be complemented with the benchmark method.

5.3.3 Assessment of soil erosion and soil compaction

The soil erosion in the three vegetation types showed a similar trend, with the lowest erosion ($p<0.01$) over the degradation gradient in the benchmark sites and with a linear increase close correlation with a decrease in basal cover. Accordingly, soil erosion was lower ($p<0.05$) in the good sites, higher in the moderate sites and the highest in the poor condition sites. The study also revealed that the higher the percentage bare ground, the higher the soil erosion. Overgrazing and mismanagement of the rangelands are responsible for the increased level of soil erosion in the rangelands (Figure 5.2)

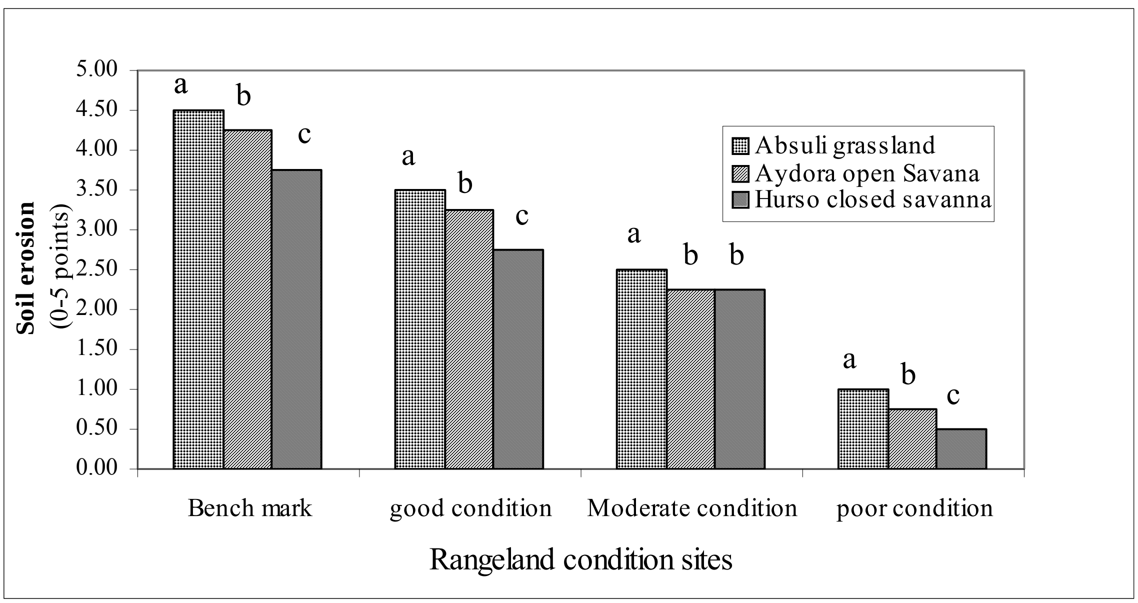

Figure 5.2 The inverse proportion of soil erosion in relation to rangeland condition classes. Different letters mean there exist significant differences ($p<0.05$).

The highest ($p<0.01$) soil compaction in the three rangeland types was observed on the cattle paths. In comparison, the soil compaction in the poor condition sites was not significantly different ($p>0.050$) from that found in the cattle paths. The compaction was slightly lower in the moderate condition sites, but significantly (p<0.05) lower in the good and excellent condition sites (Figure 5.3). Associated factors that may have attributed to the soil compaction are high levels of soil erosion due to overstocking, overgrazing and over utilization of the canopy layers of the rangeland vegetation.

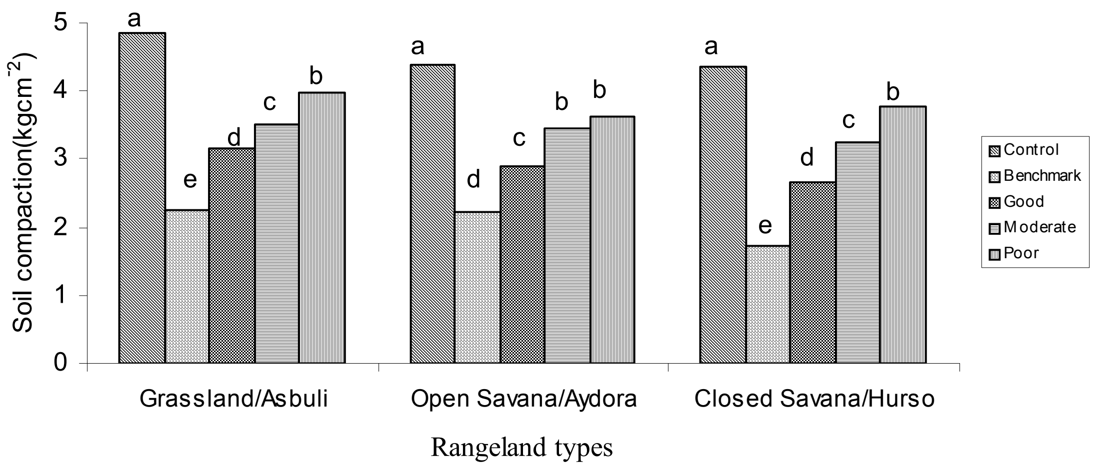

Figure 5.3 The level of soil compaction along the degradation gradients for the different vegetation types (control presents cattle paths). Different letters mean there exist significant differences (p<0.05)

In general, soil compaction and soil erosion increased as the condition of the rangelands deteriorated, which may further reduce the productivity of the rangelands and its ability to support a sustainable pastoral livestock production system.

5.3.4 Dry matter production and grazing capacity

5.3.4.1 Dry matter production

Among the different rangeland condition sites of the Asbuli and Aydora rangelands, the benchmarks showed the highest (p<0.05) DM production. There was no significant difference (p>0.05) in DM production between the benchmark and good rangeland condition sites (Table 5.7). The DM production of the good condition sites was higher (p<0.05) than that of the moderate and poor rangeland condition sites, while the DM in the poor rangeland condition site was lower (p<0.05) compared to the benchmark, good and moderate rangeland sites. Therefore, rangeland productivity in terms of DM production decreased with rangeland degradation.

Table 5.7 Dry matter yields (kg DM ha^{-1}) and grazing capacity (ha LSU^{-1}or ha TLU^{-1}) in relation to rangeland condition classes for the Shinile zone herbaceous layers

Rangeland condition class	Asbuli grassland			Aydora open savanna		
	DM yield (kg ha^{-1})	Grazing capacity		DM yield (kg ha^{-1})	Grazing capacity	
		Ha LSU^{-1}	Ha TLU^{-1}		Ha LSU^{-1}	Ha TLU^{-1}
Benchmark	9 480^{A}	1.1	0.70	9 000^{A}	1.2	0.73
Good condition	8 470^{AB}	1.23 (>2.5%)	0.80 (>14%)	7 270^{AB}	1.43 (>19.2)	0.90 (>23.3%)
Moderate condition	5 350^{C}	1.95 (>62.5%)	1.22 (74%)	4 690^{C}	2.22 (>85%)	1.40 (91.8%)
Poor condition	1 670^{D}	6.24 (>420%)	3.9 (457%)	1 600^{D}	6.52 (>443%)	4.10 (>461%)

Different letters mean there exist significant differences ($p < 0.05$) between means.(>)= extra grazing area (%) requirement (compared to that of the benchmark)

The correlation between the rangeland types and their DM yield was determined (Table 5.8). A higher production was expected from the grassland than the open savanna, but the analysis showed that there was a negative correlation ($p<0.05$) between rangeland productivity and rangeland type in terms of kg DM ha^{-1} (Table 5.8). This may be due to the availability of more productive grass species in the open savanna as opposed to the grassland.

Table 5.8 Correlation coefficient for dry matter yield (kg DM ha$^{-1)}$ in two rangeland types

Type of parameter	Yield correlation by type of rangeland	
	Asbuli grassland	Aydora open savanna
Dry matter yield vs rangeland types	-0.975*	-0.989*

*= significant difference ($p < 0.05$)

The higher DM per ha in the Shinile zone rangelands may be attributed as a result of flooding, shallowness of the water table and dominance of high yielding perennial forage species. Moreover, the DM per ha in the poor rangeland condition sites was observed to be higher in comparison to similar conditions of the arid and semi-arid rangelands of the Borana rangelands in south eastern Ethiopia (Solomon et al., 2006a) and Middle Awash of eastern Ethiopia (Abule *et al.*, 2005b). This may imply a good soil fertility of the sites in the Shinile rangelands despite the level of degradation.

5.3.4.2 Grazing capacity estimation

The grazing capacity calculated in terms of number of ha per LSU or ha per TLU showed a good potential in supporting livestock production in the study area. As indicated in Table 5.7, the deterioration of the rangeland conditions seems to have a negative impact on the grazing capacities of the rangeland sites. Reductions in potential to produce adequate fodder to support the livestock production, demanding more hectares of grazing land needed to maintain a single LSU or TLU. The study revealed that the current productive nature of the benchmark and good rangeland condition classes of the Asbuli grassland and Aydora open savanna have a high grazing capacity. Based on the daily animal feed requirements (10 kg $day^{-1}LSU^{-1}$ or 6.5 kg $day^{-1}TLU^{-1}$) (Table 5.7), for the good condition sites 12% additional land was required per LSU and 14% more per TLU in the Asbuli grassland, while for the same condition site in the Aydora open savanna about 19.2% more land per LSU and 23.3% more land per TLU was required compared to the good condition site, respectively.

In order to maintain a LSU or a TLU in the moderate rangeland conditions of the Asbuli grassland, there is an additional land requirement which is 62.5% and 74% more than the benchmark. Similarly, for the same condition site in the Aydora savanna, about 85% and 457% greater area per TLU is required compared to that of the benchmark site, respectively. With regard to the poor rangeland condition site of the Asbuli grassland about 420% more land per LSU and 457% per TLU, was required composed to the benchmark. Farther, 443% more land per LSU and 462% more land per TLU is required in the poor condition site of the Aydora savanna compared to the benchmark, respectively.

5.3.5 Key forage species and dry matter production

A total of 17 grass species were identified as key forage species in the Asbuli grassland and Aydora open savanna (Table 5.9). *Panicum coloratum*, *Sorghum abyssinica*, *Andropogon sorghum*, *Setaria lindenbergiana*, *Eragrostis biflora*, *Tetrapogon* *cenchriformis*, *Sorghum arundinacea*, *Polypogon monspliensis* and *Cyperus polystachia* gave the highest yield which is between 1.0 and 1.24 kg DM m^{-2} and did not differ significantly (p>0.05) between the species. These species represent about 53% of the key forage species and could be considered as high yielding forage crops under the arid condition of the rangelands. Ranked second, *Echinocloa haplochlada*, *Eragrostis cilianencis*, *Digitaria abyssinica* and *Eragrostis pilosa* have a moderate yield ranging between 0.9 and 0.98 kg DM m^{-2}, which was also not significantly different (p>0.05) between the species. Ranking third, *Hyphenia thebaica*, *Cynodon aethiopicus* and *Brachiaria certifolia* gave a yield between 0.67 and 0.77 kg DM m^{-2} with no significant difference (p>0.05) between the species. The last mentioned production may be concidered as low on a relative basis due to their ability to tolerate water shortages.

Table 5.9 Key forage species and their phytomass production (kg m^{-2})

No	Botanical names of grass species	DM feed yield (kg m^{-2})
1	***Andropogon sorghum***	1.19^{ab}
2	***Brachiaria certifolia***	0.67^{gh}
3	***Cynodon aethiopicus***	0.76^{h}
4	***Cyperus polystachia***	1.0^{cde}
5	***Digitaria abyssinica***	0.93^{efg}
6	***Echinochloa haplochlada***	0.98^{defg}
7	***Eragrostis biflora***	1.09^{bc}
8	***Eragrostis pilosa***	0.90fg
9	***Eragrostis cilianensis***	0.94^{defg}
10	***Hyphenea thebaica***	0.77^{h}
11	***Panicum coloratum***	1.24^{a}
12	***Polypogon monspeliencis***	1.01^{ad}
13	***Setaria lindenbergiana***	1.17^{ab}
14	***Sorghum abyssinica***	1.21^{a}
15	***Sorghum arundinaceae***	1.02^{ade}
16	***Sporobolus africana***	0.01^{defg}
17	***Tetrapogon cenchriformis***	1.04^{ad}

Different letters mean significant differences between means at $p < 0.05$.

Based on this observation, these grasses species may serve the purpose of providing substantial animal feed per unit area, but there is still a need for more focused research and development activities for better understanding and development of the potential of the forage crops.

5.3.6 Diet selection preferences and grazing behaviour of livestock species

5.3.6.1 Diet selection preference by livestock species

The diet selection study was only conducted for the herbaceous layers of the Asbuli grassland and the Aydora open savanna. The palatability ranking of the different plant species based on observations and indigenous knowledge of the pastoralist herdsmen are presented in Table 5.10. The most palatable plants were often those forage species preferred and selected by the animals. However, one or more animal types may have similar or different preference and therefore there is a selectivity ranking for the different livestock species. Identification of, which animal selects which forage species, may indicate a ranked preference of among and between classes of livestock on the available forage species.

The preference of cattle, sheep, goats, camels and donkeys by their selectivity was ranked by making an observation during grazing and by using the indigenous knowledge of the pastoral elders and herdsmen (Table 5.10). The cattle and sheep (grazers) were observed to prefer most of the perennial grasses and some of the annual grasses, whereas, the camels and goats and donkeys preferred the forbs and annual grasses followed by perennial grasses. Future studies in terms of seasonal selection would be important to understand the whole picture of selectivity preference for forage species.

5.3.6.2 Grazing behaviour of livestock species in relation to degradation gradients

This study was only conducted for the herbaceous layers of the Asbuli grassland as a representative of the grazing areas in the Shinile zone. The results on grazing behaviour of cattle, sheep, goats and camels (donkey is not an important animal in the area) were observed in terms of time spent on grazing and number of forage species selected during grazing. That was done over four degradation gradients, which included excellent (benchmark), good, moderate and poor rangeland condition classes (Table 5.11).

In comparison with the benchmark, the number of species selection by all livestock species increased on average by 17, 50 and 83% in the good, moderate and poor rangeland condition classes, respectively. The livestock species selected only 6 species out of 18 in the benchmark, 7 species out of 22 in the good condition, 9 species out of 24 in the moderate and 11 species out of 21 in the poor rangeland condition sites, respectively. The availability of preferred species was also influenced by the condition of the rangeland. This implies that rangeland condition degradation reduce the availability of preferred forage species. Under these conditions livestock will maximally utilized

Table 5.10 Ranking of plant species according to livestock preferences in the Shinile zone of the Somali region

No	Type of plant species	Preference by different livestock species			
		Highly preferred	**Preferred**	**Intermediately preferred**	**Less preferred**
1	*Andropogon micans*	Cattle	Camels, sheep	Donkeys	Goats
2	*Andropogon sorghum*	Cattle, sheep	Goats	Donkeys	Camel
3	*Brachiaria deflex*	Cattle, sheep	Donkeys	Camels	Goats
4	*Colotropus procera*	No	No	Camel	Others
5	*Croton menyharti*	Goats	Camels, donkeys	Cattle, sheep	Cattle
6	*Chrypsopogon aethiopicus*	Cattle, sheep	Donkeys,	Camel	Goats
7	*Chrypsopogon monosplensis*	Cattle, Sheep	Camels	Goats	Donkeys
8	*Chrypsopogon plumolosus*	Sheep	Cattle, camels	Goats	Donkeys
9	*Cynadon aethiopicus*	Camels, cattle	Sheep	Goats	Donkeys
10	*Cyperus polystachia*	Cattle, sheep	Camels, donkeys	Goats	No
11	*Cyperus rotandus*	Donkeys	Camels	Cattle, sheep	Goats
12	*Dactyloctenium aegyptium*	Cattle	Camels	Sheep, donkey	Goats
13	*Digitaria abyssinica*	Cattle, sheep	Camels	Goats	Donkeys
14	*Eragrostis aspera*	Sheep	Camels	Goats	Donkeys
15	*Eragrostis biflora*	Cattle	Sheep	Camels, donkeys	Goats
16	*Eragrostis cilianensis*	Camels	Cattle, goats	Sheep	Donkeys
17	*Eragrostis cylindriflora*	Cattle	Sheep	Goats, donkeys	Camels
18	*Eragrostis joponica*	Camels	Cattle, Goats	Sheep	Goats
19	*Eragrostis papposa*	Cattle	Goats	Camels, sheep	Donkeys
20	*Eragrostis pillosa*	Cattle	Sheep, donkeys	Goats	Camels
21	*Hyphenea thebaica*	Sheep	Cattle	Goats, donkeys	Camels
22	*Panicum cloratum*	Cattle	Sheep	Camels, goats	Donkeys
23	*Phalaris arundinaceae*	Camels, cattle	Sheep	Goats	Donkeys
24	*Polypogon monosplensis*	Cattle, camels	Goats	Sheep	Donkeys
25	*Sericompsis palidis*	Goats	Camels, sheep	Donkeys	Cattle
26	*Setaria lindenbergiana*	Cattle	Sheep	Goats, camels	Donkeys
27	*Sorghum abyssinica*	Cattle	Sheep	Camels	Goats
28	*Sorghum arundinaceae*	Cattle, sheep	Camels, donkeys	No	Goats
29	*Sporobolus african*	Sheep	Cattle, goats	Camels, donkeys	No
30	*Sporobolus agrostideae*	Sheep	Cattle	Goats, donkeys	Camels
31	*Sporobolus microprotus*	Sheep, camels	Cattle	Goats	Donkeys
32	*Tetrapogon cenchriformis*	Sheep	Cattle	Camels, donkeys	Goats
33	*Tetrapogon villosus*	Camels, cattle	Goats	Sheep	Donkeys
34	*Tragus beteronianus*	Cattle	Goats	Camels, donkeys	Sheep
35	*Tribulus terresteris*	Camel	Goats, donkeys	Sheep	Cattle
36	*Parthenium hystherophorus*	No	No	Camel	Others
37	*Xanthium abyssinicum*	No	No	Camel	Others

more palatable species, before relatively less palatable species are proportionally more utilized, resulting that more species being utilized as rangeland degraded (Figure 5.4).

Therefore, rangeland condition plays an important role in the grazing behaviour of livestock species.

Table 5.11 Average (±S.D) daily time (minutes) spent on grazing by different livestock species in the Asbuli rangeland of the Somali region

No	Selected species by rangeland condition classes	Livestock species and grazing time (minutes/12 hours)			
		Cattle	**Sheep**	**Goats**	**Camels**
	Benchmark (Excellent condition)				
1	***Cynodon aethiopicus***	29±1.4	25±2.8	20±14.1	44±8.5
2	***Digitaria abyssinica***	27.5±10.6	27.5±10.6	20±2.3	27.5±17.7
3	***Eragrostis cilianensis***	32.5±10.6	25±7.1	30±7.1	37.5±17.7
4	***Eragrostis joponica***	25±7.1	20±7.1	15±4.2	30±7.1
5	***Polypogon monspeliensis***	25±7.1	25±2.8	23±4.2	25±7.1
6	***Setaria lindenbergiana***	40±14.1	30±14.1	20±3.5	17.5±3.5
	Good rangeland condition site				
1	***Dactyloctenium aegyptium***	30±14.1	22.5±3.5	22±11.3	24.5±14.8
2	***Eragrostis biflora***	32.5±3.5	27.5±17.7	20±2.8	26±5.7
3	***Eragrostis cilianensis***	27±4.2	20±2.8	22.5±17.7	21±1.4
4	***Setaria lindenbergiana***	29±15.6	25±7.1	20±7.1	21.5±4.9
5	***Sporobolus agrostideae***	22.5±3.5	25±7.1	20±7.1	19±1.4
6	***Tragus racemosus***	30±2.8	22.5±3.5	26±12.7	25±7.1
7	***Tribulus terrestris***	6.5±2.1	9.5±7.8	5±1.4	20±7.1
	Moderate rangeland condition site				
1	***Chrysopogon plumolosus***	24±8.5	28±2.8	16±1.4	22.5±10.6
2	***Cynodon aethiopicus***	31±1.4	15±7.1	20±14.1	20.5±9.2
3	***Dactyloctenium aegyptium***	30±2.8	25±7.1	16±8.5	29±12.7
4	***Eragrostis biflora***	22.5±10.6	23±9.9	25±7.1	25±7.1
5	***Phalaris arundinaceae***	23.5±2.1	17.5±3.5	16±5.6	26±5.7
6	***Setaria lindenbergiana***	26.±7.8	27.5±3.5	15±7.1	22.5±10.6
7	***Sporobolus agrostideae***	22±11.3	26±1.4	20±7.1	25±7.1
8	***Sporobolus microprotus***	19±1.4	25±7.1	20±14.1	22.5±3.5
9	***Tribulus terrestris***	4.5±0.7	6.5±2.1	9±1.4	22.5±3.5
	Poor rangeland condition site				
1	***Andropogon micans***	22.5±3.5	19±1.4	17.5±3.5	20±7.1
2	***Cynodon aethiopicus***	27±4.2	22.5±3.5	15±9.2	27.5±3.5
3	***Eragrostis aspera***	21±1.4	17.5±3.5	25±7.1	20±7.1
4	***Eragrostis biflora***	25±7.1	20±2.8	29.5±6.4	25±7.1
5	***Eragrostis cylindriflora***	23±4.2	22.5±7.8	22.5±10.6	20±2.8
6	***Eragrostis papposa***	26.5±12.0	16.5±2.1	25±7.1	17.5±3.5
7	***Panicum coloratum***	17.5±3.5	24±8.5	20±7.1	25±7.1
8	***Setaria lindenbergiana***	22.55±10.6	21±1.4	20±2.8	20±7.1
9	***Sporobolus agrostideae***	27.5±10.6	27.5±3.5	20±7.1	32.5±3.5
10	***Tetrapogon villosus***	22.5±3.5	17.5±3.5	21.5±7.8	30±2.8
11	***Tribulus terrestris***	6±1.4	8.5±7.1	6.5±0.7	25±7.1

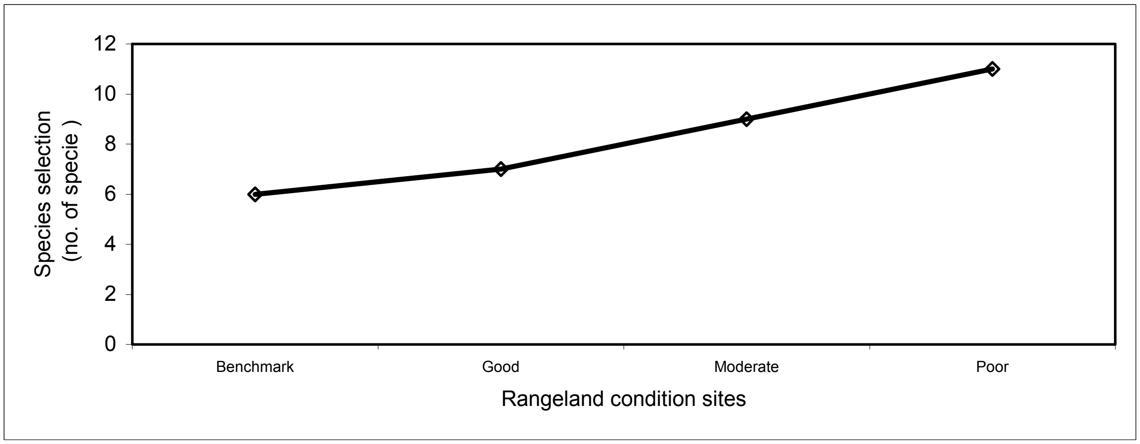

Figure 5.4 The relationship between rangeland condition and plant species selection by different animal types

In terms of grazing behaviour, the livestock species in general, spent more than 50% of their time grazing between 06:00 and 12:00, compared to the time grazing between 13:00 and 18:00 (Table 5.12). The grazing intensity by all livestock species increased following rangeland degradation from the benchmark (excellent condition) to poor

Table 5.12 Average (±SD) daily grazing time (minutes) in relation to rangeland conditions of the different livestock species in the Asbuli grassland of the Somali region.

Grazing time	Grazing time by livestock species during two periods			
	Cattle	Sheep	Goats	Camels
Benchmark				
6h00-12h00	230	170	149	213
13h:00-18h00	130	135	117	150
Total	360	305	266	363
Mean±SD	**180±70.1**	**152.5±24.7**	**133±22.6**	**195±64.0**
Good Condition				
6:00-12:00 AM	220	196	175	240
1:00-6:00 PM	155	124	96	140
Total	375	320	271	380
Mean±SD	**187.5±50.1**	**160±50.9**	**135.5±55.9**	**200±70.7**
Moderate condition				
6:00-12:00 AM	237	223	202	265
1:00-6:00 PM	179	164	112	176
Total	416	387	314	441
Mean±SD	**208±40.1**	**193.5±41.7**	**157±63.6**	**220.5±62.9**
Poor condition				
6:00-12:00 AM	276	238	267	300
1:00-6:00 PM	206	200	175	225
Total	482	438	442	525
Mean±SD	**241±49.5**	**219±26.9**	**221±65.1**	**262.5±53.0**

condition site. This indicates that increase in degradation level causes an increase in grazing time due to the availability of preferred forage species.

There was no significant difference ($p>0.05$) for livestock species in time spent on grazing in the good rangeland condition sites as compared to the time spent on grazing in the benchmark (Table 5.12). However, grazing time increased significantly ($p<0.05$) with rangeland degradation. Time spent on grazing was also a good indicator of animal grazing behaviour, where rangeland degradation have a major influence on the grazing intensity.

The average daily increase in grazing time for the cattle was higher by 15% in the moderate and 34% in the poor condition sites compared to time spent grazing in the benchmark. The grazing time of the sheep was increased by 22% in the moderate site and 44% in the poor condition site compared to the grazing time in the benchmark. For the goats the time spending on grazing was higher by 18% in the moderate and by 66% in the poor condition site, whereas the grazing time for the camels was higher by 13% in the moderate and by 34% in the poor condition site. On the other hand, the longer time spent on grazing by sheep and goats in the moderate and poor conditions, was an indication that these animals were more selective compared to cattle and camels, which were similar in their grazing behaviour (Figure 5.5).

Animal grazing behavior in terms of species selection and grazing time was influenced by rangeland degradation, whereby both parameters showed a significant increase as rangeland condition deteriorated.

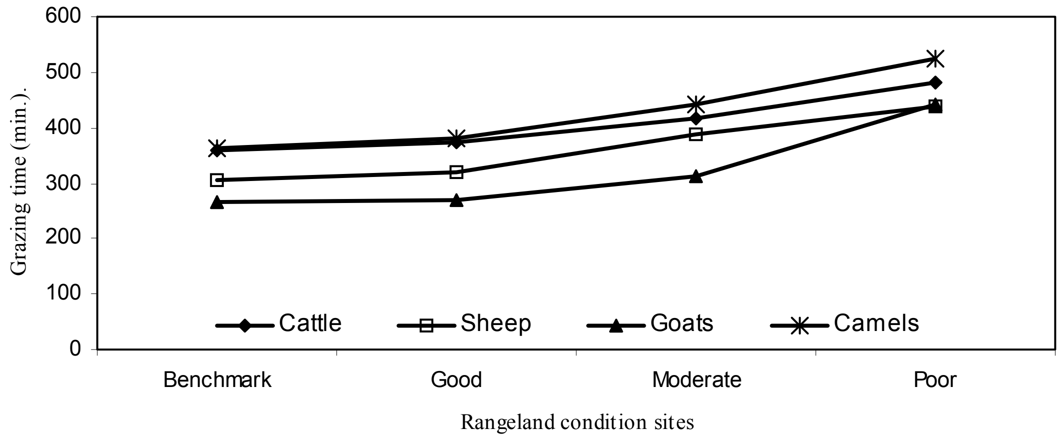

Figure 5.5 Grazing time of different livestock species in relation to rangeland condition classes in the Asbuli grassland

5.3.7 Estimation of dry matter feed intake of different livestock species

Direct intake measurements are difficult to determine on free roaming livestock and therefore feed intake were estimated from experimental animals subjected to a controlled feeding trial using 6 animals from each animal type (Table 5.13). The number of bites and intake (g per bite per animal) was the highest ($p<0.05$) for cattle, and the lowest ($p<0.05$) for sheep and goats. There was no significant difference ($p>0.05$) between the bites and intake of cattle and camels, and the same apply for sheep and goats. This implies that number of bites were not necessarily influenced by the type of the animal, but the live body weight per animal could be the most important determinant of fodder intake. Accordingly, the higher the body weight the higher the number of bites and feed intake per bite.

Table 5.13 Average (±SD) number of bites, feed intake and consumption time for consuming 1 kg (cattle and camels) and 0.2 kg (goats and sheep) of hay for the different livestock species.

Grazing parameters by type of animal	**Average body weight (kg)**	**Average parameter value**
Cattle	200	
Number of bites for consuming 1 kg of hay		421.3±14.9[A]
Minutes for consuming 1 kg of hay		27.3±3.4[AB]
Number of bites per minute		15.3±1.50[C]
Feed intake per bite in (g)		2.4±0.10[D]
Sheep	35	
Number of bites for consuming 0.2 kg of hay		222±3.90[E]
Minutes for consuming 1 kg of hay		24.4±2.1[EF]
Number of bites per minute		9.2±0.80[G]
Feed intake per bite in (g)		1.0±0.01[H]
Goat	30	
Number of bites for consuming 0.2 kg of hay		234.2±5.5[E]
Minutes for consuming 1 kg of hay		22.5±1.04[EF]
Number of bites per minute		10.4±0.40[G]
Feed intake per bite in (g)		0.86±0.02[H]
Camel	220	
Number of bites for consuming 1 kg of hay		436±2.70[A]
Minutes for consuming 1 kg of hay		31.4±0.40[AB]
Number of bites per minute		14±0.10[C]
Feed intake per bite in (g)		2.3±0.01[D]

Different letters mean there exist significant differences ($p < 0.05$)

The above results were extrapolated the grazing behaviour of the livestock species, in relation to the different rangeland condition classes. Accordingly, the results showed that there is an inverse relation between grazing time, forage intake (per day per animal), feed intake (per 100 kg live body weight) and rangeland condition. This means that feed intake was lower ($p<0.01$) in the benchmark, but showed a linear increase ($p<0.01$) with rangeland degradation (Table 5.14). Compared to the benchmark, the average forage intake in the poor rangeland condition was observed to be higher by 34.3% for cattle, 41% for sheep, 42.4% for goats and 45.3% for camels. This implies that time spent on grazing and feed intake increases as rangeland degrades. The increase in intake was higher ($p<0.05$) for the small ruminants than for cattle and camels, while all animals tended to have higher forage intake due to the higher water and lower DM at blooming stage for all plant species in the field while grazing.

Table 5.14 Interaction of proportion (%) of intake and live body weight, measured against the Benchmark in field grazing.

Grazing parameters by rangeland condition	Estimated average values by livestock species and live body weight			
	Cattle (200 kg)	Sheep (35 kg)	Goat (30 kg)	Camel (220 kg)
Benchmark				
Total grazing time day^{-1} (minutes)	360	305	266	363
Total forage intake kg day^{-1} animal^{-1}	11.04	2.81	2.38	11.70
Percentage intake of 100 kg body weight	5.5	8	7.9	5.32
Assumed percentage intake at benchmark animal^{-1}	100	100	100	100
Good condition				
Total grazing time day^{-1} (minutes)	375	320	271	380
Total forage intake kg day^{-1} animal^{-1}	11.5	2.9	2.85	12.45
Percentage intake of 100 kg body weight	5.75	8.3	9.5	5.7
Percentage additional intake above that in benchmark	4.2	3.2	9.7	6.4
Moderate condition				
Total grazing time day^{-1} (minutes)	416	387	314	441
Total forage intake kg day^{-1} animal^{-1}	12.8	3.5	3.3	14.4
Percentage intake of 100 kg body weight	6.4	10.0	11.0	6.5
Percentage additional intake above that in benchmark	16.0	24.5	38.7	23.2
Poor condition				
Total grazing time day^{-1} (minutes)	482	438	442	525
Total forage intake kg day^{-1} animal^{-1}	14.83	3.96	4.06	17.0
Percentage intake of 100 kg body weight	7.42	11.31	15.3	7.73
Percentage additional intake above that in benchmark	34.3	41.0	42.4	45.3

The relation between extrapolated daily forage intake and rangeland condition is shown in Figure 5.6. This implies that with rangeland degradation an animal may feed up to ≥ 20% of its live body weight during grazing on the herbaceous layers. Accordingly, intake by animals and rangeland degradation levels may be stated as inversely proportional. Feeding grass hay as opposed to grazing seem to affect the g DM per intake by the small ruminants due to the fact that goats and sheep tend to pick a single grass stem and chop it for a number of times to make it accessible. However, the small ruminants adjusted their daily feed intake through increased number of bites compared to the cattle and camels.

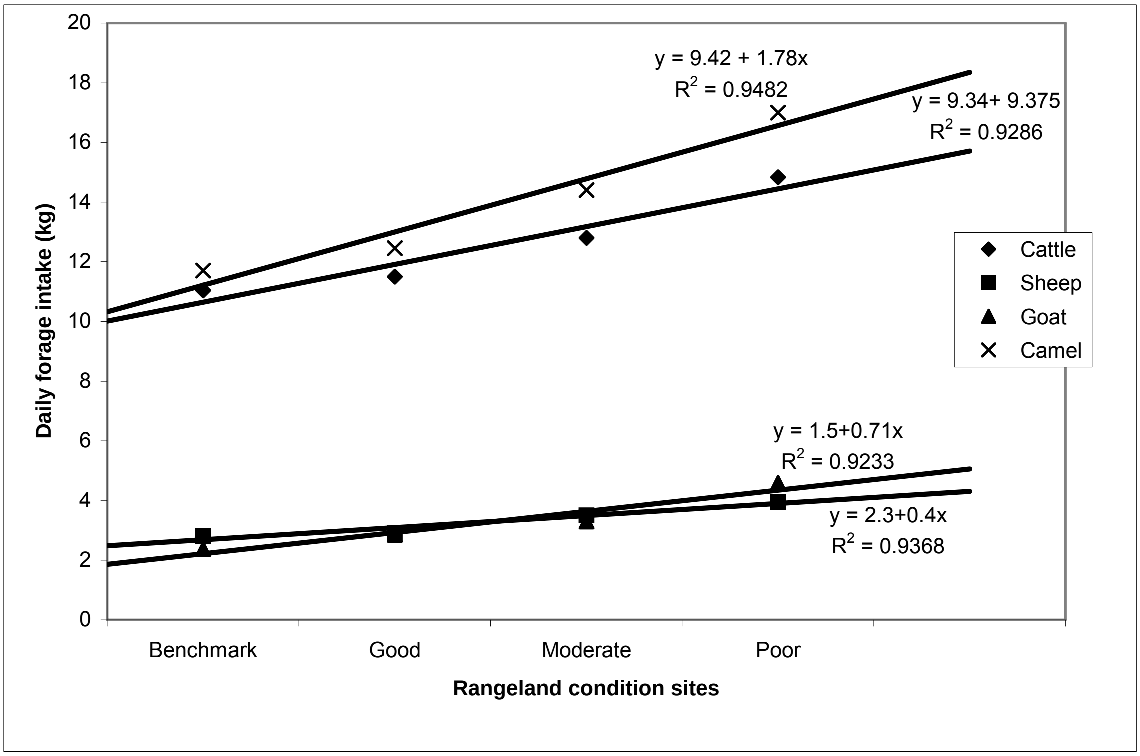

Figure 5.6 Relationship between daily forage intake and rangeland condition for different livestock species

5.4 CONCLUSIONS AND RECCOMMENDATIONS

A total of 45 grass species and non-grass species were identified in the Asbuli grassland and Aydora open savanna, but unfortunately it was difficult to identify any species in the Hurso closed savanna, due to the drought in the area. This indicates that rangeland characterization activities need to be conducted after or during rainy seasons when the vegetation gets adequate soil-water and at conditions of full regeneration of the herbaceous layers.

The length of growth period for the annuals was often less than 3 months and that of the perennials mostly about 4 months, with few species having between 5 and 6 months. This indicates early maturing herbaceous layers which are tolerant to soil-water stress under arid and semi-arid conditions. However, according to the pastoralists the population of annuals is increasing and the trend indicates more degradation of the rangelands. Due to the fact that no research conducted in the study area, the situation calls upon strong evaluation and monitoring intervention to encourage participation of the pastoral communities.

In terms of ecological grouping and palatability indexing, 13 species were subjectively identified as Decreasers, 6 species as Increaser IIa, 7 species as Increaser IIb, 9 species as Increaser IIc and 3 species as Invaders. However, the number of Decreaser species seems to be dominated due to the rangeland degradation taking place, which may in favor of Increasers and Invader species. Under such conditions, appropriate and scientific based grazing systems and rangeland management techniques need to be introduced. Future trends and factors of degradation also need further research and development (mainly extension) interventions to make a detailed analysis of the problem and the solution. Especially, the expansion of Invader species needs more attention in order to maintain productivity of the herbaceous layers by controlling or minimizing expansion of undesirable weeds and woody plants.

Although ecological grouping and palatability indexing of forage species is still valid in rangeland condition assessment, the plant species preference of the different classes of livestock (cattle, sheep, goats and camels) under the arid and semi-arid rangeland conditions need to be studied further. Under conditions of the pastoral production systems, the perception of the pastoralists on plant-animal interaction may be considered an important tool in evaluating rangeland condition. This may enable the ecological grouping to be more complete from an animal species and management perspective of the feed resources in place. More research is needed to classify species into objective ecological groups and to identify indicator species for rangeland degradation. With this data, objective rangeland condition techniques can be developed for rangelands in eastern Ethiopia, which is essential to determine the trend in rangeland condition and to monitor rangeland degradation.

Species frequency, basal cover and dry matter production per unit area was found to be higher, while bare ground, soil compaction and soil erosion were observed to be lower in the benchmark sites than that of the other rangeland conditions sites. This study showed a significant and proportional increase (>50%) in species frequency, basal cover and soil compaction with rangeland degradation, due to over-grazing and over-utilization through continuous grazing of the herbaceous layers. Likewise, forage production per unit area and grazing capacities showed a significant decline with a decline in rangeland condition. In this study, it was revealed that rangeland conditions could be subjective characterized in terms of the benchmark and therefore rangeland condition classes could be selected by using subjective methods. In doing that, the indigenous knowledge of pastoralists could also be used as an important tool besides to knowledge and experience of the rangeland conditions before selection.

The study showed that under the arid and semi-arid rangeland conditions it is possible to find key forage species in terms of their ability to produce high dry matter yield, high palatability and high preference by livestock, resilience to grazing, tolerance to soil-water stress and early maturity. This is an opportunity for screening high potential genetic materials for sustainable livestock production. Intensive research activities to characterize the forage species for different agronomic performances including seed production in order to boost feed production in the pastoral areas of Ethiopia.

Rangeland conditions significantly influence the grazing behavior of livestock in terms of species selectivity and grazing intensity over time and intake per animal. Animals are more selective in grazing behavior when forage sources are adequately available and vice versa. Under adequately availability, animals spend less time in grazing and their intake per animal was on average about 5% in the benchmark, but grazing time was increased with increases in feed intake up to 17% of live body weight in the poor rangeland condition class. In general, there was a highly significant correlation between increases in grazing parameters and deterioration of rangeland conditions. Therefore, the simulation of grazing was found important to determine the grazing behavior of animals and for estimation feed intake under extensive rangelands. However, the study need to be continued and intensified in order to support the estimation of grazing capacity of rangelands under different rangelands and soil types.

CHAPTER 6

ASSESSMENT OF THE WOODY VEGETATION AND THEIR TRADITIONAL USES IN THE RANGELANDS IN THE SOMALI REGION OF EASTERN ETHIOPIA

6.1 INTRODUCTION

The earth is covered by about 0.6 billion hectare arid and semi-arid woodlands, savannas and dry forests, while in Africa they cover about 13 million km^2 or about 43% of the total land area of the continent (NAS, 1980; Mentout *et al.*, 1995). In Ethiopia, the woodland and savanna areas cover about 20% of the 1.2 million km^2 land area of the country (Demel *et al.*, 1999), which cover an area of 111 000 km^2 (34%) of the Somali region. The woody species are diverse (SRBA, 2000) and they are most abundant in the arid and semi-arid agro-ecological zones of the region, with annual rainfall less than 500 mm and a temperature ranging between 27 to 40^{o}C.

The presence of woody plants in the area has enabled the distribution of pastoral production systems over a wide area. The woody plants have a large influence on the production systems in which there is a significant shift towards camels and goats. These animals are able to utilize the woody plants in an environment with a much reduced herbaceous layer for other grazers like cattle and goats.

The pastoral communities have developed indigenous knowledge to utilize the woody vegetation for economic purposes (Abule *et al.*, 2005a; Solomon *et al.*, 2006a). The extensive utilization of the woody plants have increased pressure on the vegetation, resulting in degradation of the resources due to over-utilization by the pastoral communities and over-browsing by livestock and game (Abule *et al.*, 2005b). However, the resources and the condition of the woodlands and savannas has not been evaluated and neither has the traditional uses been documented. To date, little or no information is available regarding the woody vegetation of the rangelands of the Somali region of eastern Ethiopia.

The grasslands and open savannas of Ethiopia in general and the Somali region in particular are also subjected to the various effects of rangeland degradation, among which bush encroachment is expanding. The excessive and undesirable increase in woody plant abundance is commonly referred to as bush encroachment (Barnes, 1979; Walker and Noy-Meir, 1982). Species such as *Acacia mellifera* and *A. nubica* are indigenous plants, while *Prosopis* spp. is exotic. These species are transforming the grasslands and open savannas into dense woody vegetation. However, quantitative data are not available regarding the current status of the bush encroachment problem. The woody vegetation of the rangelands has not been assessed in terms of their role in the rangeland ecosystems of Ethiopia. This was the motivation for this study that included the following objectives.

(i) to determine the species composition and density of the woody plants (on a species basis),
(ii) to evaluate the height structure of the woody plants in relation to different rangeland condition sites identified in Chapter 2,
(iii) to evaluate the potential competitiveness of the woody layer in terms of ETTE ha^{-1} (Evapotranspiration Tree Equivalent),
(iv) to determine the browse production of the woody plants in specific height strata and
(v) to document the traditional uses and values of the woody plants by the Somali pastoral communities.

6.2 MATERIALS AND METHODS

6.2.1 Experimental layout

The same experimental sites as described in Chapter 2, section 2.5 were used, where sampling plots were randomly selected in each of the benchmark (excellent), good, moderate and poor condition sites and 5 belt transects laid at random in each site. Each of the belt transects in Aydora open savanna was laid on 200 x 5 m and because of the thick layer in the Hurso savanna a belt transect of 200 x 2.5 each was laid. The same sites as described in Chapter 5 were used in the assessment of the woody vegetation.

6.2.2 Identifications of woody plants

The woody plants in each of the belt transects were identified in the rangeland. Samples of the woody plants that could not be identified in the rangeland was taken and sent to the herbarium of the Alemaya University for identification. Knowledgeable elders were consulted to identify each woody plant in its local name. The woody plant species in each belt transect was counted and recorded to determine their respective densities.

6.2.3 Quantification of the woody layer using the BECVOL-model

The study was conducted from October to January 2004, when most of the woody plants were at partial to full leaf carriage. The special canopy of all rooted live woody plants encountered in the belt transects were measured. The measurement consisted of the following (Smit,1989a; 1996): (i) maximum tree height, (ii) height where the maximum canopy diameter occurs, (iii) height of first leaves or potential leaf bearing stem, (iv) maximum canopy diameter, and (v) base diameter of the foliage at the height of first leaves. A measuring pole of 10 m, graduated at every 100 cm, was used to take the measurements.

In addition to simple density data (plants ha^{-1}), leaf volume and leaf dry mass estimates were calculated from the measurements taken, using a modified version of the quantitative description technique of Smit (1989a, b) as described by Smit (1994, 1996). This technique provides an estimate of leaf volume and leaf dry mass at peak biomass, based on the relationship between the tree's special canopy volume and its leaf volume and leaf mass. This technique was compiled with the BECVOL-model (Biomass Estimates from Canopy Volume, (Smit, 1994; 1996), and it incorporates regression equations, developed from harvested trees, which relates special canopy volume (independent variable) to leaf volume and leaf dry mass (dependant variables). The special tree canopy volume (x) was transformed to its normal logarithmic value while (y) represents the estimated leaf dry mass.

The number of Evapotranspiration Tree equivalents (ETTE) ha^{-1} was subsequently calculated from the leaf volume estimates (1 ETTE = mean leaf volume of a 1.5 m tall single-stemmed tree = 500 cm^3 leaf volume) (Smit 1989a, b). Since ETTE-values are based on estimates of actual biomass it is considered a more accurate measure of potential competition of woody plants compared to simple density data (plants ha^{-1}).

In addition to total leaf DM ha^{-1}, stratified estimates of the leaf DM ha^{-1} below 1.5, 2.0 m and 5.0 m, respectively, were also calculated, using the BECVOL-model (Smit, 1994). The height of 1.5 m represents the mean height of the goat (Aucamp, 1976) and impala (*Aepyceros melampus*) (Dayton 1978), while 2.0 m and 5.0 m represents the mean browsing height of the kudu (*Tragelaphus strepciseros*) (Wentzel, 1990) and giraffe (*Giraffa camelopardalis*) (Skinner and Smithers, 1990), respectively.

These browsing heights are mean heights and not maximum heights and were only used to draw comparisons. It is known that large individuals are able to reach higher than these mean heights, eg. 2.5 m and 5.5 m for kudu and giraffe respectively (Dayton, 1978) while breaking of branches may enable some browsers to utilize browse at even higher stratum (Styles, 1993). These woody plants were further divided into height classes of <0.5 m, 0.5-1 m, >1-2 m, >2-3 m, >3-4 m, >4-5 m and >5.0 m, respectively, and the number of woody plants per hectare by height class was determined.

6.2.4 Calculation for the browsing capacity

The browsing capacity was determined in context to the pastoral livestock production system in the Somali region of eastern Ethiopia, where goats and camels are the main browsing animals capable of browsing <1.5 m and <5 m, respectively. Accordingly, the browse capacity below 1.5 m (for goats) and 5.0 m (for camels) for the year 2004 was calculated. Only leaf material, the main component of utilizable browse, was quantified, though young shoots may also be utilized. Available browse was assumed to be those amounts below the specified mean browsing heights.

The leaf phenology for the months of October, November, December and January were obtained from field observations, while for the other months of the year the indigenous knowledge of the pastoralists was used. In the open savanna *Cadaba glandulosa* was common and the only evergreen species, while the other mostly Acacia species, were deciduous. In the closed savanna most woody species were deciduous with few evergreen woody species. This indicates that browsing capacities will vary between months and seasons. To average the differences therefore, the entire one year was segmented into two broader categories, namely the wet season covering six months between June-October 2004 and the dry season covering the months between December and May 2004. Accordingly, phenology values of 4 (> 70-100% leaves with average of 85% leaves) and a value of 2 (> 10-30% leaves with average of 20% leaves) was allocated for each species during the wet and dry season respectively.

6.2.5 Some characteristics and traditional uses of the common woody plants

The traditional use of the woody species by the local people was assessed with an open discussion with the elder pastoralists. Information on the phenological growth cycle of the woody plants was also obtained from the elders.

6.2.6 Data analysis

Browse capacity was calculated based on an equivalent to a browser unit defined as the metabolic equivalent of a kudu (*Tragelapus strepsiceros*), a 100% browser, with a mean body mass of 140 kg (Dekker, 1997), using the following formula proposed by Smit (1999),

$$Y = d \div \left[\frac{DM \times P \times F}{R} \right]$$

Where, Y= Browsing capacity (ha BU^{-1}),

$DM^{(1.5, 5.0)}$ = total leaf DM yield kg ha^{-1},

P = Phenology (at 0.85 = peak biomass for 6 wet months and 0.2 for 6 dry months per year),

R = Daily browse DM required per BU = 3.5 kg,

F = utilization factor or 0.4 (Pienaar, 2006) and

D = 365 days $year^{-1}$.

In determination BU ha^{-1} for goat and camel was calculated in terms of the Tropical Livestock Unit (TLU) (Jahnke, 1982). A TLU is an animal with equivalent to 250 kg live weight, which is a typical matured camel weight under the Tropics, and is identical to conditions under the Somali region animal body weight.

Descriptive statistics such as percentage and mean were used when necessary. ANOVA was calculated using Statistical Package for Social Sciences (1996) and Friedman's test (Steel and Torrie, 1980). Coefficient analysis (Hintze, 1998) was used to signify the relationship between different woody plant parameters.

6.3 RESULTS AND DISCUSSION

6.3.1 Species composition of the woody layers

A total of 5 and 21 woody plant species were identified in the rangeland condition sites of the Aydora open and Hurso closed savanna vegetation, respectively. The list of the woody plants with their scientific and vernacular (Somali) names is given in Table 6.1. In general, the species abundance differed along the belt transects of the rangeland condition sites. In the benchmark and good condition sites of the Aydora open savanna, *Cadaba glandulosa* was the only woody species recorded. The highest number of 5 species were recorded in the moderate site, and included: *Acacia nilotica, A. nubica, A.*

tortilis C. glandulosa and *Grewia ferruginea*. In the poor rangeland condition site only 2 species of woody plants, namely *C. glandulosa* and *A. nubica* were observed. However, along the gradients from poor to excellent (benchmark), the invasion by the encroaching woody plant *A. nubica* was severe and most parts of the herbaceous layers of the open savanna were in the process of being replaced by woody plants, which make the sites unsuitable for grazing herbivores.

With regard to the Hurso closed savanna, there were 9, 8, 14 and 18 species observed in the excellent (benchmark), good, moderate and poor condition sites, with some species common to all rangeland condition sites and some only specific to one or two of the condition class sites. Accordingly, 5 species namely *Acacia nilotica, A. mellifera, A. nubica, A. senegal* and *A. tortilis* were common in all rangeland condition sites with *A. fruticosa* only observed in the moderate condition site.

Table 6.1. Identified species of woody plants in the various rangeland condition sites of the Shinile zone of the Somali region

No	Scientific (species) names of woody plants	Vernacular (Somali) name	Family name
	Aydora open savanna		
1	***Acacia nilotica***	Dhiqrii Maeraah	Mimosaceae
2	***Acacia nubica***	Guumaer	Mimosaceae
3	***Acacia tortilis***	Quuraae	Mimosaceae
4	***Cadaba glandulosa***	Quelen	Capparaceae
5	***Grewia ferruginea***	Ashaado	Tiliaceae
	Hurso closed savanna		
1	***Acacia fruticosa***	Dhiqrii	Euphorbiaceae
2	***Acacia melifera***	Beelien	Mimosaceae
3	***Acacia nilotica***	Dhiqrii Maeraah	Mimosaceae
4	***Acacia nubica***	Guumaer	Mimosaceae
5	***Acacia Senegal***	Aadaad	Mimosaceae
6	***Acacia tortilis***	Quuraae	Mimosaceae
7	***Acalyha fruticosa***	Dhgrii	Euphorbiaceae
8	***Aloe somaliensis***	Da-aar	Liliaceae
9	***Aloe tricosantha***	Daar-biyoodi	Liliaceae
10	***Balanites aegyptiaca***	Quued	Balanitaceae
11	***Belpharis edulis***	Ara-aar	Acanthaceae
12	***Cadaba forinosa***	Dhi-taab	Capparaceae
13	***Cadaba glandulosa***	Quelen	Capparaceae
14	***Dobera galabra***	Guurues	Salvadoraceae
15	***Gomphocarpus fruticosus***	Wayla-woed	Asclepidiaceae
16	***Grewia ferruginea***	Ashaado	Tiliaceae
17	***Grewia villosa***	Kobosh	Tiliaceae
18	***Lanthana camara***	Issa megen	
19	***Salvadora persica***	Aadaay	Salvadoraceae
20	***Sanseviera abyssinica***	Heeg	Agavaceae
21	***Solanum carinensis***	Kirrir	Solanaceae

Balanites aegyptiaca and *Cadaba glandulosa* were common in all four rangeland condition sites. *Dobera galabra* was restricted to the benchmark and good rangeland condition sites. *Salvadora persica* was restricted to the benchmark, moderate and poor condition sites, but not in the good condition site. *Acalypha fruticosa* and *Aloe* spp. were present in the moderate and poor rangeland condition sites. Furthermore, *Grewia villosa*, *Lanthana camara* and *Solanum carinensis* occurred only in the poor rangeland condition site.

6.3.2 Density and height class distribution of the woody layers

In the Aydora open savanna (Table 6.2) the density of woody plants was the lowest ($p<0.05$) in the excellent and good condition sites compared to that of the other condition sites. It was high in the moderate condition site and highest ($p<0.05$) in the poor condition site compared to that of the other condition sites. Natural degradation processes are important phenomena in the rangeland, where *Acacia nubica* is dominating over *Cadaba glandulosa* and the herbaceous layers. This is due to the root system and shading effects of *A. nubica*.

Table 6.2 Woody plant density and % in different height classes in the Aydora open savanna of the Shinile zone

Classes of rangeland conditions	Total plants (ha^{-1})	Tree density (plants. ha^{-1})						
		<0.5	>0.5-1	>1-2	>2-3	>3-4	>4-5	>5
Excellent condition								
Plant density	98.0^{A}	0.0	6.3^{A}	37.5^{B}	33.3^{B}	20.9^{C}	0.0	0.0
Percentage	100.0	0.0	6.4^{A}	38.3^{B}	34.0^{B}	21.3^{C}	0.0	0.0
Good condition								
Plant density	118.0^{B}	0.0	20.0^{A}	56.0^{B}	24.0^{A}	8.0^{C}	10.0^{C}	0.0
Percentage	100.0	0.0	17.0^{A}	47.4^{B}	20.3^{A}	6.8^{C}	8.5^{C}	0.0
Moderate condition								
Plant density	188.0^{C}	8.6^{A}	43.6^{B}	59.0^{C}	65.8^{C}	11.0^{A}	0.0	0.0
Percentage	100.0	4.6	23.2^{B}	31.4^{C}	35.0^{C}	5.8^{A}	0.0	0.0
Poor condition								
Plant density	286.0^{D}	0.0	4.0^{A}	63.0^{B}	177^{C}	42.0^{D}	0.0	0.0
Percentage	100.0	0.0	1.4^{A}	22.0^{B}	62.0^{C}	14.6^{D}	0.0	0.0

Means in the same column with different superscripts are significantly different ($p<0.05$)

With regard to the Aydora open savanna, the plants in the 1-3 m height stratum was the most abundant, followed by the 3 - 4 m height stratum, while plants in the 0.5 - 1 m and above 4 m height stratums was not recorded. In the good rangeland condition site, the plants in the 1 - 3 m height stratum were dominant, followed by the 0.5 - 1.0 m stratum, with few plants in the 3 - 4 m stratum. Plants in the height classes below 0.5 and above 4 m were not recorded.

The increase in encroachment by woody plants has influenced both the plant density and height stratum along the degradation gradient from the benchmark to the poor condition site. In the moderate condition site, plants in the 1 - 3 m stratum was the most abundant followed by plants in the 3 - 4 m stratum, with the least number of plants recorded in the 0.5 – 1 m stratum. No plants were recorded in the height stratum <0.5 m and >4 m. In the poor rangeland condition site, plants in the height stratum between 1 - 4 m was most dominant, plants within 0.5 - 1 m negligible and no plants recorded in the <0.5 and >4 m height stratums (Appendix Table 6.1).

In the Hurso closed savanna, there was no significant difference (P>0.05) in plant density between the benchmark and good condition sites. However, the plant density was higher (p<0.05) in the poor rangeland condition site than in the moderate condition site (Table 6.3).

Table 6.3 Woody plant density and % in different height classes in the Hurso closed savanna of the Shinile zone

NO	Classes of rangeland conditions	Total plants (ha^{-1})	Tree density (plants ha^{-1}) and canopy cover (%)						
			<0.5	>0.5-1	>1-2	>2-3	>3-4	>4-5	>5
1	**Excellent condition**								
	Plant density	**480^{AB}**	0.0	0.0	103.7^{A}	227.5^{B}	95.0^{C}	53.8^{D}	0.0
	Percentage	**100**	0.0	0.0	21.6^{A}	47.4^{B}	19.8^{C}	11.2^{D}	0.0
2	**Good condition**								
	Plant density	**572^{B}**	0.0	0.0	101.8^{A}	359.2^{B}	106.4^{A}	4.6^{C}	0.0
	Percentage	**100.**	0.0	0.0	17.8^{A}	62.6^{B}	18.6^{A}	1.0^{C}	0.0
3	**Moderate condition**								
	Plant density	**1228^{C}**	6.7^{A}	162.2^{B}	677.9^{C}	320.5^{D}	54.0^{E}	6.7^{A}	0.0
	Percentage	**100**	0.3^{A}	13.7^{B}	55.2^{C}	26.1^{D}	4.4^{E}	0.3^{A}	0.0
4	**Poor condition**								
	Plant density	**1624.0^{D}**	271.1^{A}	617.0^{B}	536.0^{C}	141.3^{D}	53.6^{E}	0.0	0.0
	Percentage	**100.0^{D}**	17.0^{A}	38.0^{B}	33.0^{C}	8.7^{D}	3.3^{E}	0.0	0.0

Means in the same column with different superscripts are significantly different (p<0.05)

With regard to height stratum of woody plants in the Hurso closed savanna, the plants were dominant in the height class of >2-3 m for the benchmark site, followed by plants in the >1-2 m and >3-4 m classes, while no plants in the height class <0.5, >0.5-1 and >5 m was recorded. In the good rangeland condition site plants were dominant for the height class >2-3 m, followed by plants in the >3-4 m and >1-2 m classes. No woody plants were observed below and above 5 m height classes (Table 6.3).

In the moderate rangeland condition site, the most dominant plants were found in the height class >1-2 m, followed by the height class >2-3 m, with less plants in the height class of >0.5-1 m and the least plants in the <0.5 m and >4-5 m classes. No plants in the height class above 5 m were recorded. In the poor rangeland condition site, plants in the height class of >0.5-1 and >1-2 m were dominant, followed by plants in the class below 0.5 m, while in the 2-4 m classes the least amount of plants were found (Table 6.3). No trees were found above 4 m.

6.3.3 Evapotranspiration Tree Equivalents

The potential competitiveness of the woody layers with the herbaceous layers was computed, in order to assess the competition using ETTE (Evapotranspiration Tree Equivalents) rather than using simple density data as explained in section 6.3.2 (Table 6.4). Accordingly, in the Aydora open savanna, the ETTE ha^{-1} showed a highly significant ($p<0.05$) increase along the gradients from the benchmark towards the poor condition site. In comparison with the benchmark, the ETTE ha^{-1} in the good, moderate and poor condition sites was higher with 251, 163 and 619%, respectively. The only species contributing to the ETTE in the benchmark and good condition sites was *Cadaba glandulosa*, which is a browse species utilized by camels. However, the contribution of *Acacia nubica* (an encroacher woody plant and severe competition with grasses), were more abundant with 23% in the moderate and more than 80% in the poor condition sites. Hence, the results imply that there is severe bush encroachment in the open savanna, which would lead to a greater decline of the herbaceous layer in terms of fodder production.

Furthermore, the production of Browse Tree Equivalents (BTER ha^{-1}), was determined for the height classes <1.5 m, <2 m and <5 m height, to understand the contribution of the woody layers in the Aydora open savanna in relation to the ETTE.

In the Hurso closed savanna, the ETTE ha^{-1} was also determined in order to evaluate the competitiveness between the woody layers and the herbaceous layer. Accordingly, in the closed savanna the ETTE ha^{-1} showed a highly significant ($p<0.05$) decline along the gradients from the benchmark to the poor condition site. The highest ($p<0.05$) ETTE ha^{-1} of 10 315 was recorded in the benchmark, and this number declined by 58% in the good condition site, by 72% in the moderate condition site and by more than 80% in the poor condition sites.

In the benchmark five species namely: *Acacia tortilis*, *A. nilotica*, *Balanites aegyptiaca*, *A. mellifera* and *Cadaba glandulosa* were dominant and contributed more than 66% to the total ETTE ha^{-1}, while 16 species of woody plants make up the rest. In the good condition site, six species namely: *A. mellifera*, *A. nilotica*, *A. Senegal*, *C. glandulosa*, and *A. nubica* were dominant and contributed more than 97% of the total ETTE ha^{-1} with another two species that made up the rest. In the moderate condition site, five species namely: *A. mellifera*, *A. tortilis*, *A. senegal*, *B. aegyptiaca* and *Blepharis edulis* were dominant and contributed more than 90% of the ETTE, with nine woody species that make up the rest. In the poor condition site seven species namely: *A. nubica*, *Grewia ferruginea*, *A. tortilis*, *A. nilotica, A. melifera, Acalypha fruticosa* and *B. aegyptiaca* were dominant and contributed more than 92% of the total ETTE ha^{-1}, while the difference consisted of another eleven species of woody plants.

Table 6.4 The Evapotranspiration Tree Equivalent (ETTE) values along the degradation with indication of the percent species contribution in open and closed savannas in 2004.

No	Species by rangeland type	ETTE ha^{-1} in different rangeland condition sites							
		Benchmark		Good		Moderate		Poor	
		No.	(%)	No.	(%)	No.	(%)	No.	(%)
	Aydora open savanna								
1	***Acacia nilotica***	-	-	-	-	33	3.6	-	-
2	***Acacia nubica***	-	-	-	-	212	23.4	2010	81.2
3	***Acacia tortilis***	-	-	-	-	20	2.3	-	-
4	***Cadaba glandulosa***	344	100	1209	100	609	67.4	464	18.8
5	***Grewia ferruginea***	-	-			30	3.3	-	-
	Total	**344**	**100**	**1209**	**100**	**904**	**100**	**2474**	**100**
			-						
	Hurso closed savanna		-						
1	***Acacia nilotica***	1743	16.9	760	17.4	99	3.4	160	9.2
2	***Acacia fruticosa***	-	-	-	-	12	0.4	-	-
3	***Acacia melifera***	1008	9.7	872	20.0	895	31.0	123	7.1
4	***Acacia nubica***	50	0.5	538	12.3	3	0.1	680	39.0
5	***Acacia senegal***	502	4.9	704	16.1	424	14.7	71	4.1
6	***Acacia tortilis***	4431	42.9	696	15.9	640	22.1	181	10.4
7	***Acalygha fruticosa***	-	-	-	-	19	0.6	127	7.3
8	***Aloe somaliensis***	-	-	-	-	26	0.9	2	0.1
9	***Aloe tricosantha***	-	-	-	-	1	0.03	19	1.1
10	***Balanites aegyptiaca***	1667	16.2	56	1.3	339	11.7	87	5.0
11	***Blepharis edulis***	-	-	-	-	-	-	4	0.2
12	***Cadaba forinosa***	-	-	-	-	34	1.2	24	1.4
13	***Cadaba glandulosa***	727	7.0	685	15.7	-	-	21	1.2
14	***Dobera galabra***	57	0.6	52	1.2	-	-	-	-
15	***Gomphocarpus fruticosus***	-	-	-	-	-	-	3	0.2
16	***Grewia ferruginea***	-	-	-	-	79	2.7	251	14.4
17	***Grewia villosa***	-	-	-	-	-		18	1.0
18	***Lanthana camara***	-	-	-	-	-		4	0.2
19	***Salvadora persica***	131	1.3	-	-	17	0.6	1	0.05
20	***Sanseviera abyssinica***	-		-	-	303	10.5	-	-
21	***Solanum carinensis***	-		-	-	-	-	1	0.05
	Total	**10315**	**100**	**4362**	**100**	**2891**	**100.0**	**1742**	**100**

In this study three aspects were observed. Firstly, the woody layer is dominated by relatively few (5) species; secondly, the abundance of the most useful species has reduced due to deforestation; thirdly the abundances of less desirable species such as *Acacia mellifera* and *A. nubica* (encroacher woody plants) are expanding at an increasing rate along the degradation gradients. The diminishing pattern of the ETTE, shows that the browse potential of the closed savanna is also diminishing. On the other hand, it indicates less competition with the herbaceous layer, and the latter has the opportunity to benefit. However, the increase of the bush encroacher species is a threat for the productivity of the herbaceous layer, which will result in a decline of fodder production for livestock.

6.3.4 Browsing capacity in relation to season and rangeland condition

The browse capacity of the Aydora open savanna and the Hurso closed savanna was determined in two aspects. The first was the browse capacity referring to the Somali goat and camel breeds, and the second was the browse capacity of the rangeland vegetation types in terms of the wet season and the dry periods. The result is given in Table 6.5.

According to the results, the highest ($p<0.05$) ha BU^{-1} was in the Aydora open savanna recorded in the benchmark, due to lower plant density ha^{-1} and dominated by grazing materials. The density ha^{-1} in woody plant was increased in the good condition site, as a result ha BU^{-1} was reduced. The woody plant in the benchmark and good condition sites was *Cadaba glandulosa*, an ever green. Hence the ha BU^{-1} was not affected by season. The ha BU^{-1} in the moderate and poor condition was affected by type of species and plant density per ha.

Table 6.5. Browsing capacity estimates in ha^{-1} BU during wet and dry seasons in relation to rangeland condition sites in Shinille zone of the Somali region

Rangeland types and condition sites	Available LM ha^{-1} (<1.5 m)	Ha BU^{-1}	Browse Capacity (ha $goat^{-1}$)		Available LM ha^{-1} (<5.0 m)	Ha BU^{-1}	Browse Capacity (ha $camel^{-1}$)	
			Wet Season	Dry season			Wet Season	Dry season
Aydora open savanna								
Excellent	**47**	**80**	**24**	**24**	**77**	**48.7**	**88.5**	**88.5**
Good	**97**	**38.75**	**11.64**	**11.64**	**269**	**14.0**	**25.5**	**25.5**
Moderate	**76**	**49.46**	**7.43**	**31.5**	**203**	**18.5**	**16.83**	**41.0**
Poor	**202**	**18.6**	**2.8**	**12.0**	**577**	**6.52**	**9.1**	**25.13**
Hurso closed savanna								
Excellent	**166**	**22.64**	**3.4**	**14.42**	**2225**	**1.7**	**1.54**	**6.52**
Good	**200**	**18.8**	**2.85**	**12.0**	**985**	**3.81**	**3.5**	**14.74**
Moderate	**307**	**12.25**	**1.84**	**8.0**	**657**	**5.72**	**5.2**	**22.12**
Poor	**211**	**17.8**	**2.7**	**11.4**	**484**	**7.76**	**7.10**	**29.90**

LM = Leave mass

For the Hurso closed savanna, the amount of ha BU^{-1} was generally lower than that of the open savanna, due to the diversity and density per ha of woody plant species. However, more ha BU^{-1} was required during the dry season than in the wet season due to differences in leaf carriage among plant species at different times of the seasons. From this study, it could be understood that, stocking rates for goats and camels need to be adjusted in the open and closed savannas based on seasonality, where browsing materials are adequate or scarce.

6.3.5 Some characteristics and traditional uses of some woody plants

Based on their indigenous knowledge in the traditional uses of the woody plants, 14 species in the study area were identified as important. These species included: *Acacia mellifera, A. nilotica, A. nubica, A. senegal, A. tortilis, Acalypha fruticosa, Aloe somaliensis, Balanites aegyptiaca, Cadaba forinosa, C. glandulosa, Grewia ferruginea, Salvadora persica* and *Sanseviera abyssinica*.

The study also focused on the phenological aspects and economical and socio-cultural uses of each woody plant. The results are given in Tables 6.7- 6.11. According to reports by pastoralists all fourteen species are indigenous to the Somali region, but observed to be widely spread in the arid and semi-arid agro-ecologies, adapted to shallow and deep soils with saline or alkaline and sodic characteristics and they are drought tolerant. About 90% of these woody plants are a useful feed source for camels and goats. As a result these woody plants were found to be the basis of goat and camel production in the pastoral production system in the Somali region of eastern Ethiopia.

The pods are also eaten by camels, goats, sheep and cattle as protein supplement. Livestock are also an important means of seed disposal and propagation in the rangelands. Moreover, consumption of the pods by livestock and the delignification of the seed cover in the animal digesta is believed to contribute to the expansion of encroaching woody plants such as *Acacia mellifera* and *A. nubica* in the rangelands over a vast area.

The economic use of the woody plants were highly diversified and includes livestock feeding, house construction, firewood, charcoal making, fencing and livestock shading. However, the existing poverty and lack of understanding by the pastoralists in the study area has led to the over-use of the woody plants and eventually to a serious decline of the valuable species such as *Acacia tortilis* and *A. Senegal*. Furthermore, the pastoralists have developed widespread knowledge in the medicinal use of woody plants for human and animal treatment, food, sanitation, improvement of milk shelf life and manufacturing of house utilities and furniture in their socio-cultural systems (Tables 6.7 - 6.11).

6.4 CONCLUSIONS AND RECOMMENDATION

6.4.1 Conclusions

The woody plants of the Aydora open savanna and Hurso closed savanna of the Shinile zone in the Somali region of eastern Ethiopia were studied in terms of species composition, density and canopy cover, height distribution, browse production, browse capacity, phenology and traditional uses. Accordingly, a total of 5 woody plant species were identified in the Aydora open savanna, which is dominated by *Cadaba glandulosa* and *Acacia nubica*. A total of 21 woody species were also identified in the Hurso closed savanna, dominated by *Acacia* spp. Moreover, *A. nubica* and *A mellifera* were observed to be the most aggressive encroaching woody species in both of the rangelands types. *Acacia nubica* in particular, is virtually dominant over the herbaceous layer of the Aydora open savanna.

The plant density in the open savanna was: 98, 118, 188 and 286 plants ha^{-1} in the excellent, good, moderate and poor rangeland condition sites, respectively. This demonstrates that the open savanna is under extensive encroachment by the woody plants with increasing densities across the degradation gradient in the excellent to poor condition site. Eventually, this may lead to the suppression of the herbaceous layer, with a reduced ability to support grazing animals. In the closed savanna, plant densities were: 480, 572 1 228 and 1 624 plants ha^{-1} in the excellent, good, moderate and poor condition sites, respectively. The closed savanna is subjected to severe deforestation leading to a permanent loss of its browse production, due to over-use of the woody plants by humans. The increase in height of the woody plants in the open savanna, from the benchmark to

Table 6.7. Phenological characteristics and traditional values of woody vegetation in Shinile zone of Somali region

Phenological characteristics	Economic values	Socio-economic values
***Acacia nilotica* (Maeraah)**		
Indigenous, often grows 2-6 m high, some times up to 12 m, adapted to arid and semi-arid agro-ecologies.	Best feed for camels and goats and strategic feed during drought, pods preferred by cattle and sheep	Medicine for treating diseases like flu and duodenal ulcers by grounding and boiling the fruits as tea and then drunk.
Drought tolerant, adapted to sodic and alkaline shallow to deep soil, early shading during wet season (June-Sept).	Livestock shade, nitrogen fixing ability, useful for soil water conservation and restoration and important bees forage.	Flee repellant by smoking, moistened seed powder used for curing skins and hides.
Bear leaves in dry period (Oct), full leaf carriage in Dec-May, flower in Jan-Feb, seed setting in April, mature March-May, propagated by seeds, friendly to grasses.	Useful for fire wood, charcoal making, construction, house tools and furniture making, wind break, also gum bearing	Ground pods are important ingredients for purification of drinking water
***Acacia mellifera* (Beelien)**		
Indigenous, grows up to 5 m, adapted to shallow to deep alkaline soils, with similar thorn structure to *A. senegal*.	Leaves are best feeds of camels and goats and pods best for sheep and cattle	Useful to treat eye trachoma in cattle, camels and goats, mashed leaves used.
Early shading after rains (Dec-May), leaf bearing up to full leaf carriage is June-Aug, flowering in Aug, seed maturing in Sept, propagated by seeds, more utilized by animals.	Use for fencing and as fuel wood, nitrogen fixation and soil water conservation, but is known encroacher	Used as indicator of good or bad rainy season, if it only flowered in May (dry period) then good rains expected.
***Acacia nubica* (Guumaer)**		
Indigenous, grows in semi-arid, arid and semi-desert, adapted to alkaline/sodice shallow soils up to 5 m high.	Leaves, pods and new shoots are eaten by camels and goats but not by others.	Used to treat internal hemorrhoids mainly the new shoots.
Known as encroacher in in open savannas, not friendly to grasses, early shading and early responsive to rains, full leaf carriage in June-Aug, flower in Aug, fruits mature in Sept, shade in Nov, propagated by seeds	Used for fencing livestock premises and house compounds, dry trees as fire woods, bark used as fiber for rope making, bees forage, nitrogen fixation	The woody plant is recognized by the pastoralists as an aggressive encroacher that has invaded useful rangelands
Not friendly to grasses and *Cadaba glandulosa*, easily infected by termites and beetles. Animals are main propagators, leaf structures similar to *A. senegal*.	Currently it is the most aggressive encroacher in the Somali region and other pastoral areas of Ethiopia.	There is no identified traditional mechanism by the pastoral communities to limit its expansion

Table 6.8. Phenological characteristics and traditional values of woody vegetation in Shinile zone of Somali region

Phenological characteristics	**Economic values**	**Socio-economic values**
***Acacia senegal* (Aadaad)**		
Indigenous, grows 600 to1600 m.a.s.l, drought tolerant, perform in poor soils, longer seed dormancy, animal defecation improves germination,	Bears gum Arabic for export and local markets as cash income and industrial uses in textile and pharmaceuticals	Gum Arabic locally known as Haamek is used as medicine to rehabilitate displaced womb during child delivery
Bear leaves March -May and June -September, with full leaf carriage in May to August and flowering in September, shades in January	Leaves and pods preferred by camels and goats, cattle eat leaves and sheep and donkeys prefer the pods	Useful to treat sexual impotence and an aphrodisiac, treatment of backack through massaging it
Set seed in October, mature in November to December, seed scatter in January, companion to grasses, animal digesta enhances seed germination	Useful for charcoal making, fire wood, cash income house construction, fencing livestock camps	Used as chewing gum as energy source. the bark used as tea, the roosts as medicine,
Important in nitrogen fixation for soil fertility, soil and water conservation and gully treatment	Useful for rangeland restoration and environmental rehabilitation	More pressure on the species due to its multi uses and is becoming endangered
***Acacia tortilis* (Quuerae)**		
Indigenous, predominant in arid and semi-arid agro-ecologies, adapted to alkaline and shallow soils, ever green under shallow water tables, shade for 6 months in dry areas	Leaves and pods highly preferred by camels and goats, while flowers are best bee forages	Recognized by pastoralists for its higher canopy shading value
Flower in Nov-Dec, bear fruits in Jan-Feb, seeds mature in March and shatter in April, slow growing in nature.	Useful for house construction, charcoal, fuel wood making, for making farm equipments	Used for meetings under the canopy shade and as traditional assemblage whole
Propagated by seeds, seeds more lignified with more dormancy, animal digesta improve/activate germination	Barks as source of fiber for making traditional mats and ropes	Livestock and games use it as main shading facility after grazing
High nitrogen fixation, friendly to herbaceous layers, increase crop yield, vital in cropping systems	Fibers also used for house construction and roofing for new brides	The roots are used for stick curving relevant to age and hierarchy
***Acalypha fruticosa* (Dhigrii)**		
Indigenous, adapted to alkaline and shallow soils and arid and semi-arid agro-ecologies, bears leaves after three days of rainfall, with leaf carriage in May-Sept, flower in Aug, sets seed in Aug-Sept and mature in Oct, shade Oct-march, propagates through seeds and birds spreads it more.	The leaves are best feed for goats and camels, seeds are feed for birds and rodents, important for soil-water conservation and galley treatment, increase soil organic matter.	Used as a treatment for stomach ache in children by boiling the leaves until bleached and the juice is taken as medicine, the leaves also used for purifying butter and flavoring it.

Table 6.9. Phenological characteristics and traditional values of woody vegetation in Shinile zone of Somali region

Phenological characteristics	Economic values	Socio-economic values
***Aloe somalinensis* (Daar)**		
Indigenous, shade loving and evergreen, adapted to arid and semi-arid agro-ecologies, performs on alkaline and shallow soils, grows in clusters of 40-100 plants in a spot.	It is bitter for animals to eat, but during drought periods the roots are fed to cattle only.	It is medicinal plant for treatment of more than 35 types of human and animal diseases
Flowers in March-April, bears fruits in May, propagated via seeds and seedlings, leaves very thick and fleshy.	It is important for soil-water conservation and gully treatment	It is useful in modern medicines and pharmceutical manufacturing
***Balanites aegyptiaca* (Quued)**		
Indigenous, adapted to arid and semi-arid agro-ecologies, also adapted to shallow and deep alkaline soils, is evergreen and drought tolerant, slow growing but grow up to 10 m height	The leaves are best feed for camels and goats, the fruits are edible by pastoralists, serve as shade trees for livestock.	Fruits are used as laxative, cure is possible within 2-3 hours after eating 10 fruits, and the roots used for treating bronchitis.
Propagated through seedlings and by root suckers. Roots are cut into two parts from the edge of tillering/suckers	Useful for timber production, house construction, manufacture of house furniture and utensils,	Patients with tumor cancer are treated using flours of pound roots and heals after being treated for three days
Pastoralists kill the plant by debarking the stem, also induce sprouting by covering the uncovered/debarked part with mud or animal dung.	Used as fire wood and charcoal making, for making hand and farm tools	Milk containers are disinfected by smoking with the roots, the milk is also smoked to treat liver problems
***Cadaba forinosa* (Dhi-taab)**		
Indigenous shrub widely spread in the arid and semi-arid agro-ecologies, well adapted to saline and shallow to deep silt and sandy silt clay soils,	The leaves are best feed for camel, other livestock species do not consume it	Traditionally the roots are used to treat dizziness or depression in children.
Provides shade during the rainy season (May-June), starts leaf bearing in October, with full leaf carriage in the long dry period (October-May),	It is important for soil and water conservation and gully treatment	The roots are boiled with water and a cup or two of the supernatant given to the patient to drink
Flowers in February, fruit bearing in April and mature in March, propagated through seeds or seedlings	Less used for fire wood and construction but old or dead plants are used for fire wood.	After few hours (2-3), then the child gets cured and recovered from his/her illness.

Table 6.10. Phenological characteristics and traditional values of woody vegetation in Shinile zone of Somali region

Phenological characteristics	Economic values	Socio-economic values
***Cadaba glandulosa* (Quelen)**		
Indigenous, adapted to saline, shallow to deep silt and sandy silt clay soils, it is drought tolerant, with shallow roots.	Best feed for camels, then goats, other livestock do not feed on the leaves.	The leaves are used for treating skin diseases in animals.
An evergreen, commonly occur in the arid and semi arid agro-ecologies in the east-west belt from Djibouti Republic up to Awash Valley (800 km)	Important for soil and water conservation and gully treatment, rarely used as fire wood.	There is no recognized socio-cultural value developed by the pastoralist communities
***Dobera galabra* (Guurues)**		
Indigenous, multi-branched, ever green shrub or tree, growing up to 8 m, common in rocky hill sides, occur in arid and semi-arid agro-ecologies, drought tolerant	Leaves are best feeds for camels and less for goats, serves as shade for livestock and herdsmen/women..	The fruits are edible and used with traditional foodstuffs, often boiled with sorghum grains and milk as meal.
Adapted to saline, heavy to shallow loam soils, grows 400-1300 m.a.s.l,	Commonly used for timber purpose and furniture manufacturing	The plant is declining due to an identified reasons
Sensitive to water lodging, propagated through seedlings, flower and bear fruits in Feb-April, slow growing but hardy once established.	Traditional comb is made from the branches of the tree, important for soil-water conservation.	Only old plants are observed and new shoots or seedlings are very rear, further investigation is needed.
***Grewia ferruginea* (Asa-aado)**		
Indigenous, well spread in arid and semi-arid agro-ecologies, grow up to 7 m, drought tolerant, grown on hilly sides and under poor soil conditions.	The leaves are top feed for camels and goats, important as shade for livestock.	Used for making traditional arrows and bows for self protection against enemies and predators (hyena, fox and lion).
Early shading during the dry period, (Oct.-April), leaf bearing in short rains (April-March), flower during main rainy season (May-Aug), flower in September, fruit bearing and maturity in Oct-Nov.	The fruits are edible and of high caloric value, but aggravate thirst, very useful for traditional house construction and fencing.	It is also used for making traps for trapping rodents and rats, often smashed green leaves are used to cure human and animal skin obsessions.
Propagated by seeds and seedlings, animal digesta improves germination, natural seeds take more than a year, companion to grasses	Used as fire wood but not for charcoal, important for soil and water conservation and gully stabilization.	Used to disinfect and to perfume clothes of children less than one year.

Table 6.11. Phenological characteristics and traditional values of woody vegetation in Shinile zone of Somali region

Phenological characteristics	**Economic values**	**Socio-economic values**
	***Salvadora persica* (Aadaay)**	
Indigenous, found in arid, semi-arid and semi-desert agro-ecologies, adapted to alkaline soils, drought tolerant and indicator of soil salinity, shades in June-Aug (rainy season) with full carriage in Oct-May (dry season).propagate via seeds and root systems (vegetative), determinental effect on grasses due to shading effect.	Is best camel feed used for camel fattening and camel cows deliver female calves when fed on the leaves, important for livestock shading, soil water conservation, improves soil fertility (humus), not used for charcoal but fire wood.	Roots used for treating udder diseases, the branches used as tooth brush to prevent tooth decay, for disinfecting the mouth and keep it fresh. Roots also useful for treating human skin problems, for butter purification, increase flavor and shelf life
	***Sanseviera abyssinica* (Heeg)**	
Indigenous, shade loving dwarf sisal spp., widely spread spp. in arid and semi-arid, well adapted to alkaline soils, evergreen, drought tolerant, propagated vegetatively or via seedling.	Traditionally used for making ropes, carpets, camel saddles, milk utensils, mattresses.	Important for soil water conservation, the juice of new shoots for treating ear infections.

the poor condition site, thus indicate the encroachment by woody plants with an increased intensity from the poor condition to the benchmark direction.

The reduction in height stratum of the woody plants from the benchmark to the poor condition site implies that, there is marked deterioration in height by the woody plants in the Hurso closed savanna, mainly due to human interference or due to the fact that density increased. Major factors include over cutting of the woody plants for firewood, charcoal making, construction and expansion of irrigated agriculture.

The ETTE ha^{-1} in the Aydora open savanna, showed an increase from 344 ha^{-1} in the excellent condition site to 2 474 ha^{-1} in the poor condition site, while it decreased from 10 315 in the excellent condition site to 1 742 ha^{-1} in the poor condition site in the Hurso closed savanna. Based on these results therefore, it can be accepted that the competition between woody and herbaceous vegetation for water and soil nutrients is severe in the poor condition site of the open savanna and the herbaceous layer would continue to decline. In the closed savanna, however, the opposite is taking place but the encroachment by *Acacia mellifera* and *A. nubica* pose a potential threat for the future.

In this study, the browsing capacity of the rangeland vegetation types, were influenced by different factors such as type of rangeland vegetation type (open or closed), type of the woody plant species (deciduous or shading), plant density ha^{-1} (high or low), season of the year (dry or wet), rangeland condition (excellent, good, moderate, poor), height class of the woody plants (<1.5 m, 2.0 m and <5.0 m) and type of browser (goat or camel). Of these plant density and level of degradation of the rangeland type was found to be most important determinant of the browsing capacity. As a result, ha BU^{-1} increased from the benchmark to the poor rangeland condition sites in the closed savanna, with an opposite trend in the open savanna for reasons explained in 6.3.4.

In this study also, it was established that the woody plants have multiple value in terms of economical uses, environmental protection, ethno botany and livestock production in pastoral areas. However, the importance of each species of woody plant has not yet been documented, developed and used in a more advanced way rather than the traditional way.

6.4.2 Recommendation

The Aydora open savanna is currently being invaded by encroaching woody plants, resulting in a loss of potential grazing with little contribution to the pastoral livestock production. Also, there is no indigenous knowledge and skills for controlling the main encroacher woody plants, mainly *Acacia nubica.* As a result, the problem necessitates a solution to minimize the expansion and control of the existing expansion through integrated management with the participation of the community.

The closed savanna is also on the verge of total degradation because of misuse of the woody plants, mainly due to over cutting of the trees for different purposes without any control. Eventually the livestock production in the area will be based on uncertainty due to the degradation. Therefore, there is a need for scientific management and protection of the woody plants.

The awareness of the communities of the problems seems to be poor due to lack of adequate extension programs. Rising the level of awareness of the people is this imperative. The role of the regional government, national government and local non-governmental organizations also need to be strong shareholders in launching an appropriate extension system.

Further research on bush encroachment and integrated, community participatory and demand driven controlling mechanisms (such as mechanical, biological and chemical control), efficient use of the encroacher woody plants for economic uses, determination of sustainable grazing and browsing capacity of the rangelands, detailed phenological studies of the woody vegetation have to be addressed through the regional and national research and development systems.

In-depth studies on the ethno-veterinary and ethno-medicine of the woody vegetation developed through the traditional use by the community need to be the future research agenda at a national level in order to promote the indigenous knowledge on scientific and commercial levels, so the current vegetation resources could be maintained for a sustainable use of generations.

Development of browsing systems for camels and goats is also important as a land use system, in order to optimize animal production and prevent rangeland degradation. It is therefore, imperative that appropriate stocking rates should be developed and applied in accordance to the vegetation resource bases, degradation condition levels of the rangeland vegetation types and season of the year.

CHAPTER 7

SOIL SEED BANK GERMINATION CAPACITY OF THREE RANGELAND VEGETATION TYPES IN THE SOMALI REGION OF EASTERN ETHIOPIA

7.1 INTRODUCTION

Rangelands in the arid and semi-arid parts of the world experience different forms of degradation of the soil (physical and chemical) and vegetation. The latter includes partial to total decline of the vegetation cover, replacement of perennial grasses by annual grasses and increases in shrub density and cover (Valone and Sauter, 2004). Rangeland degradation can be attributed to different factors, but overgrazing by livestock is thought to play a major role (Bahre, 1991; Vavra *et al*., 1994; Hodgson and Illius, 1996; Van Auken, 2000). Restoration attempts often involved removal of livestock (Vetter *et al.*, 2006) however there are instances where the perennial grasses, even after 20 years of enclosure, have not recovered (Roundy and Jordan, 1988; Sharpe, 1990; Laycock, 1991). It is thus important to understand the regeneration potential of the vegetation from seed stored in the soil seed banks (Archer, 1996; Rietkirk *et al*., 1997; Snyman, 2004; Solomon *et al*., 2006a).

In Africa, woodlands including savannas and dry forests, cover approximately 13 million km^2 or 43% of the total land area (Menout *et al*., 1995). In Ethiopia, the woodlands and savannas cover about 20% of the total land area, with the *Acacia* woodland and savannas accounting for about 11% of the total area of Ethiopia (Demel Teketay *et al.*, 1999). These areas are degrading at an alarming rate due to overgrazing/over-browsing by livestock and game, expansion of cultivation, over harvesting of trees for fuel wood and wildfires or deliberate burning (Folliot *et al.*, 1995; Gemedo-Dalle *et al*., 2006). All these activities result in the removal of the vegetation cover from the wooded savannas and grasslands severely affecting seed density in the soil seed bank.

A soil seed bank is defined of seeds at/or beneath the soil surface that are capable of germination (Sagar and Mortimore, 1976), which are important in the sustainability of arid and semi-arid rangelands. Moreover, soil seed banks are the natural *in situ* plant conservation mechanisms that prevent plants from extinction. There is adequate evidence that rangeland degradation can be restored by regeneration of soil seed banks (Freeman *et al.*, 1982). Very important however, is that there should be adequate assessment of the soil seed banks before making a decision on rehabilitation measures. Seed banks are depleted through germination, predation, senescence, pathogens, drought and compaction, that would determine the turn over of the seed bank in arid and semi-arid rangeland conditions (Laura and Branda, 2000; Snyman, 2004).

The rangelands in eastern Ethiopia are rapidly deteriorating and as a result failing to support the present pastoral livestock production system. Also, no efforts are made to restore the degraded rangelands in those pastoral areas. It is not known if seeds in adequate quantities are present in the soil seed bank to ensure recovery of the vegetation. Most of the pastoralists are unsure of the status of the soil seed bank. Rehabilitation of the degraded rangelands in eastern Ethiopia, through natural regeneration is a possibility, but the potential for recovery needs to be studied. The objective of this study is therefore, to determine (i) the soil seed bank regeneration potentiality, (ii) species composition, (iii) plant density and frequency distribution, (iv) plant forms and desirability by livestock, (v) estimation of fresh weight yield, (vi) comparison with present vegetation types and (vii) understanding the chemical and physical properties of the soil seed bank, in three rangeland types in Shinile zone of Somali region, respectively.

7.2 MATERIALS AND METHODS

7.2.1 Soil sampling procedures

7.2.1.1 Sampling for soil seed bank assessment

The soil samples were collected from three different rangeland vegetation types and sites at different levels of degradation. The rangelands are the Asbuli grassland, Aydora open savanna (bush-grassland) and Hurso closed savanna (bushland) located in Erer wereda of Shinile zone of Somali region, eastern Ethiopia (Chapter 2, section 2.5). The soil samples were collected on 10 February 2004 when the vegetation was actively growing and at 50% flowering. The soil samples for the seed bank analysis were collected from randomly selected plots which included for each vegetation type a benchmark, good, moderate and poor condition site. Sampling plots of 300 mm diameter x 100 mm depth (0.9 m^3) were selected and replicated on 25 randomly selected sites on each of the rangeland condition sites. For each sampling plot the litter on the soil surface was removed, and the topsoil was cut to a depth of 100 mm with a sharp knife, after which the soil samples were collected. All samples were bulked, thoroughly mixed and 5 representative composite samples of 0.09 m^3 soils per rangeland vegetation condition site and a total of 20 composite soil samples per rangeland type were taken. In general, a total of 60 samples from the three rangeland vegetation types were taken to a greenhouse at the Alemaya University, where the experiment was conducted.

7.2.1.2 Sampling for chemical and physical analysis

At the same soil sampling sites described in 7.2.1.1, 10 soil samples were taking by using an auger (300 mm radius x 1 500 mm depth), bulked and placed in plastic bags. Two composite soil samples (1.35 m^3 each) were taken from each rangeland condition site, labeled and transported to the soil laboratory of the Alemaya University for analysis. Every sample was replicated twice to minimize the standard error (SD). The soil samples were air dried, grounded in a mortar and sieved through a 2 mm sieve. Laboratory analysis was carried out for water retention, soil texture (percentage sand, silt and clay), soil quality indicators (FAO, 1995) that include pH, organic carbon (OC), nitrogen (N), available phosphorus (P), available potassium (K) and electrical conductivity (EC).

The soil laboratory analysis was done in the laboratory of the Department Plant Sciences of the Alemaya University, Alemaya, Ethiopia. An estimate of soil compaction was made at 200 points per rangeland condition class, using a simple rod penetrometer with a pressure of 1 kg cm^{-2}, using methods described by Friedel (1987). The soil physical analysis included texture, compaction, soil fertility and water holding capacities for the different soil types collected from the three rangeland vegetation types.

7.2.2 Greenhouse studies

7.2.2.1 Facilities and materials

The controlled environment of a greenhouse provides conditions suitable for the germination of a wide range of species (Thompson and Grime, 1979). The greenhouse of the Department of Plant Sciences of the Alemaya University (Figure 7.1) was also used for the soil seed bank germination and regeneration test. The greenhouse was set to regulate the temperature at about 30^{o}C during the day and approximately 20^{o}C at night. This was done to simulate the climatic conditions of the rangelands in the Shinile zone of the Somali region.

Figure 7.1 Plastic pots of different colors used for the soil seed bank germination test in the greenhouse at Alemaya University.

A concrete platform of 1 m high, 2 m wide and 4 m long was selected for the study and cleaned and dried to avoid contamination. A total of 60 plastic pots, 300 mm in diameter and 100 mm deep, were used. Holes of 2 mm in diameter were drilled in the bottoms for drainage purpose. Different colored plates were used to clearly distinguish between the soil from the different vegetation areas (Figure 7.1). A plastic watering cane with spray nozzle, with a capacity of 6 liters was used for daily watering.

7.2.2.2 Seed germination procedures

Four of the rangeland condition sites per rangeland vegetation type were taken as treatments and each replicated 5 times. Hence there were a total of 12 treatments and 60 replicates, for each of the three rangeland vegetation types. Each of the pots were randomly assigned to treatments and replicates and labelled. Accordingly, each pot was filled with 0.9 m^3 soil and 50 g of fine dung granules by dissolving in one liter of water and filtering the supernatant to help enhancement of seed germination.

The experimentation was conducted for a period of one year, starting on 10 February 2004, where three successive regenerations took place, harvested and identified, in every four months interval. Average results were used for analysis. Different record sheets were also designed for date of germination and flowering, plant fresh weight at maturity and mineral deficiency symptoms.

7.2.3 Soil chemical and physical analysis

The pipette method was used to determine soil particle size (USDA, 1984) and classified into sand (0.05-2.0 mm), silt clay (0.002-0.05 mm) and clay (<0.002 mm) proportions. Soil water was determined before drying by placing 25 g of fine earth (<2 mm sieve) on a pressure membrane extractor (Baruah and Barthakur, 1997). The same samples were weighed immediately and oven dried at 105°C for 24 hours. The soil pH (HCL) was determined and electrical conductivity tested using methods of

Van Reeuwijk (1992). The method of Walkley and Black (1934) was employed for running soil organic carbon analysis. The Kjeldhal method (Black *et al*., 1965) was used for the determination of total nitrogen. In the determination of available phosphorus the methods of Olsen and Dean (1965) and Bray and Kurt, (1945) were used. For determining the available potassium the methods described by the Soil and Plant Analysis Council (1992) was used.

7.2.4 Data collection

7.2.4.1 Plant density and correlation between degradation parameters

The number of each plant that germinated successfully in each pot were counted, identified on species bases and the density of each plant species calculated in terms of number of plants per m^2. The influence of the different rangeland condition sites of the soil seed bank parameters such as plant density, species number and phytomass (on fresh weight bases) were analyzed.

7.2.4.2 Botanical composition

Each plant species was uprooted at full flowering stage, pressed between papers and sent to the Plant Herbarium of the Department of Plant Sciences, Alemaya University, Ethiopia for botanical identification. The same samples were also taken to the pastoral elders and herdsmen for identification of the plants by the local names. The percentage frequency of each species was calculated as the number of a plant species as percentage of the total number of plants.

7.2.4.3 Plant forms and life forms

Each plant species was classified into its plant form (as grasses, woody plants, forb, herb and weed) and life form (as annual, semi-annual and perennial) in order to understand the potentiality of the soil seed banks from plant biodiversity context. Farther, the preference of each plant species by different classes of livestock was subjectively determined using indigenous knowledge of the pastoralists in the study area.

7.2.4.4 Plant phytomass measurement

Phytomass measurement in terms of dry matter yield is a universally accepted norm. However, in this experiment there was a lack of facilities to do so. Despite the argument that may be raised, fresh mass weight per m^2 was determined for each plant species as described by Thompson and Grime (1979) using a sensitive scale. This was done in an attempt to give an indication for future research activities, when dry matter yield for the plant species was not possible to measure under conditions of this experiment.

7.2.4.5 Ecological status classification

Each of the identified plant species was further classified (Chapter 5 section 5.2.3) into its ecological status such as Decreaser, Increaser, where the latter include Increaser IIa, Increaser IIb, Increaser IIc and Invaders using methods described by Tainton (1981) and Vorster (1982).

7.2.5 Data analysis

The data were analyzed using descriptive statistics such as percentage, mean and standard deviation, which were calculated using the Statistical Package for Social Sciences (1996). Friedman's test (Steel and Torrie, 1980) was used for ranked data analysis. When the analysis revealed the existence of significant variation, the analysis of variance (ANNOVA) was performed. Correlation coefficient analysis described by Hintze (1998) was used to understand the relationships between dependent and independent variables when necessary.

7.3 RESULTS AND DISCUSSION

7.3.1 Plant density and number of species for the three vegetation types

The plant density in the soil seed bank from the excellent (benchmark) condition class of the Asbuli grassland was higher ($p<0.05$) than that in the other condition classes, while there was no difference ($p<0.05$) between the plant density of the good and moderate condition classes. The plant density was lower ($p<0.05$) in the poor rangeland condition class than that of all the other condition classes. The number of species in the good condition class was higher ($p<0.05$) and lower ($p<0.05$) in the poor condition class than that of the benchmark, but there was no difference ($p>0.05$) in number of species between the benchmark and moderate rangeland condition sites (Table 7.1). The reason for higher number of species in the good condition class was not understood, but there was no significant correlation ($p<0.05$) between species number and plant density (Table 7.2).

Table 7.1 Average (±SD) plant density and number of species from the soil seed banks of different condition classes of three rangeland vegetation types of the Shinile zone of the Somali region

Area and rangeland condition classes	**Plant density (plants per m^{-2})**	**Species (No)**
Asbuli grassland		
Benchmark (Excellent)	676 ± 65^{A}	22 ± 2.11^{A}
Good condition	648 ± 130^{B}	26 ± 2.13^{B}
Moderate condition	626 ± 125^{B}	22 ± 2.00^{A}
Poor condition	329 ± 135^{C}	16 ± 1.66^{C}
Aydora open savanna		
Benchmark (Excellent)	640 ± 57^{A}	24 ± 2.14^{A}
Good condition	580 ± 62^{A}	23 ± 2.14^{A}
Moderate condition	470 ± 43^{B}	23 ± 2.01^{A}
Poor condition	320 ± 64^{C}	22 ± 2.16^{A}
Hurso closed savanna		
Benchmark (Excellent)	600 ± 56^{A}	25 ± 2.01^{A}
Good condition	550 ± 64^{A}	23 ± 1.96^{A}
Moderate condition	500 ± 57^{A}	20 ± 1.86^{B}
Poor condition	475 ± 55^{A}	21 ± 1.66^{B}

* Means with similar letters are not significantly different at P>0.05

The plant density in the soil seed bank from the benchmark and good condition classes of the Aydora open savanna showed no significant difference ($p<0.05$), while the plant density in the moderate condition class was lower than that of the other two classes, but higher ($p<0.05$) than the poor condition, while it was lower ($p<0.05$) in the poor condition class (Table 7.1). On the other hand, there was no difference ($p<0.05$) in number of species among the four condition classes of the open savanna, while no significant correlation ($p<0.05$) occurred between plant density and number of species (Table 7.2).

The plant density in the soil seed bank from the benchmark, good, moderate and poor condition sites of the Hurso closed savanna showed no significant difference ($p<0.05$), but number of species were higher ($p<0.05$) in the benchmark and good condition classes and lower ($p<0.05$) in the moderate and poor condition classes. However, there was no difference ($p<0.05$) between the benchmark and the good condition sites in one hand and between the moderate and poor condition sites on the other (Table 7.1). In the closed savanna, plant density in the soil seed bank was highly correlated ($p<0.01$) with number of plant species (Table 7.2).

Table 7.2 Correlation coefficient (r) for three rangeland vegetation types between plant density and number of species

Rangeland and soil seed bank parameters	Plant density (Plants m^{-2})
Asbuli grassland	
Number of species	0.049^{NS}
Aydora open savanna	
Number of species	0.282^{NS}
Hurso closed savvana	
Number of species	0.613**

*Represents significant correlation at $P<0.05$
**Represents highly significant correlation at $P<0.01$
NS Represents not significant correlation $p>0.05$

The data in general indicated that as rangeland degraded the grassland, open savanna and closed savanna have an adequate amount of seeds in the soil seed bank. Hence there is the opportunity for restoration and rehabilitation of the degraded rangelands to promote farther feed production from the denuded lands in the different rangeland types to support a sustainable livestock production by the pastoral communities in the area.

In the absence of facilities to determine the dry matter yield, fresh plant weight was taken to observe the trend in aboveground biome production. From this point of view, fresh weight from plants in the soil seed bank of the benchmark and good condition classes was in general higher, medium for the moderate condition classes and lower for the poor condition classes in the three vegetation types (Table 7.3). Despite the need to study the dry matter production from soil seed banks, however, the fresh weight measurements give a good indication that rehabilitation of degraded rangelands in Shinile zone of the Somali region, could be able to produce a substantial amount of feed for livestock production.

Table 7.3 Average (±SD)fresh weight measurement from the soil seed bank of different condition classes of three vegetation types in the Shinile zone of the Somali region

Area and rangeland condition classes	Fresh weight ($g\ m^{-2}$)
Asbuli grassland	
Benchmark (Excellent)	1 182±218^{A}
Good condition	1095±211^{A}
Moderate condition	765±111^{B}
Poor condition	405±106^{C}
Aydora open savanna	
Benchmark (Excellent)	1 026±217^{AB}
Good condition	932±196^{A}
Moderate condition	597±146^{C}
Poor condition	420±109^{D}
Hurso closed savanna	
Benchmark (Excellent)	855±216^{A}
Good condition	794±214^{A}
Moderate condition	685±206^{A}
Poor condition	542±199^{B}

Means with similar letters are not significantly different at P>0.05.

7.3 2 Botanical composition and related parameters for the Asbuli grassland

7.3.2.1 Botanical composition

In terms of botanical composition a total of 41 plant species have germinated and were identified from the soil seed bank of the Asbuli grassland (Table 7.4). This included 19 (46.34%) grass species, 9 (21.95%) woody plant species, 9 (21.95%) weed species and 1 (2.44%) legume species. The number of species in the soil seed bank from the different rangeland condition classes included 22 in the excellent condition (benchmark), 26 in the good condition, 22 in the moderate condition and 16 in the poor condition.

The species composition showed markable differences between the different rangeland condition classes. Accordingly, the percentage contribution of individual species ranged from 2.08 to 10.4% in the soil seed bank from the excellent rangeland condition site, 2.08 to 10.42% in soil from the good rangeland condition site, 2.56 to 10.26% from the moderate rangeland condition and 3.13 to 12.5% from the poor condition site. *Cenchrus settigures, Cyperus rotandus, Echinochloa haploclada, Eriochloa nubica, Eragrostis cilianensis,* and *Euphorbia hirta* were the most abundant species found in the soil seed bank. Although *Cyperus rotandus* was one of the most abundant species in the soil seed bank, it was not noted in the field surveys as discussed in Chapers 4, 5 and 6. *Sorghum abyssinica* was the dominant species for the benchmark and good condition sites in the field (Table 5.3), but was not found in the soil seed bank. The same applies for *Digitaria abyssinica* for the moderate condition sites. *Tribulus terrestris* was dominant in the poor condition site (Table 5.3), but seeds germinate only in the good and moderate condition sites.

A higher abundance in plant species ($p<0.05$) was recorded in the soil seed bank from the good rangeland condition site compared to that of the excellent condition site of the Asbuli grassland. Two reasons may be suggested as causes for the result, namely that firstly this may be due to increased trampling by animals inducing increased seed scattering in the soil. Secondly, it might be due to the fact that animals spend relatively more time in the good condition rangeland site than in the excellent rangeland condition, resulting in more seeds entering the soil seed bank from fecal defecation.

Compared to the benchmark, however, a significant decline ($p<0.05$) in species abundance in the soil seed bank was observed as the rangeland condition declined from an excellent to a poor rangeland condition. Abundance in plant species was lower ($p<0.05$) in the soil seed bank of the moderate condition site of the grassland compared to that of the good condition, while the poor condition site was lower ($p<0.05$) compared to the moderate condition site. There was no significant difference ($p>0.05$) in species abundance between the benchmark and the moderate condition sites of the Asbuli grassland (Figure 7.2).

7.3.2.2 Plant forms

The plants that germinated from the soil seed banks of the Asbuli grassland area were grouped into their respective plant forms and presented in Figure 7.3. The plant forms regenerated from the soil seed bank of the excellent rangeland condition site (benchmark) were composed of 77% grasses 17%, forbs and 6% weeds, whereas no woody plants were observed from the soils. In the soil of the good rangeland condition site, the plant composition included: 58% grasses, 23% forbs, 10% woody plants, 7% weeds and 2% leguminous plants.

Table 7.4 Species composition and related parameters for plants regenerated from the soil seed bank from the different condition sites of the Asbuli grassland

No	Botanical name of plant species	Frequency (%) of plant species				Average fresh weight (g plant^{-1})	Plant forms
		Excellent	Good	Moderate	Poor		
1	*Amaranthus dubius*				3.13	5	Woody plant
2	*Calylusea abyssinica*			2.56		8	Woody plant
3	*Cenchrus ciliaris*	2.08	2.08			15	Grass
4	*Cenchrus settigures*	8.32	10.43	2.56	9.37	41	Grass
5	*Chenopodium album*		2.08			20	Forb
6	*Chloris virgata*	2.08				8	Grass
7	*Chorchorus trilocularis*		2.08	2.56	6.25	16	Woody plant
8	*Convolvulus sagittatus*	6.25	4,17			23	Forb
9	*Conyza bonariensis*	4.20	2.08		3.12	32	Forb
10	*Crotolaria albicaulis*				5.13	13	Woody plant
11	*Crotolaria pycnostachya*				6.25	6	Woody plant
12	*Cyperus rotandus*	8.33	10.42	10.26	12.50	49	Grass
13	*Dactyloctenium aegyptium*	4.2				12	Grass
14	*Echinochloa haploclada*	10.4	4.17	7.70	6.25	72	Grass
15	*Eriochloa nubica*	10.4	4.17	7.69	11.00	45	Grass
16	*Eragrostis cilianensis*	4.17	8.34	10.26	6.25	20	Grass
17	*Eragrostis papposa*	2.08		2.56	6.25	7	Grass
18	*Eragrostis schweinfurthi*		2.08	2.56		20	Grass
19	*Eragrostis tef*	2.08	2.08			17	Grass
20	*Eriochloa fatmensis*	2.08				11	Grass
21	*Euphorbia hirta*	4.17	4.17	10.26	9.37	13	Forb
22	*Gelinosonga parviflora*		2.08			22	Woody plant
23	*Leucas spp.*	2.08				24	Weed
24	*Lintonia nutans*	4.17		5.13		24	Grass
25	*Lotus corniculatus*		2.08			18	Woody plant
26	*Medicago spp.*		2.08	2.56		9	Legume
27	*Nicotinia spp.*		2.08			4	Woody plant
28	*Parthenium hysterophorus*	6.25	6.25	5.13	6.25	19	Weed
29	*Portulaca spp.*		4.17		3.13	12	Forb
30	*Raphanos raphonostrum*		2.08		6.25	13	Forb
31	*Setaria acromelana*	2.08	2.08			26	Grass
32	*Setaria verticillata*		2.08			54	Grass
33	*Sorghum arundinaceae*	6.25		2.56		83	Grass
34	*Sphaeranthus suaveolens*		2.08	2.56		16	Woody plant
35	*Tetrapogon cenchriformis*			2.56		6	Grass
36	*Tragus berteronianus*	2.08	6.25	5.13	12.5	14	Grass
37	*Tragus racemosus*		4.17			5	Grass
38	*Tribulus terrestris*		2.08	2.56		9	Forb
39	*Verbesina enceloides*	2.08		2.56		8	Forb
40	*Veronica anagalis*			2.56		15	Forb
41	*Xanthium abyssinicum*	4.17		7.70		20	Weed
	Total (%)	100.0	100,0	100.0			

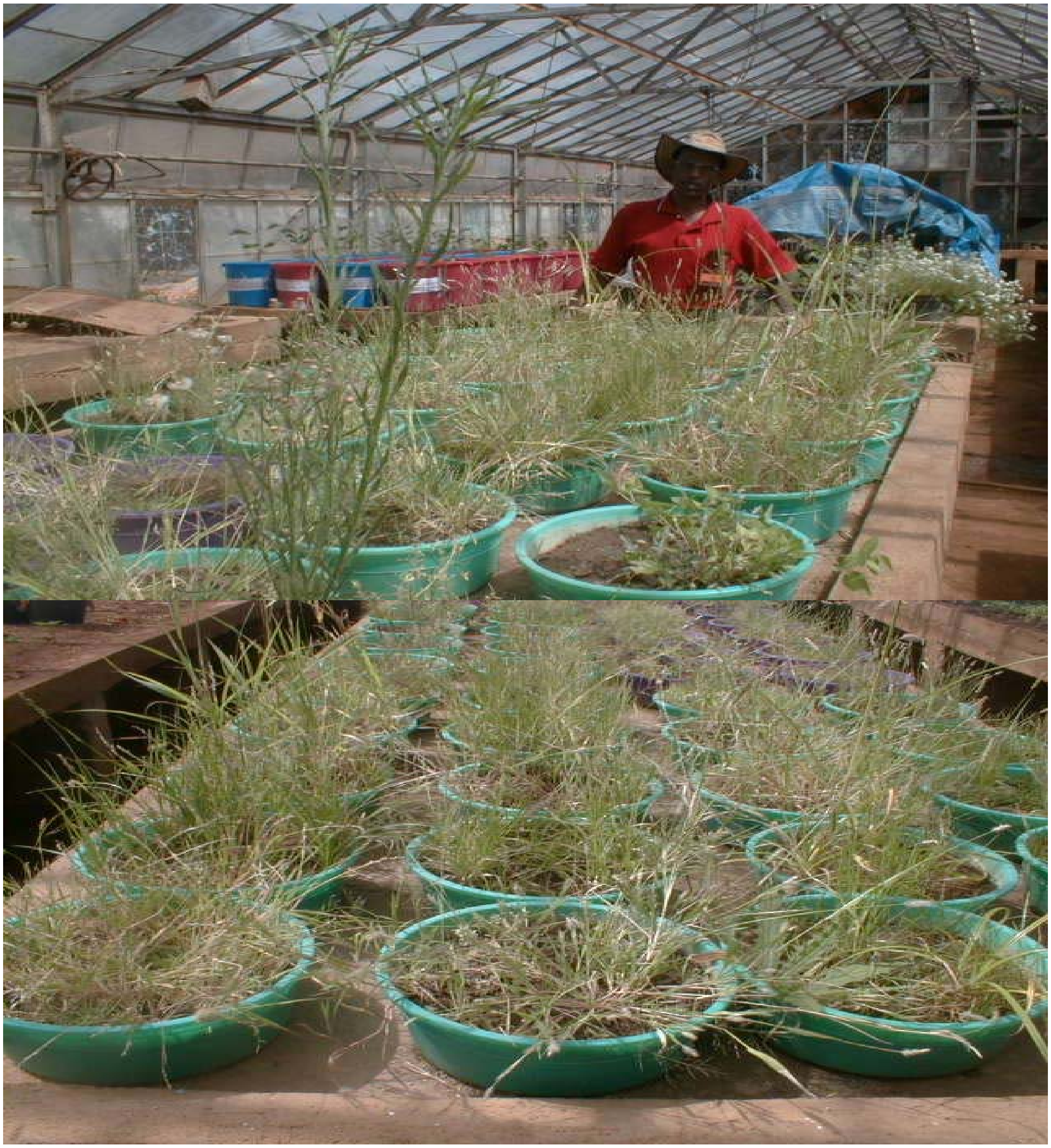

Figure 7.2 Vegetation regeneration from soil seed collected along a degradation gradient of the Asbuli grassland

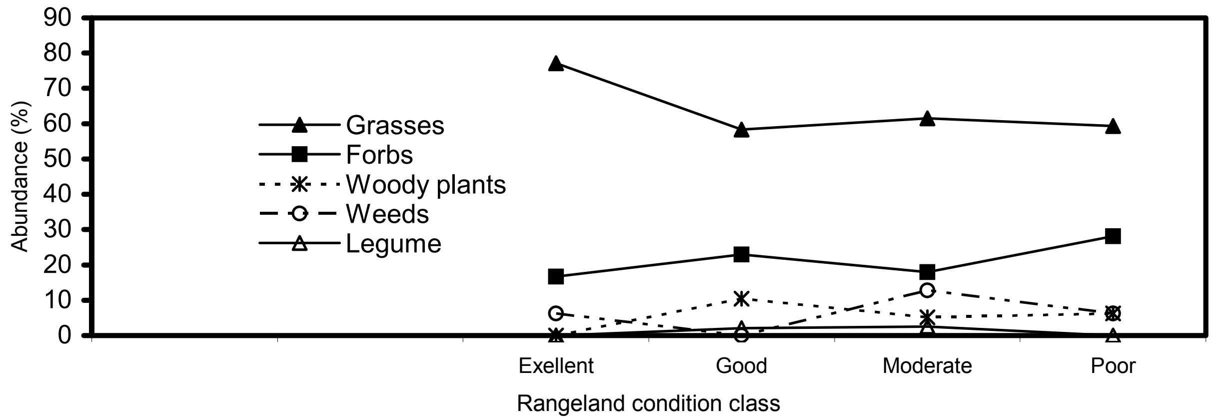

Figure 7.3 The pattern of plant forms along a degradation gradient in the Asbuli grassland area

From the soil seed bank of the moderate rangeland condition site, the plant composition consisted of 61% grasses, 18% forbs, 13% weeds, 5% woody plants and 3% leguminous plants. The plant composition from the soil of the poor rangeland condition site included 59.38% grasses, 28.12% forbs, 6.25% woody plants and 6.25% weeds, while no leguminous plants were observed.

7.3 3 Botanical composition and related parameters for the Aydora open savanna

7.3.3.1 Botanical composition

A total of 40 plant species have germinated and were identified in the soil seed bank of the Aydora open savanna (Table 7.5 and Figure 7.4). This included 21 (52.5%) grass species, 5 (12.5%) species of woody plants, 10 (25%) species of forbs and 4 (10%) species of weeds with different population sizes along the degradation gradients. The number of species in the soil seed bank from the different rangeland condition sites included 24 in the excellent condition (benchmark), 23 in the good condition, 23 in the moderate condition and 22 in the poor condition. In terms of number of plant species, there was no significant difference ($p>0.05$) in the soil seed bank of the different condition sites of the Aydora closed savanna.

The species composition showed noticeable differences between the different rangeland condition classes. Accordingly, the percent contribution of individual species ranged from 1.7 to 14.56% in the soil seed bank from the excellent rangeland condition site, 1.72 to 15.52% from the good rangeland condition site, 2.04 to 10.20% from the moderate

Table 7.5 Species composition and related parameters for plants regenerated from soils from the different condition sites of the Aydora open savanna

No	Botanical name of plant species	Frequency (%) of plant species				Average fresh weight (g plant^{-1})	Plant forms
		Excellent	Good	Moderate	Poor		
1	*Becium flamentosum*	1.7	1.72	2.04		15	Forb
2	*Casia italica*		1.72			12	Grass
3	*Cenchrus settigerus*				2.27	5	Grass
4	*Chloris virgata*	3.39	1.72	2.04	4.54	30	Grass
5	*Chorcorus trilocularis*			4.08	2.27	20	Woody plant
6	*Convolvulus sagittatus*	10.17	1.72	4.08	2.27	17	Forb
7	*Conyza bonariensis*	6.78	6.7	4.08	4.54	29	Forb
8	*Crotolaria pycnostachya*	3.39	1.72	6.12	4.54	29	Woody plant
9	*Cyperus rotandus*		6.70	2.04		25	Grass
10	*Dactyloctenium aegyptium*		1.72	2.04	4.54	20	Grass
11	*Digitaria erantha.*				2.27	17	Grass
12	*Echinochloa haploclada*		8.62	6.12	4.54	21	Grass
13	*Eragrostis cilianensis*	13.56	6.7	8.16	11.36	27	Grass
14	*Eragrostis papposa*			4.08	2.27	19	Grass
15	*Eragrostis schweinfurthi*	1.7				15	Grass
16	*Eragrostis tef*	1.7	3.45	8.16	11.36	27	Grass
17	*Erica arborea*		3.45	2.04		24	Woody plant
18	*Eriochloa haploclada*	1.7			2.27	11	Grass
19	*Eriochloa nubica*	3.39	15.52	4.08	6.82	32	Grass
20	*Euphorbia hirta*	3.39	6.7	4.08	4.54	24	Forb
21	*Fagonia brouguieria*			2.04		21	Forb
22	*Glycine weightii*	3.39				21	Grass
23	*Helotropium aegyptiacum*		5.17	2.04		24	Forb
24	*Indigofora amorphoides*				2.27	10	Forb
25	*Leucas spp*	3.39	6.7	2.04		16	Weed
26	*Lintonia nutans*	3.39	6.7	10.20	2.27	20	Grass
27	*Melilotus suaveolens*				2.27	20	Forb
28	*Ocimum basilicum*	3.39				23	Weed
29	*Parthenium hysterophorus*	3.39		2.04	2.27	25	Weed
30	*Ruellia patula*				4.54	14	Woody plant
31	*Setaria acromelaena*	1.7	1.72			17	Grass
32	*Setaria verticillata*	1.17	1.72			22	Grass
33	*Sonchus oleraceus*	3.39		6.12	4.54	20	Woody plant
34	*Sorghum arundinacea*	5.08				80	Grass
35	*Tetrapogon cenchriformis*		1.72			56	Grass
36	*Tragus berteronianus*	6.78	3.45	8.16	6.82	27	Grass
37	*Tragus racemosus*	5.08				18	Grass
38	*Tribulus terrestris*	5.08	1.72	4.08	4.54	17	Forb
39	*Verbesina enceloides*	3.39				28	Forb
40	*Xanthium abyssinicum*		1.72			23	Weed
	Total in percent	100.0	100,0	100.0			

rangeland condition and 2.27 to 11.36% in the soil seed bank from the poor condition site. *Convolvulus sagittatus, Conyza bonariensis, Cyperus rotandus, Echinochloa haploclada, Eragrostis cilianensis, E. tef, Eriochloa nubica, Lintonia nutans* and *Tragus berteronianus* were the most abundant species. Of the dominant species in the seed bank, only *Eragrostis cilianensis* was noted in plant surveys in previous chapters for the open savanna.

Figure 7.4 Vegetation regeneration from soil seed bank collected along a degradation gradient of the Aydora open savanna

7.3.3.2 Plant forms

The plants regenerated vegetation from soil of the Aydora open savanna were grouped into their respective plant forms in relation to the degradation gradient. The results are shown in Figure 7.5. Accordingly, the plant forms regenerated from the soil seed bank of the excellent condition site were composed of 52.54% grasses, 23.73% forbs, 16.95% woody plants and 6.78% weeds, but no leguminous plants were observed in the soils of the open savanna. In the good rangeland condition class, the plant forms included 58.62% grasses, 17.4% forbs, 10% 15.52% woody plants and 8.62% weeds, however, no leguminous plants were observed from the soil seed bank in the good condition site. In the moderate condition site the plant forms consisted of 55.1% grasses, 18.37% of forbs, 22.45% of woody plants and 4.62% weeds, but with no leguminous plants being observed. In the poor rangeland condition site the plant forms included: 60.64% grasses, 20.45% forbs, 15.91% woody plants and 3% weeds, whereas no leguminous plants were observed.

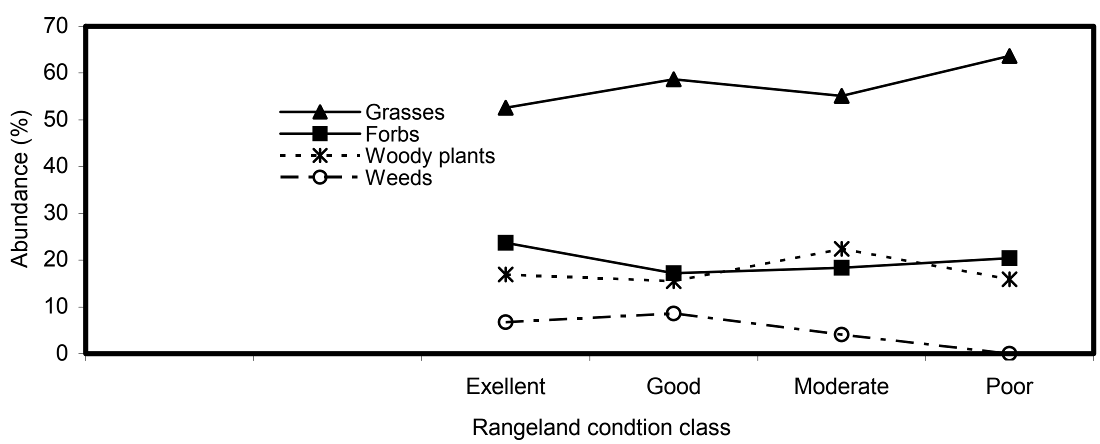

Figure 7.5 The dynamics pattern of plant forms (±SD) along a degradation gradient in the Aydora open savanna

The tested plant composition for different plant forms along the degradation gradient showed a significant increase ($p<0.05$) in composition of grasses in the soil seed bank across the degradation gradients. This is in contrast to the expectations, which may be explained by the gentle land slope of the Aydora open savanna. Over the years the plant seeds could have been transported and silted down stream by erosion processes. On the other hand, the forbs showed an increase in occurrence along the degradation gradients, while the woody plants and weeds showed a decline with degradation.

7.3.4 Botanical composition and related parameters for the Hurso closed savanna

7.3.4.1 Botanical composition

A total of 41 plant species have germinated and were identified from the soil seed banks of the Hurso closed savanna degradation gradients (Table 7.6). These include: 14 (35%) grass species, 13 (32,5%) species of woody plants, 12 (30%) species of forbs and 1 (2.2%) weed species, with different levels of population size along the degradation gradient.

The number of species in the soil seed bank was 25 species in the excellent rangeland condition (benchmark), 23 species in the good rangeland condition class, 20 species in the fair rangeland condition and 21 species in the poor rangeland condition class. The results revealed that the soil seed banks of the Hurso closed savanna area are adequate for future rehabilitation of the degraded rangeland conditions. The scenario is shown in Figure 7.6.

The species composition in the soil seed bank showed differences between the different rangeland condition classes. Accordingly, the percent contribution of individual species ranged from 1.64 to 9.84% in the soil seed bank from the excellent rangeland condition site, 2.17 to 10.87% from the good rangeland condition site, 2.44 to 12.2% from the moderate rangeland condition and 3.13 to 12.5% from the poor condition site. *Crotolaria pycnostachya, Dactyloctenium aegyptium, Eragrostis cilianensis, E. papposa, Setaria verticillata,* and *Sonchus oleraceus* had the highest distribution.

Table 7.6 Species composition and related parameters for plants regenerated from soils from the different condition sites of the Hurso closed savanna

No	Botanical name of plant species	Frequency (%) of plant species				Average fresh weight (g plant^{-1})	Plant form
		Excellent	Good	Moderate	Poor		
1	*Acalypha indica*	1.64	2.17	2.44	2.56	27	Woody plant
2	*Amaranthus dubius*			4.88		30	Woody plant
3	*Anagalis spp.*		2.17			25	Woody plant
4	*Becium flamentosum*	3.28		2.44	2.56	17	Forb
5	*Chemopodium procerum*		4.35	2.44		16	Woody plant
6	*Chemopodium album*	3.28			2.56	22	Forb
7	*Chloris virgata*			2.44	2.56	13	Grass
8	*Chorchorus triocularis*		4.35	2.44		23	Woody plant
9	*Cleome gynandra*		2.17			22	Woody plant
10	*Covolvulus sagittatus*	1.64				18	Forb
11	*Conyza bonariensis*			2.44	2.56	41	Forb
12	*Crotolaria pycnostachya*	1.64	4.35	2.44	10.27	25	Woody plant
13	*Cynodon dactylon*	1.64	2.17			16	Grass
14	*Cyperus robicundus*	1.64		2.44	2.56	16	Grass
15	*Cyperus rotandus*	4.92	2.17	4.88	2.56	28	Grass
16	*Dactyloctenium aegyptium*	4.56	10.87	12.2	7.7	33	Grass
17	*Digitaria velutina*		2.17			14	Grass
18	*Equistum ramosissimum*		2.17	2.44		45	Woody plant
19	*Eragrostis cilianensis*	9.84	10.87	12.2	10.27	38	Grass
20	*Eragrostis papposa*	9.84	4.3	7.31	10.27	31	Grass
21	*Eragrostis tef*	3.28		4.88	2.56	25	Grass
22	*Eriochloa nubica*	4.92	4.35	7.31		27	Grass
23	*Euphorbia hirta*	1.64	4.35			15	Forb
24	*Helotropium aegyptiacum*	3.28			5.13	18	Forb
25	*Kalancho petitiana*	1.63				13	Forb
26	*Lanthana camara*	3.2				27	Woody plant
27	*Leucas martinicensis*	1.64				15	Forb
28	*Lintonia nutans*		2.17			18	Grass
29	*Nicotiana spp.*				2.56	28	Woody plant
30	*Panicum spp.*	3.28		2.44		54	Grass
31	*Parthenium hysterophorus*	4.92	6.25	7.31	2.56	32	Weed
32	*Portulaca quadrifida*	4.92	2.17			14	Woody plant
33	*Portulaca spp.*				2.56	15	Forb
34	*Ruellia patula*		2.17		2.56	24	Woody plant
35	*Setaria verticillata*	6.56	8.7	4.88	2.56	21	Grass
36	*Sonchus oleraceus*	9.84	8.7	9.75	5.13	35	Woody plant
37	*Tragus berteronianus*				12.82	15	Grass
38	*Tragus racemosus*		4.35			40	Grass
39	*Tribulus terrestris*	1.64			5.13	14	Forb
40	*Verbesina enceliodes*	3.28				22	Forb
41	*Vialancheo petitiana*		2.17			24	Forb

7.3.4.2 Plant forms

The regenerated vegetation from the Hurso closed savanna soil seed banks was classified into respective plant forms for the different rangeland classes. The plant forms from the soil seed bank of the excellent rangeland condition (benchmark) were composed of grasses (50.82%), forbs (21.31%), woody plants (22.95%) and weeds (4.92%), while no leguminous plants were observed. The plant forms in the soil seed bank of the good

Figure 7.6 Vegetation regeneration from soil seed collected along a degradation gradient of the closed savanna

rangeland condition site included 54.3% grasses, 11% forbs, 34.7% woody plants and 2.5% weeds, while there were no leguminous plants found in the soil seed bank. In the soil seed bank of the moderate rangeland condition, the composition for grasses was 61%, forbs 4.9%, woody plants 26.8% and weeds 7.3% with no leguminous plants being observed. The composition from the soil seed bank of the poor rangeland condition site was consisted of 53.85% grasses, 17.95% forbs, 25.64% woody plants and 2.56% weeds, while no leguminous plants were observed (Figure 7.7).

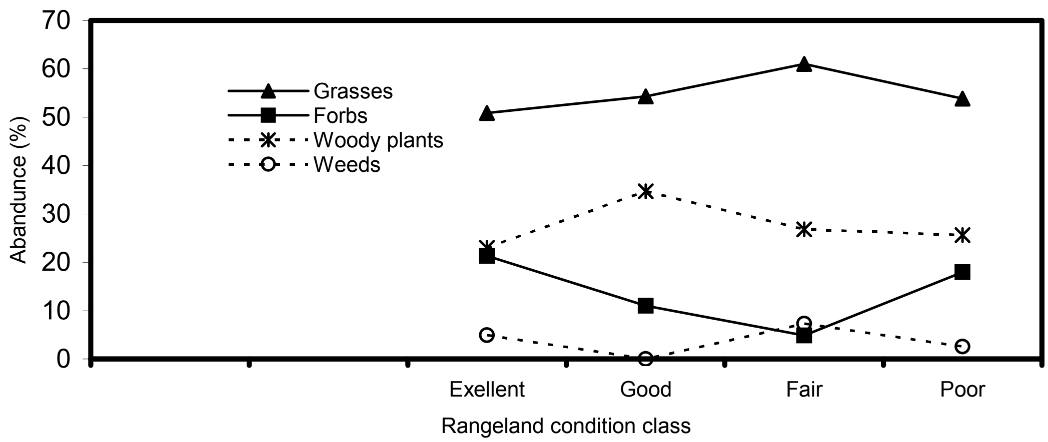

Figure 7.7 The dynamics in pattern of plant forms along a degradation gradient in Hurso closed savanna

Based on these results, the contribution of grass in the soil seed bank of the moderate rangeland site, was significantly ($p<0.05$) higher than that of the other rangeland condition classes. The forbs showed a significant ($p<0.05$) increase in the benchmark and in the poor rangeland condition, but showed a decline in the soil seed bank from the good to moderate rangeland condition sites. The woody plants significantly increased ($p<0.05$) in the good condition rangeland site but showed no difference ($p<0.05$) between the other rangeland condition sites. The weeds composition in the soil seed bank showed to be inconsistent across the different rangeland condition sites.

7.3.5 Comparison of regenerated plants with present aboveground species in the field for the three vegetation types

7.3.5.1 The regenerated grass species

A comparison of the extent of availability of regenerated plant species with that of the species in the field showed that from the 27 regenerated species of grasses, about 59% were observed in the fields of the rangelands, while 41% did not occur on the fields but only in the soil seed banks (Table 7.7). On the other hand, the pastoralists reported that, among 11 species that were found only in the soil seed banks, 6 species (54.5%) are

Table 7.7 Rangeland presence, commonness, life forms, palatability and ecological index of regenerated plant species in the different rangeland vegetation types

No	Botanical composition (Species names)	Presence in rangeland	Availability of species in soil seed bank			Vegetation related parameters		
			Asbuli grassland	Aydora open savanna	Hurso closed savanna	Life forms	Palata bility*	Ecological index
1	***Cassia italica***	**NP**	**NA**	**A**	**NA**	**Annual**	**HP**	**Decreaser**
2	***Cenchrus ciliaris***	**P**	**A**	**NA**	**NA**	**Perennial**	**HP**	**Decreaser**
3	***Cenchrus settigerus***	**P**	**A**	**A**	**NA**	**Perennial**	**HP**	**Decreaser**
4	***Chloris virgata***	**NP**	**A**	**A**	**A**	**Perennial**	**IP**	**Inc IIa**
5	***Cynodon dactylon***	**P**	**NA**	**NA**	**A**	**Annual**	**IP**	**Inc IIa**
6	***Cyperus robicundus***	**NP**	**NA**	**NA**	**A**	**Perennial**	**LP**	**Inc IIc**
7	***Cyperus rotandus***	**P**	**A**	**A**	**A**	**Perennial**	**LP**	**Inc IIc**
8	***Dactyloctenium aegyptium***	**P**	**A**	**A**	**A**	**Annual**	**LP**	**Inc IIc**
9	***Digitaria eratha***	**NP**	**NA**	**A**	**NA**	**Perennial**	**HP**	**Decreaser**
10	***Digitaria velutina***	**NP**	**NA**	**NA**	**A**	**Perennial**	**HP**	**Decreaser**
11	***Echinochloa haploclada***	**P**	**A**	**A**	**A**	**Perennial**	**HP**	**Decreaser**
12	***Eragrostis cilianensis***	**P**	**A**	**A**	**A**	**Annual**	**IP**	**Inc IIb**
13	***Eragrostis papposa***	**P**	**A**	**A**	**A**	**Annual**	**IP**	**Inc IIa**
14	***Eragrostis schweifurthi***	**NP**	**A**	**A**	**NA**	**Annual**	**IP**	**Inc IIa**
15	***Eragrostis tef***	**P**	**A**	**A**	**A**	**Annual**	**HP**	**Decreaser**
16	***Eriochloa fatmens***	**NP**	**A**	**NA**	**NA**	**Annual**	**IP**	**Inc IIa**
17	***Eriochloa nubica***	**P**	**A**	**A**	**A**	**Perennial**	**HP**	**Decreaser**
18	***Eriochloa haploclada***	**P**	**A**	**A**	**NA**	**Perennial**	**IP**	**Inc IIa**
19	***Glycine weighti***	**NP**	**A**	**A**	**NA**	**Annual**	**LP**	**Inc IIb**
20	***Lintonia nutans***	**NP**	**A**	**A**	**A**	**Perennial**	**LP**	**Inc IIa**
21	***Panicum spp.***	**P**	**NA**	**NA**	**A**	**Perennial**	**HP**	**Decreaser**
22	***Setaria acromelana***	**NP**	**A**	**A**	**NA**	**Annual**	**IP**	**Inc IIa**
23	***Setaria verticillata***	**NP**	**A**	**A**	**A**	**Annual**	**LP**	**Inc IIb**
24	***Sorghum arundinaceae***	**P**	**A**	**A**	**NA**	**Perennial**	**IP**	**Inc IIa**
25	***Tetrapogon cenchriformis***	**P**	**A**	**A**	**NA**	**Annual**	**HP**	**Inc IIa**
26	***Tragus berteronianus***	**P**	**A**	**A**	**A**	**Annual**	**IP**	**Inc IIc**
27	***Tragus racemosus***	**P**	**A**	**A**	**A**	**Annual**	**HP**	**Inc IIa**
	Total		**21**	**21**	**16**			

* In this study palatability refers to those grazing animals mainly cattle and sheep

P=Present, NP= Not present, A=Available, NA=Not available, HP=Highly palatable, LP=Less palatable, IP=Intermediately palatable, Inc=Increaser.

known to be indigenous, but have disappeared some 30-50 years ago. In contrast, the other 5 species were not indigenous and may have been transported through soil erosion from the highland water shades on the western part of the rangelands, which might have been silted and remaining dormant in the soils for years.

Furthermore, out of the regenerated 27 grass species in the soil seed bank, 12 species (44.4%) were commonly available in the field across the three types of rangelands. Seven species (26%) were observed in two of the rangelands only, while 8 species (29%) were common in either of the rangeland types. The pastoralists also reported that abundance of grass species along the rangeland types have declined with time. Mainly this has clearly been observed during the past 30-40 years.

In terms of life forms, 13 species (48.15%) were perennial grasses and 14 species (51.85%) were annuals. The life forms scenario has also followed a similar trend as the current situation of the herbaceous layers of the rangelands. Out of the total of 27 species, 11 species (40.74%) were highly palatable, 10 species (37%) were of intermediately palatable and 6 species (22.26%) had low palatability. The ecological index for the regenerated grass species showed that 9 species (33.33%) were Decreasers, 11 species (40.74%) were Increasers IIa, 3 species (11.11%) were Increasers IIb and 4 species (14.82%) were Increasers IIc (Table 7.7).

7.3.5.2 The regenerated non- grass species

A total of 41 non-grass species, regenerated from the soil seed banks from the three rangeland types, were identified and classified (Table 7.8). These included 19 species (46.34%) of woody plants, 17 species (41.46%) of forbs, 4 species (9.76%) weeds and 1 (2.44%) legume plant species. Of the woody plants, 2 species were common in all three of the rangeland vegetation types and another 2 species were common in only two of the rangeland types, while 15 species were distributed in either of the rangeland types. Further 10 species (52.63%) of the woody plants were present in the field and 9 species (47.27%) were not observed in the field. No *Acacia* spp. germinating from the soil seed bank. This could probably be a matter of hardseededness not allowing the seed to germinate during the same year of development.

However, the pastoralists reported that the same species were common 20-40 years earlier and disappeared in time, but left seeds in the soil. In terms of preference by classes of livestock, the pastoralists reported that almost all species (100%) of the woody plants are preferred by camel, while goats preferred 13 species (68.42%) among the woody plants, sheep preferred 4 species (21.05%) and cattle preferred only 2 species (10.52%).

With regard to the species of forbs, 5 species (29.41%) were common in all three of the rangeland types, 3 species (17.65%) in two types of rangelands and 9 species (52.94%) were observed in either of the rangeland vegetation types. In terms of preference by livestock species, camel consumed almost all (100%) of the species, but with differences in preference among individuals. For the forbs, goats preferred 8 species (47.05%), cattle preferred 6 species (35.3%) and sheep preferred 5 species (29.41%). Concerning the weeds, 3 species (75%) were commonly observed in two types of rangelands and were also present in the field. Only 1 species was observed in one type of the rangelands. However, none of the weeds were preferred by any of the livestock species. The legume plant was eaten by all the livestock species.

7.3.6 Regeneration potential of the soil seed bank along degradation gradients for the different rangeland vegetation types

There was more or less a similarity in regeneration capacity of the seeds in the soils of the rangeland types, in terms of number of species and number of plants (density). In contrast there was a declining trend in plant regeneration capacity along the degradation gradients in each of the rangelands (Figures 7.8 and 7.9), but this was not a problem in the soils from the excellent and good condition sites, but showed a decline in moderate and poor condition sites of all rangeland types, mainly in terms of plant density and number of plants. For example, in the grassland, number of species and plant density

Table 7.8 Rangeland presence, commonness, and livestock preference of regenerated plant species in the different rangeland vegetation types

No	Botanical compositions (scientific names) by plant forms	Availability of species in soil seed banks			Ranked preference by classes of livestock	Presence on rangeland
		Asbuli grassland	Aydora open savanna	Hurso closed savanna		
A	**Woody plants**					
1	*Acalypha indica*	NA	NA	A	Camel, goat	NP
2	*Amaranthus dubius*	A	NA	A	Camel	P
3	*Anagalis spp.*	NA	NA	A	Camel, goat	NP
4	*Calylusea abyssinica*	A	NA	NA	Camel, cattle	NP
5	*Chemopodium procerum*	NA	NA	A	Sheep, goat	P
6	*Chorchorus triocularis*	A	A	A	Camel, goat	P
7	*Cleome gynandra*	NA	NA	A	Camel, goat	NP
8	*Crotolaria albicaulus*	A	NA	NA	Sheep, goat	P
9	*Crotolaria pycnostachya*	A	A	A	Camel	P
10	*Equistium ramosissimum*	NA	NA	A	Camel, goat	NP
11	*Erica arborea*	NA	A	NA	Camel, sheep	P
12	*Gelisonga parviflora*	A	NA	NA	Camel, goat	NP
13	*Lanthana camara*	NA	NA	A	Cattle, camel	P
14	*Lotus corniculatus*	A	NA	NA	Sheep, goat	P
15	*Nicotinia spp.*	A	NA	A	Goat, cattle	P
16	*Portulaca quadrifida*	NA	NA	A	Camel, goat	NP
17	*Ruellia patula*	A	NA	NA	Sheep, goat	NP
18	*Sonchus oleraceus*	A	NA	NA	Camel, sheep	P
19	*Sphaeranthus suaveolens*	A	NA	NA	Camel, goat	NP
B	**Forbs**					
1	*Becium flamentosum*	NA	A	A	Camel	P
2	*Chemopodim album*	NA	NA	A	Camel, cattle	P
3	*Convolvulus sagittatus*	A	A	A	Camel, sheep	P
4	*Conyza bonariensis*	A	A	A	Camel, goat, sheep	NP
5	*Euphorbia hirta*	A	A	A	Camel, sheep	P
6	*Fagonia brouguieria*	NA	A	NA	Camel, goat	NP
7	*Helotropium aegyptiacum*	NA	A	A	Camel, sheep, goat	P
8	*Indigifora amorphoides*	NA	A	NA	Camel, cattle, sheep	NP
9	*Kalancho petitiana*	NA	NA	A	Camel, goat	NP
10	*Leucas martincesis*	NA	NA	A	Sheep, goat	P
11	*Melilotus suavelones*	NA	A	NA	Camel, cattle, goat	NP
12	*Portulaca spp.*	A	NA	A	Sheep, cattle	P
13	*Raphanos raphonistrum*	A	NA	NA	Camel, goat	NP
14	*Tribulus terrestris*	A	A	A	Camel, cattle	P
15	*Valancheo petitiana*	NA	NA	A	Camel, goat	NP
16	*Verbesina enceloides*	A	A	A	Camel, cattle	NP
17	*Veronica anagalis*	A	NA	NA	Camel, goat	NP
C	**Weeds**					
1	*Leucas spp.*	A	NA	NA	Not preferred	P
2	*Ocium basilicum*	A	NA	A	Not preferred	NP
3	*Parthenium hysterophorus*	A	NA	A	Not preferred	P
4	*Xanthium abyssinicum*	A	A	NA	Not preferred	P
D	**Legumes**					
1	*Medicago spp.*	A	NA	NA	All livestock species	P

P=Present, NP= Not present, A=Available, NA=Not available decreased from rangeland in good to moderate condition site and then sharply declined from the moderate to the to poor condition sites. In comparison, the decline in plant species in the grassland area, for the different rangeland condition sites was significantly higher ($p<0.05$) than that of the open and closed savanna rangeland types.

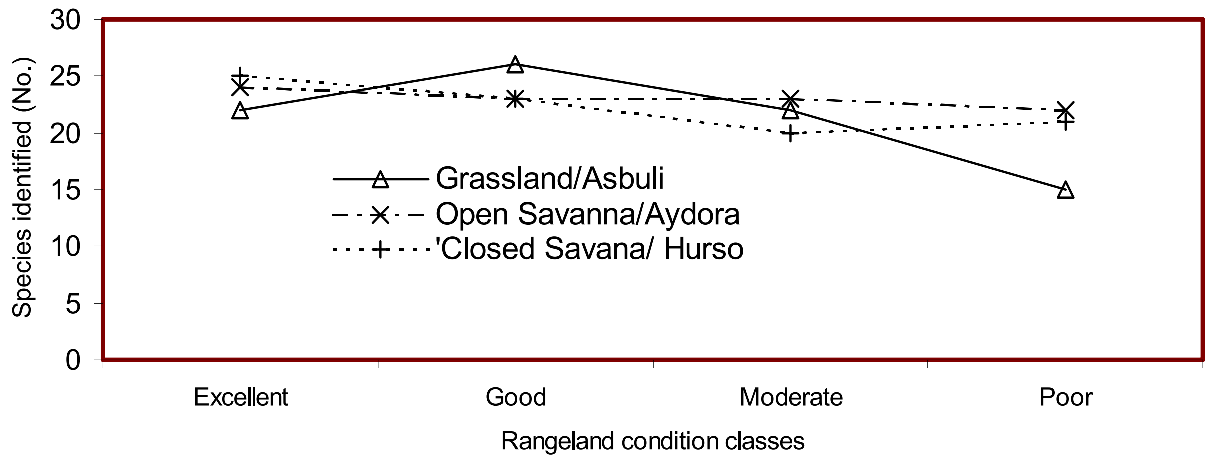

Figure 7.8 Plant population dynamics along a degradation gradient in three rangeland types

However, there was no significant difference ($p<0.05$) in regeneration capacity between the open and closed savanna rangeland types. Soil seed bank parameters were relatively lower in the poor rangeland condition, compared to the other three types of rangeland condition classes. The findings were also in agreement to reports by (Solomon *et al*., 2006b; Friedel *et al*., 2003; Snyman, 2004; Valone, 2004; Kinloch, 2005). Despite some observed differences, the degraded rangeland areas contain soil seed banks in terms of vegetation diversity for restoration and utilization under an adequately designed grazing management system.

Figure 7.9 Plant regeneration capacities of the soil seed banks from three types of rangelands in Shinile zone of the Somali region of eastern Ethiopia

The correlation analysis for the Asbuli grassland type revealed that plant density did not influence the number of species, but the vise versa. In the Aydora open savanna rangeland type, plant density had no effect on number of species while in the Hurso closed savanna plant density highly influenced ($p<0.05$) the number of species.

7.3.7 Soil characteristics in relation to degradation conditions sites for the three rangeland vegetation types

7.3.7.1 The soil physical characteristics of the three rangeland types

Comparatively, most physical soil parameters were higher in the benchmark and lower in the moderate and poor condition sites for all three rangeland types (Table 7.9). In terms of a rangeland type, there was no difference ($p>0.05$) for the content in silt clay, but a significant difference ($p<0.05$) for contents in clay and silt in the three rangeland types were observed. Based on the results for texture, except for the Hurso closed savanna, it seem possible to indicate that the soil type was dominated by mainly a silt clay in all rangeland vegetation types, which showed to decline with increases in soil degradation. Generally, the rangelands were mainly dominated by Vertisol soils, followed by Rigosol type of soils. Itanna (2005) classified soil types with >18% silt as susceptible to crust formation and such soils increase bareness of the ground and enhance runoff under heavy grazing by livestock and as a result reduce forage production. Moreover, such soil types have been observed to enhance gully formation in the rangelands favoring more loss of seeds from the soils. This necessitates appropriate soil and water management.

Table 7.9 Percent soil texture content for the three rangeland types along degradation gradients

Rangeland condition sites	**Asbuli grassland**			**Aydora open savanna**			**Hurso closed savanna**		
	Silty clay	**Clay**	**Silt**	**Silty clay**	**Clay**	**Silt**	**Silty clay**	**Clay**	**Silt**
Excellent condition	55.44	42.72	11.28	55.44	33.28	11.28	45.44	23.28	31.28
Good condition	56.00	26.72	17.28	52.00	36.72	11.28	55.44	19.28	25.28
Moderate condition	44.00	48.72	7.28	45.44	19.28	35.28	47.44	19.28	32.28
Poor condition	22.44	33.28	37.28	37.44	13.28	49.28	49.44	19.28	31.28
Average for the rangelands	44.47	37.86	18.28	47.58	25.64	30.28	49.45	20.28	30.03

An important aspect of the soil physical characteristics for the different rangeland vegetation types was the degree of soil compaction of the different rangeland conditions (Table 7.10). The highest ($p<0.05$) soil compaction was observed in all the cattle routes compared to the different rangeland condition sites. Among the rangeland condition sites, the soil compaction in the poor condition rangeland classes, were higher ($p<0.05$), followed by the moderate and the good condition sites. The moderate and good condition sites showed a higher compaction ($p<0.05$), compared to the benchmark, but there was no difference ($p>0.05$) between both sites. There was a significantly lower ($p<0.05$) soil compaction in the benchmarks as compared to the rangeland condition sites in each of the rangeland type. According to the results, the soil compaction was increased along the degradation gradients from the benchmark to the poor condition sites, while the degree of compaction in the poor rangeland condition site was comparable to the compaction in the cattle routes.

Table 7.10 Penetrometer readings (kg cm^{-2}) for measuring soil compaction of rangeland condition classes in comparison to cattle routes for the different vegetation types

No	Rangeland condition sites	Asbuli grassland (kg cm^{-2})	Aydora open savanna (kg cm^{-2})	Hurso closed savanna (kg cm^{-2})
1	**Cattle route**	4.8^{A}	5.0^{A}	4.5^{A}
2	**Excellent condition**	2.3^{B}	2.2^{B}	2.0^{B}
3	**Good condition**	3.2^{C}	3.0^{C}	2.7^{C}
4	**Moderate condition**	3.5^{C}	3.5^{C}	3.0^{C}
5	**Poor condition**	4.2^{D}	4.5^{D}	4.0^{D}

Means with similar letters are not significantly different at $P>0.05$

In general, the results imply that soils under degraded rangeland conditions get more compacted than none degraded rangelands resulting in less water infiltration. Compaction also reduces aeration in the soil and hampers plant respiration (Snyman and Van Rensburg, 1986). Generally, soil compaction increases run-off and creates high levels of soil erosion and makes soil seed bank regeneration very difficult or impossible unless the soil crust is broken using mechanical means such as ploughing or disking.

7.3.7.2 The soil chemical characteristics for the three rangeland vegetation types

The soil scientists at Alemaya University of Ethiopia broadly classified the soil colors of the different rangeland and related it to their chemical, physical and biological characteristics. Accordingly the soil colors for the Asbuli grassland, Aydora open savanna and Hurso closed savanna are black to dark brown, light black and red to yellow brown, respectively.

The Asbuli and Aydora soils have higher water content and nutrients with moderate organic matter due to decomposition of plant and animal residues, having a substantial influence on the vegetation production associated with the soils. The Hurso closed savanna rangeland soil color is also an indication of the presence of adequate iron oxides and hydroxides supplying iron needed for plant growth. The same color in the sub-soil was also taken as soil well supplied with oxygen for the growth of plants and microbes. Almost all the soils for all rangeland vegetation types were found to be of the sodic type, explained as high in Na^{++} cations, but with an acceptable range of salt accumulation (Table 7.10).

Table 7.10 Soil analysis (±SD) in relation to rangeland conditions in three rangeland types of the Shinile zone in the Somali region

Rangeland type and condition classes	H_2O (%)	EC (ms/cm)	Nutrients					PH
			Avail.K (ppm)	N (%)	OC (%)	OM (%)	Avail.P (ppm)	
1.Asbuli grassland								
Excellent	9.93±1.1	0.40±0.008	21.16±4.4	0.08±0.01	1.17±0.04	2.01±0.10	7.72±0.35	8.63±0.01
Good	12.81±1.1	0.60±0.015	23.13±4.0	0.11±0.01	1.5±0.06	2.58±0.21	14.26±0.63	8.33±0.02
Fair	11.15±1.08	0.50±0.37	20.01±2.95	0.10±0.00	1.34±0.07	2.32±0.18	12.03±0.54	8.45±0.02
Poor	5.11±1.1	0.37±0.03	16.5±3.85	0.06±0.01	0.67±0.01	1.15±0.10	6.62±0.32	8.61±0.01
2. Aydora open savanna								
Excellent	11.15±1.13	1.55±0.017	22.23±4.10	0.08±0.03	1.16±0.03	2.0±0.42	9.51±0.43	8,02±0.01
Good	9.74±1.06	0.27±0.01	24.14±3.80	0.08±0.02	1.02±0.2	1.75±0.14	5.70±0.26	8.58±0.04
Fair	7.8±1.12	0.28±0.06	15.90±3.60	0.08±0.03	1.17±0.04	2.01±0.10	2.63±0.12	9.02±0.01
Poor	5.43±0.25	0.91±0.013	20.03±3.15	0.06±0.01	0.96±0.02	1.65±0.10	2.49±0.12	8.72±0.01
3.Hurso closed savanna								
Excellent	10.85±1.05	2.26±0.030	8.87±1.60	0.10±0,02	1.24±0.05	2.14±0.10	1.75±0.10	8.05±0.01
Good	11.21±0.5	0.39±0.029	11.68±2.10	0.09±0,03	1.49±0.20	2.56±0.14	4.25±0.19	8.60±0.01
Fair	8.18±1.12	0.34±0.010	14.06±4.50	0.08±0.03	1.23±0.05	2.13±0.10	3.81±0.18	8.81±0.01
Poor	9.74±1.08	0.63±0.050	24.69±2.6	0.10±0.01	1.41±0.06	2.43±0.12	6.62±0.32	8.31±0.02

In all rangeland types the amount of available phosphorus (P) and potassium (K) was low, leading to a deficiency in these nutrients and inadequately support forage production with poor performance of the livestock species. To the contrary, the amounts of nitrogen (N_2), organic carbon (OC) and organic matter (OM) were moderate and sufficient for plant growth and phytomass production. This may be attributed to animal dung, urine and defoliation of plants during grazing in the different rangeland vegetation types.

7.4 CONCLUSIONS AND RECOMMENDATION

A total of 122 plant species were regenerated and identified from all three rangeland types. These included: 41 plant species (31.95%) in soils from the Asbuli grassland, 40 plant species (34.6%) from the soils from the Aydora open savanna and 41 plant species (33.4%) in soils from the Hurso closed savanna. There were similarities among the soil seed/seedling density and regeneration capacities, indicating that there exists substantial potential in seedlings in soils of the rangelands along degradation gradients.

This gives therefore, the opportunity to undertake rangeland restoration and rehabilitation activities. Solomon *et al.*, (2006b) also stated similar potentialities for different degradation levels in the Borana district rangelands in the Orimya region of Ethiopia. Moreover, the seeds in the soils proved the existence of plant diversity (grasses, forbs, woody plants). However, there still exist weed seeds in the soils, which is an indication for the need to control weeds during restoration of the denuded rangelands. Nevertheless, all soils showed to be poor in leguminous plants.

Soil compaction was affected by rangeland degradation and proportionately increased following an increase in degradation of the rangeland vegetation types. Higher compaction levels would therefore prevent germination and regeneration of the soil seed banks and restoration of denuded rangelands may be difficult without breaking the compacted soil.

Based on the results in general, the following recommendations could be practically applied by all stakeholders. These include the pastoral communities, the Somali Regional State, the federal Government of Ethiopia, the Somali Region Pastoral and Agro-Pastoral Research Institute and local and international non-governmental organizations.

(i) The soil seed banks along the degradation gradients in the grasslands, open and closed savanna rangeland types of the Somali region, have proved to contain adequate quantities of seed to enable rangeland restoration and rehabilitation programs using indigenous plant species. The importation of forage seeds for restoration of the degraded rangelands is not recommended.

(ii) Given the feed shortages in the Somali region in general and the Shinile zone in particular, restoration and rehabilitation of degraded rangeland in the region need to be institutionalized under relevant governmental and non-governmental organizations in the region, with short and long term plans, budget and manpower. Such interventions would alleviate the current feed shortages.

(iii) Rangeland restoration would be more effective if the compaction of the soil crust is broken up to a 300 mm depth, which was also found as effective during the experiment. Efforts without breaking the crust may result in little success due to the fact that the soil surfaces for most of the degraded rangelands showed various levels of soil compaction. Those rangelands with modest to severe degradation conditions need a breaking of the surface crust in order to facilitate aeration, water infiltration and germination of the soil seed banks. Discs, ploughs, oxen ploughs and manpower can be used as options for breaking the crust.

(iv) Soil and water conservation measures should be encouraged in order to avoid or minimize runoff and improve water infiltration for enhanced forage production. In doing this, community involvement would make an important contribution. Rangeland restoration interventions also have to provide adequate resting periods by excluding human and livestock interference. The main objective of this should also be to enable the production of enough seed reserves in the soil seed banks by encouraging seed dispersion and avoiding grazing before flowering and after seed dispersion.

(v) Further research is needed to launch awareness creation in the pastoral communities. Such research and development activities however, need an adequate land area (3 000-5 000 ha) for undertaking natural regeneration experiments and demonstration programs. Determination of botanical composition, productivity per hectare of land and by every regenerated plant species, as well as grazing capacities for different livestock species need to receive adequate attention by the regional rangeland and livestock research system.

(vi) Due to the fact that rangelands in the Somali region are extensive and seriously degraded, restoration of such land areas is unmanageable by a single institute in terms of finances, manpower and the like. Thus, restoration and rehabilitation of the currently denuded rangelands need integrated and collaborative action by all concerned stakeholders. Such efforts need to be organized and mobilized by a suitable organization.

(vii) Effective aftercare program must be implemented for restoration and rehabilitation of rangelands. Therefore the development of objective rangeland condition techniques is very important in future research. The quantification of long-term grazing capacity in relation to rangeland condition is also an aspect that must be addressed in future research.

CHAPTER 8

DROUGHT SIMULATED LIVESTOCK FEEDING TRIAL ON INDIGINEOUS LIVESTOCK BREEDS IN THE SOMALI REGION OF EASTERN ETHIOPIA

8.1 INTRODUCTION

Drought, both climatological and human induced, is a common phenomenon in the pastoral areas of Ethiopia. The effects of these droughts are severe and are a major reason for the expansion of poverty and destitution, especially where the pastoral production system is unable to make provision for these events. These areas are also faced with future challenges, because there is no certainty whether these droughts, especially human induced droughts, can be effectively dealt with in the future (Oba, 1998; Gemedo-Dalle *et al*., 2006).

The major constraints of the pastoral production system in Ethiopia had been reviewed in numerous studies (Coppock, 1994; Alemayehu, 1998; Oba, 1998; Biruk and Taffese, 2000; Zinash *et al.*, 2000; EARO, 2001; Getachew, 2001; Yacob, 2001). Unfortunately, most of these studies focused on the result of the drought in terms of animal mortalities without due consideration of the actual processes that took place during a drought. Despite the problems normally associated with droughts, not enough has been done to prevent livestock mortalities in the pastoral areas of Ethiopia. Some efforts have been made between 1970 and 1990 to understand the dynamics of the rangelands in the southern, south-eastern and north-eastern parts of the country. This was aimed at buffering the effect of droughts through the development of livestock marketing strategies, veterinary services and water provision (Oba, 1998; Ayana and Baars, 2000; Solomon, 1993; Taffese, 2001). Livestock conditioning initiatives were also established to help the pastoralists earn fair prices for their animals, which they might have lost due to drought. However, this was not supported by an adequate early warning system, which is essential in providing relevant information, for making objective decision.

The few rangeland improvement projects in eastern Ethiopia were hampered by political decisions, rather than decisions based on science and without due consideration for the specific needs of the pastoralists (Taffese, 2001; Gemedo-Dalle *et al.*, 2006). Subsequently, in ignorance of the current rangeland ecological theories and practices, no effort was made to revise and improve the principles, objectives and implementation of the existing rangeland development practices. This also resulted in a lost opportunity to undertake studies on livestock performances during periods of drought and also on post drought recovery programs. As a result, studies on the impact of drought on livestock performance under controlled, simulated drought conditions appear more practical in obtaining relevant information. This then was the motivation for this study, which was undertaken with the following objectives: (i) to evaluate the spatial and temporal effect of a simulated drought over a period of time on livestock performance and mortality, and (ii) to develop practical drought mitigation mechanisms for the pastoral areas.

8.2 STUDY AREA

The study was conducted in the Jerer valley, about 70 km from Jigjiga (capital city of the Somali region) and 75 km from Dire Dawa in eastern Ethiopia. The area is located at an altitude of 1 000 m.a.s.l with a mean annual rainfall of 400-500 mm and temperatures ranging between 27^0C and 37^0C. It was done at the main Camel Experimental Station of the Department of Animal Sciences of the Alemaya University. The experiment was run almost for a period of one year from 10 October 2004 up to 30 November 2005.

8.3 MATERIALS AND METHODS

8.3.1 Purchase of experimental animals and fodder

The main criteria used during the purchase of suitable experimental animals were breed, age, sex and physical appearance/body conformation. Jigjiga cattle, Black head Somali sheep and goats of Somali breeds with good body confirmation were selected. Since the pastoralists normally do not sell female animals, except for special occasions, all the experimental animals were males. A total of 24 animals were purchased for the feeding trial, which included eight cattle, eight sheep and eight goat. The experimental animals were purchased from the Jigjiga town livestock market and transported to the experimental station.

Dental counting was used to determine the age of each animal, which was done by a veterinarian. The average age of the experimental animals was four years for the cattle and two years for the sheep and goats. These are considered the ideal breeding ages under pastoral practices. A heart girth meter was used to determine the initial live body weight of the animals after 24 hours of starvation, in order to excrete the digesta in the rumen. The average (±SD) initial live weight was 195 (±15.30) kg for the cattle, 31 (±1.75) kg for the sheep and 24.1 (±2.22) kg for the goats. The pastoralists consider these weights as normal for breeding animals of the various species.

Adequate hay for the experiment was not locally available. Subsequently, baled *Panicum coloratum* hay was purchased from a commercial site called Sululta, located about 25 km north of Addis Ababa and transported over a distance of 580 km to the experimental site. This grass species is common in the grasslands of the Somali region.

8.3.2 Holding facilities

A cattle shade that covered an area of 80 m^2 with a 16 m^2 working corridor was constructed. For the sheep and goats, 16 existing pens was repaired, one for each of the experimental animals. An open store was also available for storing the baled hay. The experimental animals were fed in the holding pens with free access to water.

8.3.3 Veterinary examination

At the experimental station each of the experimental animals were tested and treated for endo and ecto parasites, as well as contagious diseases. During the first week, the cattle and small ruminants were dosed(using a drenching gun) with Albandazole and sprayed with Vetazinon for endo parasites. At the same time the bulls were vaccinated against anthrax and blackleg, while the small ruminants were vaccinated against anthrax and pasteurolosis. During the second week, all animals were drenched with Albandazole for endo parasites and vaccinated with Trypadonium-Samarin against trypanosomiasis infection. During the third week the cattle were vaccinated against pasteurolosis and all animals received an Oxytetracycline injection against skin diseases.

8.3.4 Chemical analysis of fodder

The hay was analyzed for its nutrient content by taking a composite sample of 500 g, which was oven dried for 48 hours at 72^{O}C to determine the dry matter (DM) content. A sample of 300 g was grounded in a Whilley mill with a 2 mm sieve. Crude protein (CP) was determined from the N content, which was determined with the Kjeldahl technique. Organic matter (OM), acid detergent fiber (ADF) and neutral detergent fiber (NDF) ash were analyzed using methods developed by Van Soest (1967) and metabolizable energy (ME kg^{-1} DM) was calculated. Calcium (Ca) and Phosphorus (P) were analyzed using an Atomic absorption spectrometer described by AOAC (1990).

8.3.5 Experimental treatments

All the experimental animals were allowed an adaptation period of four weeks with *ad-lib.* feeding and watering to: (i) determine the optimum intake (kg DM feed 100^{-1} kg live weight) for each animal, (ii) improve their body condition by compensating for possible lost body weight before the experimentation started, and (iii) allow the animals to adapt to the new environment.

Each group of treatments was replicated eight times with each of the eight animals of the three species considered as a replicate (Drane, 1989). The experiments were run for a period of 20 weeks. It was divided into four phases consisting of: (i) phase I with a 50% feed reduction, (ii) phase II with a 75% feed reduction, (iii) phase III with a 50% feed increment and (iv) phase IV with a 100% feed increment. The reductions or increment of the feed refers to the amount of a daily ration based on 4% of live body weight of each animal.

The duration of each phase was five weeks, identified as week 0 to week 4, respectively. During week 0 the initial body weight of the experimental animals were recorded after the animals were starved for 24 hours in order to empty the animal's digestive system. Thereafter, each animal was weighed at 9:00 am at the end of every week (weeks 1-4) (Coates and Penning, 2000). A cattle scale with a capacity of 1 500 kg was used for the cattle and for the sheep and goats a smaller scale with a capacity of 50 kg.

Based on the preliminary observation at *ad libitum* feeding level the daily ration of each animal was determined to be 4% of the animal's body weight or 40 g dry matter (DM) kg^{-1} live body weight. Water was given freely throughout the experiment. In order for simulating the feed shortages created during drought periods the feed level of 40 g DM kg^{-1} live body weight day^{-1} $animal^{-1}$ was reduced by 50% for all animals during Phase I and then by 75% during Phase II. The response of the experimental animals to this gradual nutritional stress was measured in terms of body weight losses, changes in behavior, physical condition and mortalities.

The animals that survived the drought simulation experiment were used in the post-drought experiment, with the intention to determine the rate of compensatory growth by each of the livestock species during a post-drought period, where feed is not a limiting factor. Accordingly, the daily DM feed (ration) for each animal was increased by 50% during Phase III and by 100% during Phase IV, based on the pre-determined requirement of 40 g DM kg^{-1} live body weight per animal.

8.3.6 Data collection and analysis

Animal performance data were analyzed with simple linear regression analyses ($y = a+bx$), where y = predicted body weight for each animal, a = constant (intercept), b (slope) = rate of change in body weight (kg) and x = % reduction or increment in feed levels. The changes in live weight (dependent variable) against changes in feed levels (independent variable) were described using coefficients of determination (r^2). The significance of differences of weight loss or gain in kg (*b*) values against the initial live body weight was also tested within *p* values. The slope (*b*) (that is loss or gain in live weight) was calculated as: vertical increment (y_2-y_1)/horizontal increment (x_2-x_1). The general trend in animal performance, losses or gains in live body weight for each animal was calculated as the difference (mean ±SD) between initial and final body weights and expressed in percentage, while arithmetic means were used when necessary.

8.4 RESULTS AND DISCUSSION

8.4.1 Feed nutrient analysis

The *Panicum coloratum* hay fed to the experimental animals consisted of 91.5% dry matter, with a nutrient content of 6.5% ash, 5.4% crude protein, 61.6% neutral detergent fiber, 6.61% acid detergent fiber, 0.39% Ca and 0.10% P. The nutrient contents in terms of g per kg dry matter feed (DMF) consisted of: 59 g crude protein, 71 g ash, 674 neutral detergent fiber, 72.3 acid detergent fiber, 4.3 g calcium and 1.1g phosphorus with a metabolizable energy (ME) content of 9.8 Mega Joule (MJ) per kg dry matter (kg^{-1}DM).

The results showed that the grass hay was highly palatable with a good nutrient content, but low in crude protein and phosphorus, implying the need for supplementary feeding in order to meet the daily nutrient requirements of the livestock species. Accordingly, there is a clear need to assess the nutrient contents of the grazing/browsing material of the rangeland in the Somali region to determine the quantity and quality of nutrients in the forage on offer.

The grazing/browsing capacities of the specific rangeland types, according to their perspective conditions (that is excellent, good, moderate and poor), needs to be assessed and the need for supplementation evaluated for each of the livestock species for optimal performance. In this study, the nutrient requirements of cattle, goats and sheep breeds of the Somali Regional State are expressed in terms of their daily DM feed requirements, in relation to the nutrient content of the fodder. No supplementation was given in an attempt to simulate the normal grazing on the rangelands under pastoral grazing systems.

8.4 2 Cattle experiment

8.4.2.1 Effect of feed reduction on cattle live weight performance

The live weight performance results are presented in Table 8.1 and Figure 8.1. Two of the cattle or about 25% of the total number of cattle (n=8) have died within a period of eight weeks (2 months) after the feeding trial commenced. The first animal died at end of phase I (4 weeks), after losing 27.4% of its body weight. The regression analysis showed that 97.5% (r^2=0.975) of the variability in body weight (dependent variable) was explained by the feed reduction at a 50% level (independent variable). The rate of decline rate in body weight of -6.9 kg per week (Figure 8.1a) was highly significant ($p<0.01$) for the first animal. The second animal died after losing 30% of its body weight (15% in phase I and 15% in phase II), where 96.9% (r^2= 0.969) and 98.2% (r^2= 0.982) of the body weight loss was explained by changes in feed reductions at 50% and 75% levels, with a highly significant ($p<0.01$) weekly decline in body weight (Figure 8.1b) at the rate of -7.5 kg and -6.1 kg on weekly basis, respectively.

Table 8.1 Effect of reductions in DM feed levels by 50% and 75% on body weight performance of Somali cattle breeds

Cattle No	50% feed reduction			r	y= a+bx	75% feed reduction			r	y= a+bx
	IBW (kg)	FBW	(%)			IBW	FBW	(%)		
1	179	150	-27.4	0.987	184.3-6.9x**	Dead	-	-	-	-
2	200	170	-15.0	0.984	207.5-7.5x**	170	145	-15.0	0.990	177.1-6.1x**
3	191	157	-18	0.962	194-8.6x**	157	140	-11.0	0.993	156.4-4.2x**
4	203	182	-10	0.970	201.4-4.8x**	182	158	-13.2	0.995	187.5-6.1x**
5	171	151	-12	0.937	173.4-5x**	151	135	-11.0	0.993	155.4-4.2x**
6	182	156	-14.3	0.999	181.8-6.4x**	156	137	-12.2	0.995	160.4-4.8x**
7	209	183	-12.4	0.999	209.2-6.5x**	183	158	-14.0	0.998	188.7-6.1x**
8	220	190	-14.0	0.998	219.6-7.5x**	190	163	-14.2	0.999	189.8-6.7x**

IBW represents initial live body weight and FBW represents final live body weight, where y = change in body weight, a= constant intercept, b= rate of change in body weight dependent variable, x= % change in feed level (independent variable) and ** = Highly significant at $p<0.01$

In relation to the body weight loss, both animals showed a more pronounced emaciation having visible rib bones, immersed paraphosa and a drop in water intake which the pastoralists identified them as pre-drought symptoms. Dizziness was prevalent in the behaviour of the animals with weak response towards lacking stimuli to any attempted aggravation and were unable to manage standing and walking. The skin was dry and rough with standing hairs and fading colors of the eye cornea, which are also common during feed shortages at times of drought period.

In the field, cattle under adequate feed conditions were observed to spend an average of 80% of their time in standing (including mobility during grazing) and 20% in a resting position in eight hours period, respectively. However, the first animal that died spent 90% of the time in resting and 10% in standing. The second animal, which also died, was resting for 80% of the time and standing for 20% of its time. Hence, this may indicate that the animals were exhausted due to depletion in energy to make adequate movement. Such animals, showing more stress, could not be trekked over long distances for feeding and watering.

Cattle number 3 lost a total of 29% of its body weight (18% in phase 1 and 11% in phase II). According to the result, r^2= 0.926 and r^{-2}=0.988 of the variability in body weight was explained by the reduction in feed levels of 50% and 75%, respectively. The loss in body weight (Figure 8.1c) at the rate of -8.6 and -4.2 kg per week (7 days) for each feed level was highly significant ($p<0.01$) respectively. Cattle number 4 reduced 23.1% of its body weight (10% reduction in phase I and 13.2% in phase II), where 94.2% (r^2= 0.942 and 0.991) of the losses in body weight were highly significant ($p<0.01$) namely (Figure 8.1.d) -4.8 and -6.1 kg due to 50% and 75% reduction in feed levels, respectively. The animals spent 60% of their daily time in resting and 40% in standing, with pronounced emaciation, visible rib bones, drier skin, immersed paraphosa and rough and standing hairs. Pastoralists compared the symptoms as similar to symptoms during a few months of a drought period. Despite the loss in body weight however, the animals were active and respond to induced stimuli and seem to manage walking over distant areas for food and water. This may imply the existence of differences in genetic merit among the Somali cattle breed, for resistance to feed shortages during a drought period.

Cattle number 5 lost 23% of its body weight (12% in phase I and 11% in phase II), influenced by feed reductions at levels of 50% (r^2= 0.878) and 75% (r^2= 0.987) with a highly significant ($p<0.01$) rate in weekly body weight loss (Fig. 8.1e) of -5.0 and -4.2 kg at each level, respectively. Cattle number 6 lost 26.5% of its body weight (14.3% in phase I and 12.2% in phase II) whereby r^2=0.999 and r^2=0.996 at 50% and 75% feed reductions, with highly significant ($p<0.01$) declines in weekly live weight loss of -6.4 and -4.8 kg (Fig. 8.1f) respectively. Both animals also spent about 70% of their time in resting and 30% in standing. Despite the obvious emaciation, they had a fair physical condition that could enable them to trek over a long distance for food and water. This was another example of the genetic variability among the Somali cattle breed population for resisting feed shortages and for ability to respond differently under similar environmental conditions.

Cattle number 7 lost 26.4% of its body weight (12.4% in phase I and 14% in phase II), as a result of reductions in feed levels at 50% (r^2= 0.999) and 75% (r^2= 0.996), with a highly significant ($p<0.01$) rate of weight change (Figure 8.1g) of -6.5 and -6.1 kg per week for each level, respectively. Cattle number 8, lost a total of 28.2% (14% in phase I and 14.2% in phase II), due to feed reduction of 50% (r^2=0.998) and 75% (r^2= 0.999), where b = -7.5 and b= -6.7 (Figure 8.1h), the weight loss on a weekly basis showed highly significant differences ($p<0.01$) respectively. In terms of behavior both animals spent about 50% of their time in lying and 50% of the time in standing which was different from animals grazing in the field and both animals did not also showed a pronounced emaciation.

In relation to this, it seems possible to suggest that there exists a difference in genotypic merit for resistance to feed shortages, among the Somali cattle breed, that may enable the pastoralists and researchers to apply selection of the cattle that have the ability to perform under prolonged feed shortages for post drought breeding schemes. The critical issue

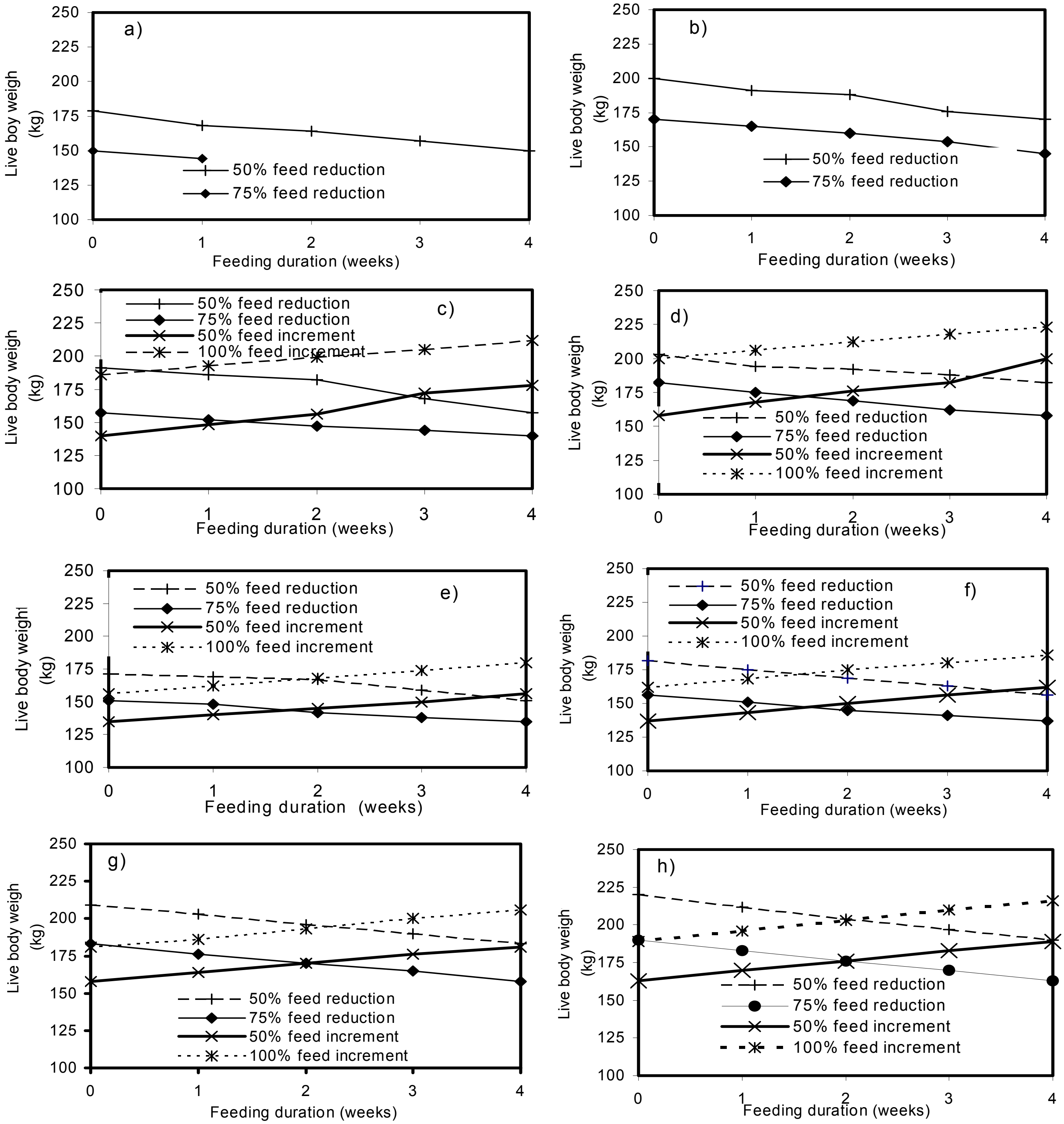

Figure 8.1 Relations between live body weight (kg) and feeding durations (weeks) at different feeding levels by Somali cattle breeds

would be how to maintain them with a minimum of 50% of the daily feed amount of a maintenance level and if possible with limited supplementary feeding.

8.4.2.2 Effect of increases in feed levels on cattle live weight performance

Those six cattle that survived the drought simulation feeding trial discussed in 8.3.1.2 were subjected to a feeding regime of 50% (phase III) and 100% (phase IV) increment of their daily DM feed requirements (Table 8.2 and Figure 8.1).

Table 8.2 Effect of increment in DM feed levels of 50% and 100% on body weight performance of Somali cattle breeds

	50% feed increment			**r**	**y= a+bx**	**100% feed increment**			**r**	**Y= a+bx**
Cattle No	**IBW (kg)**	**FBW (kg)**	**(%)**			**IBW**	**FBW**	**(%)**		
1	Dead	-	-	-	-	-	-	-	-	-
2	Dead	-	-	-	-	-	-	-	-	-
3	140	178	+27.1	0.989	138.8+10x**	186	212	+14.0	0.999	**186.2+6.4****
4	158	200	+27.0	0.981	147.4+9.8x**	200	223	+11.5	0.999	**194.4+5.8x****
5	135	156	+16.0	0.999	129.6+5.2x**	156	180	+15.4	1.0	**150+6x****
6	137	162	+18.2	0.999	130.7+6.3x**	162	186	+15.0	0.999	**156.2+6x****
7	158	186	+18.0	0.998	152.8+5.63x**	186	213	+14.5	0.999	**179.5+6.7****
8	163	189	+16.0	0.999	163.2+6.5**	189	216	+14.3	0.999	**189.2+6.8****

IBW represents initial live body weight and FBW represents final live body weight, where y= change in body weight, a= constant intercept, b= rate of change in body weight dependent variable, x= % change in feed level (independent variable) and ** = highly significant at p<0.01

Accordingly, cattle number 3 gained 41.1% of its body weight (with 27.1% in phase III and 14% in phase IV), where the coefficient of determination r^2=0. 98 and r^2= 0.999, for feed level by 50 and 100%, with a highly significant ($p<0.01$) in weekly live weight gain (Figure 8.1c) of 10 kg and 6.4 kg, respectively. Cattle number 4 gained a total of 38.5% of its initial body weight (27.1% in phase III and 11.5% in phase IV) with r^2=963 and r^2=0.999 for the increase in feed level by 50 and 100%, making a highly significant ($p<0.01$) weekly body weight gain of 9.8 and 5.8 kg (Figure 8.1d), respectively.

Cattle number 5 gained 31.4% of its initial live body weight (16% in phase III and 15.4% in phase IV), where r^2=0.999 and r^2=1.00 for 50 and 100% feed increment, having a highly significant ($p<0.01$) weekly body weight gain of 5.2 and 6.0 kg (Figure 8.1e), respectively. Cattle number 6 had a total gain of 33.2% of its initial weight (16% in phase III and 15.4% in phase IV), explained by r^2=0.999 and r^2=0.998, with a highly significant ($p<0.01$) weekly body weight gain of 6.3 and 6.0 kg (Figure 8.1f) for the feed increments at a level of 50 and 100%, respectively.

Cattle number 7 also gained 32.5% of its initial live body weight (18% in phase III and 14.5% in phase IV) with r^2= 0.992 and r^2=0.999 due to feed increase at 50 and 100% levels , with a highly significant ($p<0.01$) weekly body weight gain of 5.63 and 6.7 kg (Figure 8.1g), respectively. Cattle 8 gained 33% in body weight (16% in phase I and 14.3% in phase II), due to feed increment at 50% level with r^2=0.992 and at 100% level with r^2=0.999, where the weekly body weight gain (Figure 8.1h) of 6.5 and 6.8 kg was highly significant ($p<0.01$), respectively. In general the results were in agreement to the theory of compensatory growth after events of droughts.

8.4 3 Goat experiment

8.4.3.1 Effect of feed reduction on goat live weight performance

The Somali goat breeds responded to the different levels of feed reductions at 50 and 75% levels (Table 8.3 and Figure 8.2). An important observation was that those goats that lost above 60% of their body weights were more prone to death. Goat 4 lost a total of 64.3% of its initial body weight, attributed by 33.0% loss due to 50% feed reduction and 33.3% loss due to 75% reduction in feed level (Figure 8.2d). The animal died at the end of phase II, after losing about 64% of its initial live body weight and was observed to spend about 90% of its time in resting. Goat 6 also died at the end of phase II after losing 69.3% of its live body weight, with 30% due to feed reduction at 50% and a loss of 39.3% in body weight due to the 75% feed level reduction (Figure 8.2f). In general, 25% of the experimental goats died due to feed shortages, while 75% of them survived the shortages with different levels of body weight loss and emaciation.

Accordingly, goat number 1 lost about 33.6% of its body weight with 15.4% and 18.2% losses during reductions in feed amount by 50 and 75% explained by r^2 =1.0, with a highly significant (p<0.01) weekly body weight loss of 1 by -1.0 kg (Figure 8.2a), respectively. In a similar trend, goat number 2 lost about 30% of its initial body weight attributed by 20 and 10% loss, with r^2 =0.964 and r^2 =0.1.0 at feed reduction levels of 50 and 75%, with a highly significant (p<0.01) weekly body weight loss of -1.2 and -1.0 kg (Figure 8.2b), respectively.

Table 8.3 Effects of reductions in DM feed levels by 50% and 75% on body weight performance of Somali goat breeds

Goat No	50% feed reduction			r	y= a+bx	75% feed reduction			r	y= a+bx
	IBW (kg)	FBW	(%)			IBW	FBW	(%)		
1	26	22	-15.4	1.0	26-1x**	22	18	-18.2	1.0	22-1x**
2	24.6	20	-20.0	0.982	24.6-1.2x**	20	16	-20.0	1.0	20-1x**
3	25.8	20	-22.5	0.986	25.8-1.4x**	20	15	-25.0	0.986	20.2-1.2x**
4	25.4	18	-31.0	0.980	25.4-1.5x**	18	12	-33.3	1.0	18-1.5x**
5	22	16.5	-25.0	0.999	21.7-1.3x**	16.5	12	-27.3	0.988	16.3-1.15x**
6	20	14	-30.0	0.996	19.8-1.4x**	14	8.5	-39.3	0.970	13.5-1.4x**
7	23	19	-17.4	1.0	23-1x**	19	13	-32.0	0.994	19.3-1.55**x
8	26	21	-19.2	0.981	25.6-1.2x**	21	14	-33.3	0.997	20.9-1.7**x

IBW represents initial live body weight and FBW represents final live body weight, where y = change in body weight, a= constant intercept, b= rate of change in body weight dependent variable, x= % change in feed level (independent variable) and ** = highly significant at p<0.01

Both animals spent about 70% of their time in standing and 30% in resting, while the deterioration in physical condition was not pronounced. Goats in this condition could be relied on to trek over longer distances for food and water. Accordingly, both goats were graded as the most tolerant types within the Somali goat breeds.

Goat 3 lost 45.5% of its total body weight (22.5% in phase I and 25% in phase II), with equal effects of r^2= 0.973, with highly significant (p<0.01) weekly weight loss of -1.2 and -1.0 kg (Figure 8.2c), at 50 and 75% feed reduction levels, respectively. Goat number 8 lost a total of 40.1% of its body weight (19.2% in phase I and 20.1% in phase II) with r^2=0.963 r^2=0.995 by feed reduction at a 50 and a 75% level, showing a highly significant ($p<0.01$) weekly weight loss of -1.2 and -1.7 kg (Figure 8.2h), respectively.

Despite loss in body weight, the goats spent about 60% of their time in standing and 40% in resting, with no pronounced deterioration in physical condition except that slight signs of dizziness were observed. This indicated that animals in this condition could manage walking longer distances in search of feed resources. Such merits of the animals make them more preferable for genetic selection for feed shortage tolerance during drought periods.

Goat 5 lost a total of 52.3% of its body weight (25% in phase I and 27.3% in phase II) due to reductions in feed at a 50% and a 75% level, with equal values of r^2=0.997 and with a high ($p<0.01$) weekly body weight loss of -1.3 and -1.15 kg (Figure 8.2e), respectively. Goat number 7 lost about 49.4% of its body weight due to the cumulative losses of 17.4 and 32% in phase I and II, which was reflected by r^2=1.0 and r^2=0.985 due to reductions in feed levels of and 75%, with high ($p<0.01$) weekly body weight loss of -1.0 and -1.55 kg (Figure 8.2f), respectively.

Both animals equally spent about 40% of their time in standing and 60% in resting and showed a poor body condition, pronounced emaciation and dizziness. Accordingly, goats in this condition most likely may not manage to travel long distances and goats with similar symptoms need to be sold at an earlier stage of the drought or should be slaughtered for dried meat production.

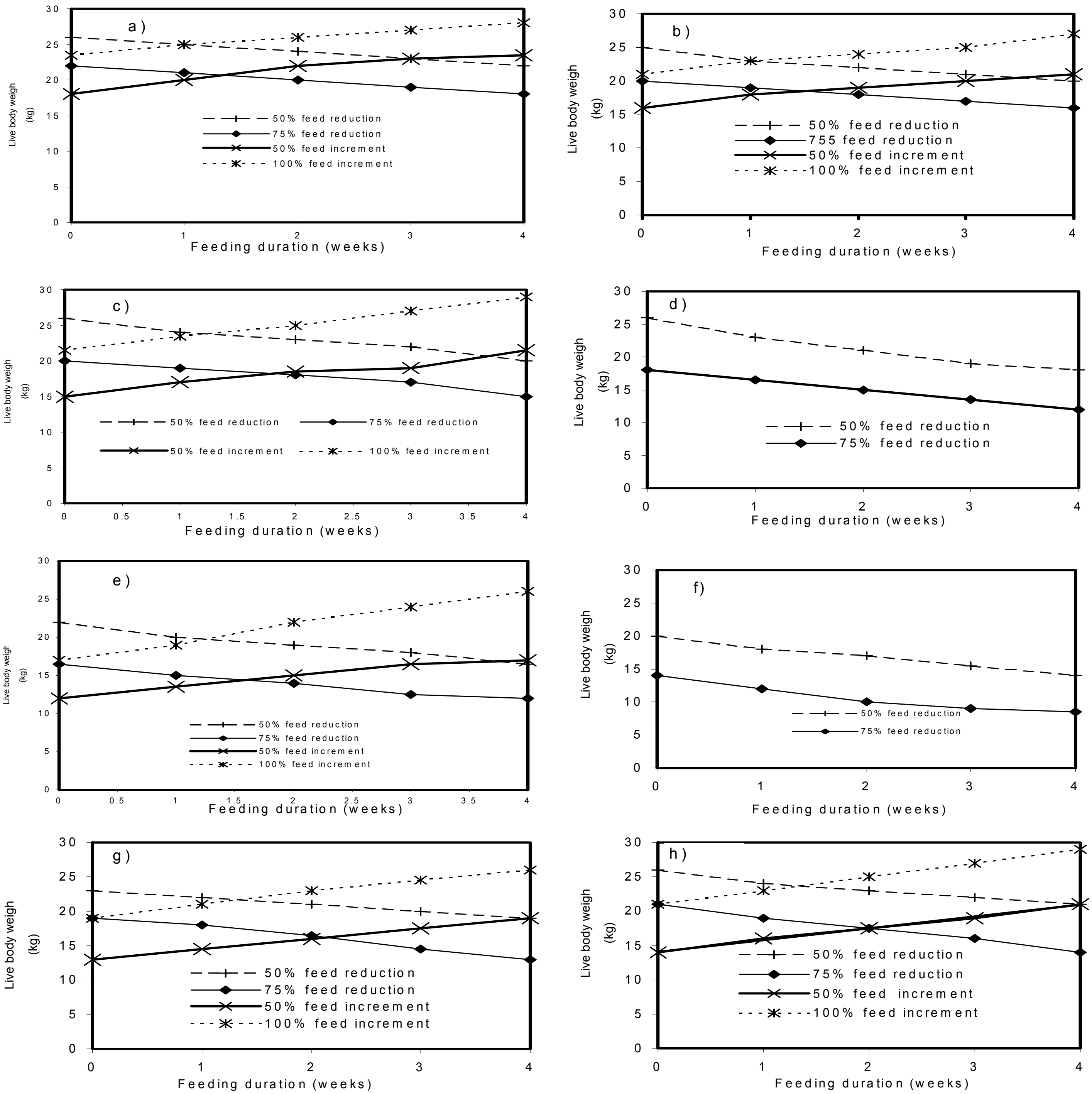

Figure 8.2 Relations between live body weight (kg) and feeding durations (weeks) at different feeding levels by Somali goat breeds

8.4.3.2 Effect of increases in feed levels on goat body weight performance

Only six goats, which survived the drought simulation trial, were used in the experiment (Table 8.4 and Figure 8.2). Accordingly, goat 1 gained 50.1% of its initial body weight attributed by 31.1% and 19.1% gains at a 50% and a 100% feed level increase, with r^2=0.942 and r^2=0.992, respectively. The effect showed a highly significant ($p<0.01$) weekly body weight gain of 1.4 and 1.1 kg (Figure 8.2a), respectively. Goat 2 gained 60.2% of its initial body weight (31.2% in phase III and 29% in phase IV), whose effect was explained by r^2=0.973 and r^2=0.98, with a high ($p<0.01$) weekly gain of 1.2 and 1.4 kg (Figure 8.2b), respectively.

Table 8.4 Effect of increment in DM feed levels by 50 and 100% on body weight performance of Somali goat breeds

Cattle No	50% feed increment			r	y= a+b	100% feed increment			r	y= a+bx
	IBW (kg)	FBW (kg)	(%)			IBW (kg)	FBW (kg)	(%)		
1	18	23.5	+31.0	0.942	18.5+1.4x**	23.5	28	+19.1	0.992	23.7+1.1x**
2	16	21	+31.2	0.973	16.4+1.2x**	21	27	+29.0	0.98	21.2+1.4x**
3	15	21.5	+43.3	0.966	15.2+1.5x**	21.5	29	+35.0	0.998	21.5+1.8x**
4	Dead	-	-	-	-	-	-	-	-	-
5	12	17	+42.0	0.997	12.2+1.3x**	17	26	+53.0	0.994	17+2.3**
6	Dead	-	-	-	-	-	-	-		-
7	13	19	+46.1	1.0	13+1.5x**	19	26	+37.0	0.992	19.2+1.75**
8	14	21	+50.0	0.995	14.1+1.7x**	21	29	+30.1	1.0	21+2**

IBW represents initial live body weight and FBW represents final live body weight, y= Change in body weight, a= constant intercept, b= rate of change in body weight dependent variable, x= % change in feed level (independent variable) and ** = highly significant at $p<0.01$

Goat number 3 increased by 78.8% of its body weight, as a result of 43.3% gain at a 50% and 35.5% gain at a 100% feed increase, with the impact of r^2 =0.96 and r^2 =0.998, resulting in a highly significant ($p<0.01$) weekly weight gain of 1.5 and 1.85 kg (Figure 8.2c) at a 50 and a 100% feed increment, respectively. Goat number 8 achieved a total of 80.1% of lost body weight attributed by 50.1% in phase III and 30.1% gain in phase IV. The effect was explained by the values of r^2= 0.995 and r^2= 1.0, where weekly gain of 1.7 and 2.0 kg (Figure 8.2h) was high significant ($p<0.01$), respectively.

Goat number 7 made the highest body weight gain of 83.1% as a result of the cumulative gains of 46.1 and 37% reflected by r^2 =1.0 and r^2 =0.992 due to the increase in feed at 50 and 100% levels, with a highly significant ($p<0.01$) weekly gain of 1.5 and 1.75 kg (Figure 9.2g), respectively. Goat number 5 also made the highest of 96% of initial live body weight, attributed by 42% in phase III and 53% in phase IV, with a 50% and a 100% feed level increment, with the effect explained by r^2 = 99.7 and r^2 =0.994, with a highly significant ($p<0.01$) weekly gain of 1.3 and 2.3 kg (Figure 8.2e), respectively.

During the study, it was evident that variability in genetic merits existed in terms of the potential for early compensatory growth ranging from faster to slower rates among the Somali goat breed population under similar environmental conditions. The difference in compensatory growth for lost body weight during the period of feed reductions was 50.1, 60, 78.8, 80.1, 83.1 and 96% by goat numbers 1, 2, 3, 8, 7 and 5 during the period of feed increments, respectively.

8.4 4 Sheep experiment

8.4.4.1 Effect of feed reduction on sheep body weight performance

The feeding trial was conducted on the Black head Somali sheep breed known for its fatty rump and tail (Table 8.5 and Figure 8.3). Sheep numbers 3 and 6 showed more or less a similar trend in body weight loss. Sheep number 3 lost 34.4% of its initial weight with 19.4 and 15% at a 50 and 75% feed level reduction, explained by r^2= 0.964 and r^2 =1.0, which was a highly significant ($p<0.01$) weekly body weight loss of -1.5 and -1.0 kg, (Figure 8.3c), respectively. Sheep number 6, lost as much as 32.5% in body weight (20% in phase I and 12.5% in phase II), explained by r^2= 1.0 and r^2= 0.96, showing a highly significant ($p<0.01$) weekly body weight loss of -1.0 and -0.75 kg (Figure 8.3f) at a 50 and a 75% reduction in feed levels, respectively. Both animals spent about 35% of the time in resting and 65% of the time in standing.

Table 8.5 Effect of reductions in DM feed levels by 50% and 75% on body weight performance of Black Head Somali sheep breed.

Sheep No	50% feed reduction			r	y=a+bx	75% feed reduction			r	y=a+bx
	IBW (kg)	FBW	(%)			IBW	FBW	(%)		
1	30	26	-13.3	1.0	30-1x**	26	22.5	-13.5	0.999	25.9-0.9x**
2	32	28	-12.5	1.0	32-1x**	28	24	-14.3	1.0	28-1x**
3	33.5	27	-19.4	0.980	33.1-1.5x**	27	23	-15.0	1.0	27-1x**
4	30	24	-20.0	0.986	29.8-1.4x**	24	20	-17.0	1.0	24-1x**
5	30	24	-20.0	0.986	29.8-1.4x**	24	21	-12.5	0.916	24-0.65x**
6	30	26	-20.0	1.0	30-1.4x**	26	23	-11.5	0.980	26.2-0.75x**
7	33.5	29	-13.5	0.994	33.3-1.1x**	29	24	-17.2	0.965	29.3-1.3x**
8	29	25	-14.0	1.0	29-1x**	25	21	-16.0	1.0	25-1x**

IBW represents initial live body weight and FBW represents final live body weight, where y= change in body weight, a= constant intercept, b= rate of change in body weight dependent variable, x= % change in feed level (independent variable) and ** = highly significant at $p<0.01$

The highest loss in live body weight was observed in sheep numbers 4 and 5, with about 37% loss by each animal (20% loss in phase I and 17% loss in phase II) with the same value of r^2= 0.973 and a highly significant ($p<0.01$) weekly body weight loss of -1.4 kg at 50% (Figure 8.3d and 8.3e), at 50 and 75% feed reductions, explained by r^2= 1.0 and r^2= 0.84 and with a highly significant ($p<0.01$) weekly body weight loss of -1.0 and -0.6 kg (Figure 8.3d and e), respectively. Despite the visible emaciation in body condition each animal spent 70% of the daily time in resting and 30% in standing. This means the sheep may manage to walk long distances for water and food.

In general, the Black Head Somali breed was observed to be the most tolerant for feed shortages during periods of drought. However, based on the performance of each animal it is possible that there exist genetic variability to perform under drought conditions. This variability therefore, may give the opportunity to select the best animals to breed as more tolerant to feed shortages. None the less, feed levels below 50% of the animal requirement have a negative effect on the body weight of the sheep breed.

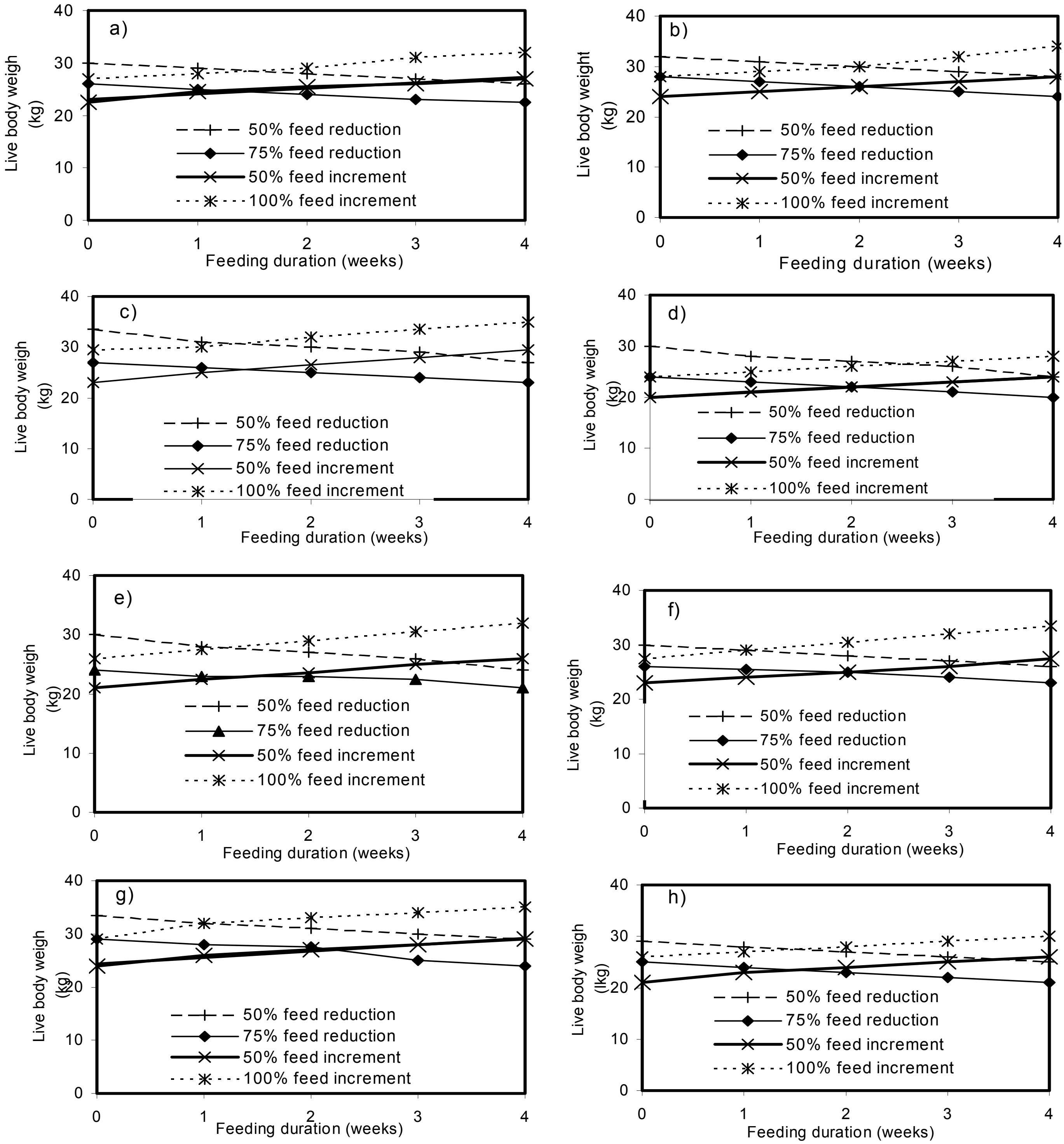

Figure 8.3 Relations between live body weight (kg) and feeding durations (weeks) at different feeding levels by Somali sheep breeds

8.4.4.2 Effect of increases in feed levels on sheep body weight performance

All eight sheep in the drought simulation experiment were used during the post-drought simulation trial (Table 8.6 and Figure 8.3). The total gain for sheep number 1 was 38.5% of its body weight attributed by 20% in phase III and 18.5% in phase IV, when the feed level was increased with 50 and 100%, explained by r^2= 0.923 and r^2= 0.977, with high ($p<0.01$) weekly weight gain of 1.03 and 1.3 kg (Figure 8.3a), respectively. Similarly, sheep number 2 also gained 38.4% of its initial body weight with 17 and 21.4% gain at a 50 and 100% feed increment explained by r^2= 1.0 and r^2= 0.96, and with a highly significant ($p<0.01$) weekly body weight gain of 1.0 and 1.5 kg (Figure 8.3b), respectively.

Table 8.6 Increment in DM feed levels by 50 and 100% on body weight performance of Black Head Somali sheep breed

Sheep No	50% feed increment			r	y= a+bx	100% feed increment			r	y= a+bx
	IBW (kg)	FBW (kg)	(%)			IBW	FBW	(%)		
1	22.5	27	20.0	0.923	23+1.05x**	27	32	18.5	0.977	26.8+1.3x**
2	24	28	17.0	1.0	24+1x**	28	34	21.4	0.960	27.6+1.5x**
3	23	29.5	28.3	1.0	23.2+1.6x**	29.5	37	25.4	0.970	29.1+1.5x**
4	20	24	20.0	1.0	20+1x**	24	28	17.0	1.0	29+1x**
5	21	26	24.0	0.993	21.1+1.5x**	26	32	23.1	1.0	26+1.5x**
6	23	27.5	20.0	0.989	22.9+1.1x**	27.5	33.5	22.0	1.0	27.5+1.5x**
7	24	29	21.0	0.964	24.4+1.2x**	29	35	21.0	0.964	29.8+1.4x**
8	21	26	23.8	0.964	21.4+1.2x**	26	30	15.4	1.0	26+1x**

IBW represents initial live body weight and FBW represents final live body weight, where y = change in body weight, a= constant intercept, b= rate of change in body weight dependent variable, x= % change in feed level (independent variable) and ** = highly significant at $p<0.01$

Sheep numbers 3, 6 and 7 showed higher performance in terms of body weight gain compared to the other experimental sheep, except for sheep 5 (Table 8.6). Sheep number 3 had a gain of 43.8% of its initial body weight by 28.3 and 25.4% due to feed level increment of 50 and 100%, explained by of r^2 = 1.0 and r^2 = 1.0 0.97, which was a highly significant ($p<0.01$) body weight gain of 1.60 and 1.45 kg (Figure 9.3c) per week, respectively. Sheep number 6 also showed a gain of 44% in body weight due to the gains of 20 and 22% at feed levels of 50 and 100% increment, where the dependent variable was explained by r^2 =0.989 and r^2 =1.0, with a high ($p<0.01$) weekly weight gain of 1.1 and 1.5 kg (Figure 8.3f), respectively.

Sheep number 7 had a total gain of 42% of its initial body weight attributed by 21 and 21% due to increased levels of 50 and 100%, equally explained by r^2= 0.964, with high ($p<0.01$) weekly body weight gain of 1.2 and 1.4 kg (Figure 8.3g), respectively. Sheep number 5 had the highest weight gain of 47.1% as a result of the gains of 24% at a 50% feed level and 23.1% at a 100% feed level increment, with the effect explained by r^2 =0.003 and r^2 =1.0, with a highly significant ($p<0.01$) weekly body weight gain of 1.5 kg (Figure 8.3e), respectively.

Sheep numbers 4 and 8 also showed more or less similar trends in weight gain. Sheep number 4 achieved a total gain of 37% of its initial body weight due to 20 and 17% gain as a result of feed level increment of 50 and 100%, where the effect of the independent variable was equally expressed by r^2 =1.0, with a highly significant ($p<0.01$) weekly body weight gain of 1.0 kg (Figure 3.3d) at each level, respectively. Sheep number 8 gained about 39.2% in body weight attributed by 23.8 and 15.4% due to a 50 and a 100% feed level increment and explained by r^2= 0.964 and r^2= 1.0 with a high ($p<0.01$) weekly body weight gain of 1.2 and 1.0 kg (Figure 8.3h), respectively.

Based on the results, therefore, it seems to be possible to suggest that the Somali Black Head sheep has a higher capability to compensate for body weight loss due to feed shortages created by drought. This will further imply that this sheep breed is suitable for fattening purposes. Depending on the feed situation, pastoralists could be advised to rear this sheep as an important animal under arid environments.

8.5 CONCLUSIONS AND RECOMMENDATION

8.5.1 Effect of feed reduction livestock breeds of the Somali region

As expected the body weight losses of all livestock species were highly significantly correlated with the reduction in daily dry matter feed of 50% and 75%, respectively. More than 50% of the animals under both treatments showed pronounced emaciation and physical weakness and a 25% of the cattle and goats collapsed and died within ten weeks after the trial started.

The daily behaviour of each experimental animal was also noted, in terms of the time spent in resting and standing for a period of eight hours a day. The results showed that most animals spent more time resting than standing. On average, the cattle spent about 63.75% of their time resting and 36.25% standing. The goats spent their time equally (50%) resting and standing, while the sheep spent 33.75% resting and 66.25% standing. Under normal feeding conditions, all species spent about 80% standing (including grazing/browsing) and 20% resting. In this study, therefore, the higher the reduction in the daily ration of the animals, the higher decline in physical capacity with a reduced ability to migrate in search of feed and water under the traditions of the pastoral production system. The increased time spent resting may be an indication of weakening of the animal. This animals must therefore, either rehabilitated or culled in a way that could ensure income generation by the pastoralists.

The cattle deaths occurred after a loss of 30% and more of their body weight, while the deaths of goats occurred above a loss of 50% in body weight. No death has occurred among the sheep. In addition, some variation was observed between the Somali cattle and goat breeds, but not among the Black Head Somali sheep. These observations indicate genetic variability with regards to tolerance to feed shortages among and between the livestock species and breeds. Accordingly, 25% of the cattle and 25% of the goats died at 50% feed level reduction after a five weeks period, while the sheep showed an acceptable type of emaciation in their body condition except for 25% showing pronounced deterioration. Furthermore, 25% of the cattle and 25% of the goats were highly emaciated and collapsed when fed after the 75% level feed reduction of an additional five weeks.

About 50% of the cattle and goats and 75% of the sheep were tolerant to the feed shortages at levels of 50 and 75% of the daily ration, but showed severe emaciation, due to high body weight losses. Therefore, it may be possible that the Somali cattle and goat breeds may have genetically a lower resistance to feed shortages compared to the sheep breeds. As a result, a death rate of about 25% from the cattle and goat populations within the first two months of a drought can be expected, depending on the amount of animals grazing the area. The death rate could however, rise to 50% or more for each breed, within a period of 4 to 5 months under prolonged feed shortages during long drought periods. Under similar conditions the death rate for Black Head Somali sheep may rise to 25% or more. These results were in agreement with reports by the Somali Region Drought Preparedness and Prevention Commission (SRDPPC, 2003), which reported a death rate of about 25% among cattle, 30% for goats and 15% among sheep in a two months period during the drought in 2003. The same report also indicated a death rate of more than 50% for cattle and goats and 25% for sheep during the 2001 and 2003 drought years in the Somali Regional State.

The potential losses of livestock establishes a clear need for a contingency plan for the timely selling of the animals before they reach severe deterioration in body condition. An integrated marketing strategy is required to market animals before they loose condition. Pastoralists should also select the most resistant animals and maintain them at level of at least 50% of their daily feed requirement. To that end, governmental and non-governmental institutions have to intervene in rangeland rehabilitation as a contingency for drought period feeding.

The sheep breed proofed to have a better resistance to feed shortages than the cattle and goat breeds. This may be due to the fatty tail, rump and subcutaneous fatty layers (fatty tissues), which could be converted by the processes of lipolysis converting fatty acids into energy at times of feed shortages. All experimental sheep survived the different levels of feeding, but with differences in the level of emaciation or body weight loss. Despite the Somali sheep breed being the most drought tolerant animal, there is thus scope for further selection for genetic resistance to feed shortages.

8.5.2 Effect of feed increment on Somali livestock species

On average each of the cattle, goats and sheep compensated for body weight loss during 50% feed reduction by 92.63, 83.43 and 87.5% and body weight increased after being fed on a 50% increase in feed for five weeks, respectively. On average cattle, goats and sheep recovered by about 106, 112 and 106% after being fed on a 100% feed increment in five weeks, with further body weight gains of 12.3 kg (6.38%), 3.0 kg (12%) and 2 kg (6%), respectively due to normal tissue growth.

The results showed that the Somali livestock breeds have the potential of recovering from body weight losses due to feed shortages at times of drought, within a period of less than two months where forage availability is not limiting. Accordingly, pastoralists should select and maintain a nucleus breeding herd for post-drought breeding purposes if there is the possibility of providing at least 50% of the daily dry matter feed requirements for each animal on the basis of live body weight. The need for supplementary feeding beyond maintenance feed level for a viable breeding stock, mainly during drought periods, is not excluded.

According to the results of this study, the Somali cattle, sheep and goat breeds were responsive to post-drought feeding, despite the differences in rate and intensity of compensatory growth between animals. Therefore, it can be anticipated that those pastoralists engaged in animal breeding as well as fattening enterprises could benefit from compensatory growth of the cattle breeds during post-drought periods.

It can also be suggested from the study that there is a lack of homogeneity among the cattle, sheep and goat breeds, in terms of their ability to uniformly compensate during the post-drought (where feed availability was not a limiting factor), for the amount of live weights lost at times of drought. In general therefore, the Somali cattle, sheep and goat breeds seem to have genotypic variability regarding compensatory growth, that may need further selection and improvement in terms of resistance to feed shortages and early growth. However, the study indicated that pastoralists could benefit from the compensatory growth, both for breeding and fattening purposes during post-drought periods using the goats in the region.

8.5.3 Recommendation on drought related livestock coping options

The drought period and post-drought period simulated feeding experiments were found to represent the actual impacts on livestock performance and the related problems. Although it could be agreed that much more work is needed to further refine the results, it is possible to arrive at the following recommendations:

(i) Given the human and livestock pressure on the rangelands in one hand and the increasing rangeland degradation on the other, the situation calls upon a balanced stocking rate based on the potential of the rangelands to support production of grazing and browsing fodder. Any negligence or over looking the current grazing/browsing capacities may lead to more livestock mortalities during drought or may force animals to perform below potential under normal climate, due to inadequate feed resource to feed the existing livestock population. For this reason, there is a need to introduce new thinking in the pastoral communities to minimize the herd size in balance to the available feed resources.

(ii) Drought must be accepted as part of the pastoral life and there should be an adequate early warning system regarding livestock feed availability and strategies of appropriate mitigation systems. Rainfall patterns in those pastoral areas of Ethiopia need to be predicted using modern techniques such as meteorological data and spatial analysis, while the indigenous knowledge of the pastoral communities for rainfall prediction could also be used as a supporting tool.

(iii) Under a good early warning system, the trend in feed availability and the range of intervals as period of critical feed shortage could be determined, by indicating the balance between the available and required feed amount, in relation to the periods of adequacy and periods of scarcity in proportion to the livestock population in place. To this end, the grazing capacities of the rangelands can be roughly estimated through continuous monitoring and evaluation processes as part of an early drought warning system. In view of pastoral areas of the country, the latter may assist in estimating the rate of off-take (projection of number of animals to be sold) from the respective pastoral areas subject to drought as part of a preparedness strategy.

(iv) The pastoralists often remain poorer during post-drought periods for most of their animals are dead (Chapter 3). It is also understood that an important number of the pastoral households remain without any breeding stock to restart animal production after the drought. To date there exist no post-drought animal restocking policy for both the Somali Regional State and the Federal Government of Ethiopia. Besides neither the local nor the international non-governmental organizations (NGOs) are involved in such schemes. Because of the obvious consequences of drought on the pastoral livestock production systems and its far-reaching impacts on the regional and national economy, there is an urgent need for developing an appropriate policy and strategy on post-drought livestock restocking. Such interventions however, need to be institutionalized with adequate infrastructures in place. One major component could be the establishment of a "livestock feed relief and rehabilitation program", that can supply adequate feed sources for a number of livestock for post-drought breeding.

(v) It is also possible to expect livestock deaths (all species) of at least 50% or more of the population, due to severity in drought, intensity of feed shortage and lack of institutional preparedness. Decreasing stocking rate before the drought could be more advisable as experienced in Australia with Merino sheep. Under Ethiopian conditions however, this could include cattle, goats, sheep and camels. In order to achieve the latter, early drought warning systems have to be adequately supported by strong and proper marketing strategies. Accordingly, there should be pre-planned drought disposal mechanisms at regional and national levels. Such interventions could also include value adding measures, such as fattening of emaciated livestock herds before or during the onset of the drought, in order to benefit the pastoral communities in earning a fair price for their animals.

(vi) Implementing the above strategy may require integrated livestock rehabilitation or reconditioning programs, with the provision of feed resources on cost recovery packages to the pastoral communities. Those emaciated animals could be fed to increase in body weight (value adding) so as to attract better market prices. However, this need to be supported with an adequate and an efficient early warning system, marketing infrastructures, supply and demand information networking and detailed livestock marketing strategies. The latter also need to be part of a larger livestock feeding, rehabilitation and marketing program for pastoral areas in Ethiopia. Moreover, a holistic implementation of the latter will require the collaboration of governmental and non-governmental organizations and traditional pastoral community institutions, respectively.

(vii) Under difficult conditions, where feed is getting too scarce and beyond the pastoral coping mechanisms, the animals should also not be allowed to die with no use. When drought periods are prolonged and saving of the entire livestock is beyond the capacity of the regional and national governments, non-governmental institutions and the community, there should be a scheme to make use of the animals before total death. Therefore, institutionalized drought periods, livestock slaughter preparation and distribution schemes have to be introduced and developed to supply the drought-affected communities with healthy dried red meat as animal protein supplement to their traditional food, which may be integrated with the national and regional food relief programs. Emergency slaughter would also help to save the skins and hides of the animals and assist the leather industries with adequate raw materials to produce at capacity.

(viii) Finally, the experimental results indicated the existence of genetic variability for tolerance to feed shortages and in rates of compensatory growth among and between breeds of the Somali livestock population. This further indicates the opportunity for breed improvement through breeding and selection research schemes at a regional or national level. However, the study should be continued for a longer period of time under drought simulated conditions and on actual grazing/browsing trials in the field in order to make more observations.

CHAPTER 9

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The study was conducted in the Somali region of eastern Ethiopia, with an arid to semi-arid climate. Although rangelands in this region are known to be degrading, aggravated by sporadic droughts, very little information are available on the dynamics of these ecological sensitive areas. The objectives of this study were to characterize the rangeland resources, assess the current condition of the rangeland, understand pastoral perceptions on rangeland degradation and develop drought feeding strategies for livestock.

Three experimental sites, representative of the three predominant vegetation types of eastern Ethiopia were selected. They were the arid Asbuli grassland which was used as grazing area for large and small ruminants, the arid Aydora open savanna (bush-grassland), which was entirely used for grazing/browsing by all types of livestock, and the semi-arid Hurso closed savanna (bushland), which was selected for its importance as browsing for camels and goats. These areas represented nearly 85 000 km^2 of the rangeland of the Somali region of Ethiopia. A degradation gradient was identified in each of the three vegetation types. Based on the observed rangeland condition, a further four areas were identified along each degradation gradient, subjectively classified as excellent (named the benchmark), good, moderate and poor.

The plant biodiversity of each of the three main vegetation types were studied, as well as the perceptions of the pastoralist on rangeland degradation. Along the various degradation gradients the botanical composition and basal cover of the herbaceous layer were surveyed and the rangeland condition assessed. The dry matter production of both the herbaceous and woody layer was determined, while the grazing and browsing capacity calculated. The occurrence of soil erosion was also recorded. Key forage species were identified and the grazing pattern of various livestock species along the degradation gradient studied. The soil seed bank regeneration potential was assessed in a greenhouse experiment and the response of cattle, sheep and goats to a simulated drought, in terms of reduced fodder was conducted under controlled conditions. This provided the basis for the development of a recommended drought feeding strategy.

The results of the study confirmed the existence of severe rangeland degradation that occurred since 1944 and which was aggravated after the 1974 drought. This contributed to an increase in the number of poor households. The average livestock holding per household declined from 809 Tropical Livestock Units (TLU) before 1974 to 483 TLU after 1974. Livestock holding shifted from a predominance of cattle to small ruminants, which are able to utilize the degraded rangeland more effectively. Camels are now the most important livestock species in terms of milk and meat production, mainly due to their ability to tolerate drought. They are also of increasing value due to their use as pack animals. Traditional disaster coping mechanisms of the pastoralist are getting weaker in view of the increasing rangeland degradation and more frequent droughts. It is therefore very important for sustainable animal production in the Somali region of eastern Ethiopia to develop objective rangeland condition techniques and to start with rangeland monitoring.

From the survey among the pastoralist it become clear that immediate interventions are needed to alleviate the expanding poverty. In order to improve the living conditions of the pastoralist it were concluded that the feeling of marginalization among the pastoral communities be addressed. Effort should be made in developing and improving access to water and feed shortages should be reduced through the rehabilitation of degraded rangelands. The effects of climatological droughts must be minimized by establishing effective early warning systems and livestock disease management in the pastoral areas must receive priority attention. Livestock marketing infrastructures and information systems must be developed and the national and regional governments and non-governmental organizations should encourage and promote well planned, designed and facilitated settlement schemes around potential permanent river basins.

A loss in biodiversity of the rangeland vegetation due to over utilization of the ecosystem, poverty and unemployment was observed. However, the potential of the rangelands in terms of species diversity was demonstrated with a total of 49 plant species (38 grasses and 11 non-grasses) that were recorded in the Asbuli grasslands, and 33 plant species (20 grasses and 13 non-grasses) recorded in the Aydora open savanna. Very few herbaceous species were recorded in the Hurso closed savanna, but it was rich in woody plants with a total of 60 species that were recorded. There were indication of an expansion of weeds and undesirable woody plants. In the Hurso closed savanna, over-cutting of the desirable woody plants was observed, which pose a threat to goat and camel production due to a decline in browse material.

A clear need for the development of appropriate utilization-based conservation strategies and policies was identified. This will invariably involve the promotion of awareness among pastoral communities of the threats. The development and application of appropriate extension services, promotion of integrated scientific and traditional control measures of encroacher weeds and woody plants and the implementation of community participation-based rangeland vegetation monitoring and evaluation systems were identified as priorities.

The abundance of herbaceous plants, basal cover, dry matter production and grazing capacity was found to be higher in the benchmark sites compared to the other rangeland conditions. There was also a corresponding increase in percentage bare ground, soil compaction and soil erosion along the degradation gradients from the benchmark to the poor rangeland condition sites. Over-grazing and over-utilization through continuous grazing of the herbaceous layer were identified as the main causes of these differences. The pastoralists had a good understanding and knowledge of the valuable grass species. With their assistance and using criteria such as a high production potential, palatability, preference by livestock, resilience to grazing and tolerance to soil-water stress, 17 key forage species were identified. These species were also identified as important from a plant genetic point of view, that can be used in future rangeland restoration programs.

Rangeland condition was observed to significantly influence the grazing behaviour of livestock in terms of plant species selection, grazing intensity and intake per animal.

When forage sources were adequately available, animals selected fever plant species. As forage resources declined the animals spend more time grazing and more species selected, including less palatable species. The number of bites, intake per bite and intake as a percentage of the animal's body mass also increased as the rangeland become more degraded.

The woody plants of the Aydora open savanna and Hurso closed savanna were studied in terms of species composition, density, canopy cover, height distribution, browse production, browse capacity, phenology and traditional uses. A total of 5 woody plant species were identified in the Aydora open savanna, which was dominated by *Cadaba glandulosa* and *Acacia nubica*. A total of 21 woody species were identified in the Hurso closed savanna, dominated by *Acacia* species. *Acacia nubica* and *A. mellifera* were identified as aggressive encroaching species in both of the rangelands types. The Aydora open savanna experienced extensive encroachment by woody plants with increasing plant densities across the degradation gradient from the excellent to poor condition sites. The Hurso closed savanna experienced an opposite trend where severe deforestation and a loss of valuable browse species occurred, mainly as a results of over cutting of the woody plants for firewood, charcoal making, construction and the clearing of the land for planted crops. A loss of savanna structure was also observed with larger trees being replaced with low growing shrubs.

The awareness of the communities of the problems was found to be inadequate due to a lack of extension programs. Increasing the awareness of the people of the problems and possible solutions is thus imperative. The regional government, national government and local non-governmental organizations need to co-operate in launching appropriate extension programs. Further research on bush encroachment and practical solutions such as mechanical, biological and chemical control, with involvement of pastoral communities, needs to be undertaken. Woody plants are valuable from an ethno-botany (veterinary and human medication) point of view and a wealth of information on traditional uses exists. Development of sustainable browsing systems for camels and goats is also important as a form of land use.

The study on the soil seed bank of soil collected along the various degradation gradients showed a high abundance of plant seed present in the soil, confirming the potential of the area for rangeland restoration. However, soil compaction associated with rangeland degradation may prevent the germination and regeneration of the seed present in the soil seed banks and restoration of denuded rangelands may be difficult without breaking the compacted soil.

A total of 122 plant species were identified from seed that germinated in the soil from the three rangeland types. These included 41 species (31.95%) in soil from the Asbuli grassland, 40 species (34.6%) in soil from the Aydora open savanna and 41 species (33.4%) in soil from the Hurso closed savanna. Of some concern was the presence of seed of weeds. In view of the critical feed shortages in the Somali region, restoration and rehabilitation of degraded rangeland in the region need to be institutionalized under relevant governmental and non-governmental organizations. Soil and water conservation measures should also be encouraged in order to avoid or minimize runoff and improve water infiltration for enhanced forage production.

As expected the body weight losses of all livestock species in the controlled feeding trial were highly significantly correlated with the reduction in daily dry matter feed of 50% and 75%, respectively. More than 50% of the animals under both treatments showed pronounced emaciation and physical weakness and 25% of the cattle and goats collapsed and died within ten weeks after the trial started. This explained the large scale mortalities of livestock during prolonged droughts.

Drought must be accepted as part of the pastoral life and there should be an adequate early warning system regarding livestock feed availability and strategies of appropriate mitigation strategies. Accordingly, there should be pre-planned disposal mechanisms of excess livestock at regional and national levels. Such interventions could also include value adding measures, such as fattening of emaciated livestock herds before or during the onset of the drought, in order to benefit the pastoral communities in earning a fair price for their animals. More realistic stocking rates is the obvious solution to the avoidance of stock losses during droughts, but in view of the well established culture of the pastoralists it is highly doubtful if they will be willing to reduce their animal numbers.

Rainfall patterns in the pastoral areas of Ethiopia need to be predicted using modern techniques such as meteorological data and spatial analysis, while the indigenous knowledge of the pastoral communities for rainfall prediction could also be used as a supporting tool. The grazing capacity of the rangelands can be roughly estimated through continuous monitoring and evaluation as part of an early drought warning system.

To date there exist no post-drought animal restocking policy for both the Somali Regional State and the Federal Government of Ethiopia, and there is an urgent need for developing an appropriate policy and strategy on post-drought livestock restocking. Such interventions need to be institutionalized with adequate infrastructures. Implementing the above strategy may require integrated livestock rehabilitation or reconditioning programs, with the provision of feed resources on cost recovery packages to the pastoral communities. Those emaciated animals could be fed to increase in body weight (value adding) so as to achieve better market prices. However, this needs to be supported with an adequate and an efficient early warning system, marketing infrastructures, supply and demand information networking and detailed livestock marketing strategies. The latter also need to be part of a larger livestock feeding, rehabilitation and marketing program for pastoral areas in Ethiopia. In addition, a holistic implementation of the latter will require the collaboration of governmental and non-governmental organizations and traditional pastoral community institutions, respectively.

In conclusion, the experimental results indicated the existence of genetic variability among the various Somali livestock breeds regarding the tolerance to feed shortages and in rates of compensatory growth. This demonstrates the opportunity for improving the genetic composition of the Somali herds through selection.

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APPENDICES

APPENDIX 1 (CHAPTER 1)

Legend descriptions of the Dryland agro-ecologies of Ethiopia

No.	Abbreviations	Description of the agro-ecological classifications
1	A1.1	Hot to warm arid plains
2	A1.3	Hot to warm arid valleys and escarpments
3	A1.7	Hot to warm mountains
4	A2.1	Tepid to cool arid plains
5	A2.7	Tepid to cool arid mountains
6	M1.1	Hot to warm moist plains
7	M1.2	Hot to warm moist lakes and rift valleys
8	M1.3	Hot to warm moist valleys and escarpments
9	M1.4	Hot to warm moist gorges
10	M1.7	Hot to warm moist mountains
11	SA1.1	Hot to warm semi-arid plains
12	SA1.5	Hot to warm semi-arid mountains and plateau
13	SA2.2	Tepid to cool semi-arid lakes and rift valleys
14	SM1.1	Hot to warm sub-moist plains
15	SM1.2	Hot to warm sub-moist lakes and rift valleys
16	SM1.3	Hot to warm sub-moist valleys and escarpments
17	SM1.4	Hot to warm sub-moist river gorges
18	SM1.7	Hot to warm sub-moist mountains
19	SM2.1	Tepid to cool sub-moist plains
20	SM2.2	Tepid to cool sub-moist lakes and rift valleys
21	SM2.5	Tepid to cool sub-moist plains, mountains and plateau
22	SM2.7	Tepid to cool sub-moist mountains
23	SM3.7	Cold to very cold sub-moist mountains

APPENDIX 2 (CHAPTER 5)

GPS coordinates and belt transect measurements for the Asbuli grassland

No	Rangeland conditions	Coordination points	Longitude (°N)	Latitude (°E)	Altitude (m.a.s.l.)	Distance in km (from-to)	Remarks[2]
1	Excellent condition	a	09°59'.787	041°19'.407	760	3.2 (a-i)	Initial
		b	10°00'.627	041°18'.064	750	2.9 (a-b)	
		c	10°00'.674	041°17'.175	744	1.62 (b-c)	
		d	10°00'.908	041°17'.381	748	1.6 (c-d)	
		e	10°00'.964	041°17'.381	748	1.8 (d-e)	Terminal
2	Good condition	f	09°59"787	041°19'.407	760	3.7 (e--f)	Initial
		g	09°58'.959	041°19'.833	757	3.72 (f-g)	Initial
		h	09°59'.024	041°20'.282	753	1.83 (g-h)	
		i	09°59'.187	041°20'.288	754	1.80 (h-i)	
		j	10°59'.964	041°17'.381	748	3.7 (i-j)	Terminal
3	Fair condition	k	09°59'.187	041°20'.288	754	3.0 (i-k)	Initial
		l	09°59'.787	041°20'.288	754	3.3 (k-l)	
		m	10°00'.023	041°19'.351	745	1.5 (l-m)	
		n	10°00'.227	041°19'.767	747	1.5 (m-n)	
		o	09°58'.667	041°20".661	769	3.32 (n-o)	Terminal
4	Poor condition	p	10°00'.227	041°19'.767	747	3.58 (m-p)	Initial
		q	09°59'.187	041°20'.288	754	3.84 (p-q)	
		r	09°57'.823	041°20'.356	769	1.66 (q-r)	
		s	09°57'.199	041°19'.688	766	1.68 r-s)	
		t	09°58'.667	041°20'.661	769	3.32 o-t)	Terminal

APPENDIX 3 (CHAPTER 5)

GPS coordinates and belt transect measurements for the Aydora open savanna

No	Rangeland conditions	Coordination points	Longitude (°N)	Latitude (°E)	Altitude (m.a.s.l.)	Distance in km (from-to)	Remarks[2]
1	Excellent condition	a	09°49'.787	041°20'.463	808	2.5(a-d)	Initial
		b	09°48'.855	041°19'.988	815	1.2 (a-b)	
		c	09°49'.473	041°21'.288	820	2.53 (b-c)	
		d	09°49'.490	041°21'.300	818	2.5 (c-d)	Terminal
2	Good condition	e	09°49'.473	041°21'.288	818	3.37(c-e)	Initial
		f	09°49'.473	041°21'.288	820	3.37 (e-f)	
		g	09^{0}47'.764	041°21'.591	826	3.2 (f-g)	
		h	09°47'.686	041°20'.942	825	3.2 (g-h)	
		i	09°59'.187	041°20'.288	754	3.4 (h-i)	Terminal
3	Fair condition	j	09°59'.187	041°20'.288	754	3.4 (j-k)	Initial
		k	09°47'.764	041°21'.288	826	2.5 (k-l)	
		l	09°46'.249	041°22'.064	846	2.93 (l-m)	
		m	09°46'.195	041°21'.516	836	1.5 (m-n)	
		n	09°47'.686	041°20'.942	825	3.5 (n-i)	Terminal
4	Poor condition	o	09°46'.195	041°21'.516	836	3.4(k-o)	
		p	09°46'.249	041°22'.064	846	2.5 (o-p)	
		q	09°44'.151	041°22'.128	863	2.5 (p-q)	
		r	09°43'.871	041°21'.945	858	2.8 (q-r)	
		s	09°47'.686	041°20'.942	825	3.5 (r-s)	Terminal

APPENDIX 4 (CHAPTER 5)

GPS coordinates and belt transect measurements for the Hurso closed savanna

No	Rangeland conditions	Coordination points	Longitude (^{o}N)	Latitude (^{o}E)	Altitude (m.a.s.l.)	Distance in km (from-to)	Remarks[2]
1	Excellent condition	a	09^{o}37'.131	041^{0}38'.466	1098	2.2 (a-d)	Initial
		b	09^{o}37'.144	041^{0}38'.655	1102	0.5 (a-b)	
		c	09^{o}37'.317	041^{0}38'.668	1087	0.52 (b-c)	
		d	09^{o}37'.578	041^{0}38'.431	1086	2.0 (c-d)	Terminal
2	Good condition	e	09^{o}37'.247	041^{0}38'.333	1098	2.8 (a-i)	Initial
		f	09^{o}37'.131	041^{0}38'.466	1092	0.51 (e-f)	
		g	09^{o}37'.578	041^{0}38'.431	1086	1.0 (f-g)	
		h	09^{o}37'.571	041^{0}38'.209	1089	0.51 (g-h)	
		i	09^{o}37'.650	041$^{0'}$38'.588	1100	1.2 (h-i)	Terminal
3	Fair condition	j	09^{o}37'.281	041^{0}38'.163	1088	0.5 (j-k)	Initial
		k	09^{o}37'.386	041^{0}38'.049	1092	0.52 (k-l)	
		l	09^{o}37'.660	041^{0}38'.089	1082	0.51 (l-m)	
		m	09^{o}37'.571	041^{0}38'.209	1089	0.55 (m-n)	
		n	09^{o}37'.383	041^{0}38'.252	1095	0.54 (n-i)	Terminal
4	Poor condition	o	09^{o}37'.281	041^{0}38'.163	1088	0.45(k-o)	
		p	09^{o}46'.249	041^{0}22'.064	846	0.5 (o-p)	
		q	09^{o}37'.247	041^{0}38'.333	1098	0.45 (p-q)	
		r	09^{o}37'.066	041^{0}38'.386	1100	0.5 (q-r)	
		s	09^{o}37'.071	041^{0}38'.137	1104	0.5 (r-s)	Treminal

APPENDIX 5 (CHAPTER 6)

Appendix Table 6.1 Biomass estimates for rangeland condition classes of Aydora open savanna in Shinile zone of Somali region, eastern Ethiopia

No	Species of woody plants by rangeland condition classes	Different biomass estimate parameters for the different species of woody plants in each rangeland condition class												
		Plant density (no. ha^{-1})	LVOL	ETTE	LMAS	LM (<1.5m)	LM (<2m)	LM (<5m)	BTE	BTE (<1.5m)	BTE (<2m)	BTE (<5m)	CSI-1	CSI-2
A	**Excellent condition**													
1	*Cadaba glandulosa*	98	172	344	77	47	68	77	307	188	274	307	3.8	0.0
	Total	**98**	**172**	**344**	**77**	**47**	**68**	**77**	**307**	**188**	**274**	**307**	**3.8**	**0.0**
B	**Good condition**													
1	*Cadaba glandulosa*	118	605	1209	269	97	152	269	1075	387	608	1075	13.0	7.5
	Total	**118**	**605**	**1209**	**269**	**97**	**152**	**269**	**1075**	**387**	**608**	**1075**	**13.0**	**7.5**
C	**Moderate condition**													
1	*Acacia nilotica*	6	17	33	8	5	8	8	31	21	30	31	0.3	0.0
2	*Acacia nubica*	20	106	212	50	17	34	50	199	67	135	199	2.7	0.0
3	*Acacia tortilis*	4	10	20	5	1	2	5	18	3	9	18	0.2	0.0
4	*Cadaba glandulosa*	122	304	609	136	49	92	136	543	197	368	543	7.6	0.3
5	*Grewia ferruginea*	36	15	30	5	4	5	5	20	17	20	20	0.2	0.0
	Total	**188**	**452**	**904**	**203**	**76**	**140**	**203**	**811**	**306**	**562**	**811**	**10.9**	**0.3**
D	**Poor condition**													
1	*Acacia nubica*	200	1009	2010	474	153	294	474	1895	612	1176	1895	22.9	0.4
2	*Cadaba glandulosa*	86	232	464	103	49	84	103	413	194	336	413	5.7	0.0
	Total	**286**	**1240**	**2474**	**577**	**202**	**378**	**577**	**2308**	**806**	**1512**	**2308**	**28.6**	**0.4**

LVOL= Estimated true leaf volume (cm^3), ETTE= Evapotranspiration Tree Equivalent value (volume/500), LMAS= Estimated leaf Dry Mass (kg), LM< 1.5m= Estimated leaf Dry Mass below a browsing height of 1.5 m, LM< 2.0 m= Estimated leaf Dry Mass below a browsing height of 2.0 m, LM< 5m= Estimated leaf Dry Mass below a browsing height of 5 m, BTE= Browse Tree Equivalent ((leaf DM/250), BTE< 1.5 m= BTE-value for leaf DM below a browsing height of 1.5 m, BTE< 2.0 m= BTE-value for leaf DM below a browsing height of 2.0 m, BTE< 5 m= BTE-value for leaf DM below a browsing height of 5.0 m, CSI= The area spanned by the tree canopy (m^2)

APPENDIX 6 (CHAPTER 6)

Appendix Table 6.2 Biomass estimates for excellent and good rangeland condition site of Hurso closed savanna of Shinile zone in Somali region

No	Species of woody plants by rangeland condition classes	Different biomass estimate parameters for the different species of woody plants in each rangeland condition class												
		Plant density (ha^{-1})	LVOL	ETTE	LMAS	LM (<1.5m)	LM (<2m)	LM (<5m)	BTE	BTE (<1.5m)	BTE (<2m)	BTE (<5m)	CSI-1	CSI-2
A	**Excellent condition**													
1	***Acacia nilotica***	52	871	1743	417	10	34	373	1667	41	137	1491	19.1	15.9
2	***Acacia mellifera***	64	504	1008	238	50	103	238	952	199	411	952	10.2	4.3
3	***Acacia nubica***	4	25	50	12	5	9	12	47	21	38	47	0.6	0.0
4	***Acacia senegal***	24	251	502	119	15	43	119	476	60	170	476	6.5	0.0
5	***Acacia tortilis***	180	2215	4431	1056	28	125	920	4226	110	502	3680	49.2	33.3
6	***Balanites aegyptiaca***	112	833	1667	370	4	41	360	1482	15	166	1439	18.0	13.6
7	***Cadaba glandulosa***	36	363	727	161	50	102	161	646	199	409	646	11.9	0.0
8	***Dobora galabra***	4	28	57	13	0	3	13	51	1	11	51	0.6	0.6
9	***Salvadora persica***	4	65	131	29	4	10	29	116	16	39	116	1.5	1.5
	Total	480	5157	10315	2416	166	470	2225	9662	663	1882	8898	117.6	69.3
B	**Good condition**													
1	***Acacia nilotica***	7.6	380	760	178	7	50	178	713	29	199	713	11.6	0.6
2	***Acacia mellifera***	100	436	872	204	68	130	204	817	271	520	817	9.7	0.0
3	***Acacia nubica***	40	269	538	127	26	53	101	509	106	212	404	5.0	0.2
4	***Acacia senegal***	104	352	704	164	33	92	164	655	134	369	655	8.6	0.0
5	***Acacia tortilis***	124	348	696	162	8	54	162	646	33	218	646	9.2	0.5
6	***Balanites aegyptiaca***	12	28	56	12	0	4	12	50	1	16	50	1.0	0.0
7	***Cadaba glandulosa***	108	342	685	152	51	107	152	610	204	427	610	10.6	0.0
8	***Dobera galabra***	8	26	52	12	6	10	12	46	23	40	46	0.6	0.0
	Total	572	2181	4362	1012	200	500	985	4046	801	2001	3941	56.4	1.4

LVOL= Estimated true leaf volume (cm^3), ETTE= Evapotranspiration Tree Equivalent value (volume/500), LMAS= Estimated leaf Dry Mass (kg), LM< 1.5m= Estimated leaf Dry Mass below a browsing height of 1.5 m, LM< 2.0 m= Estimated leaf Dry Mass below a browsing height of 2.0 m, LM< 5m= Estimated leaf Dry Mass below a browsing height of 5 m, BTE= Browse Tree Equivalent ((leaf DM/250), BTE< 1.5 m= BTE-value for leaf DM below a browsing height of 1.5 m, BTE< 2.0 m= BTE-value for leaf DM below a browsing height of 2.0 m, BTE< 5 m= BTE-value for leaf DM below a browsing height of 5.0 m, CSI= The area spanned by the tree canopy (m^2)

APPENDIX 7 (CHAPTER 6)

Appendix Table 6.3 Biomass estimates for moderate rangeland condition site of Hurso closed savanna of Shinile zone in Somali region

No	Species of woody plants by rangeland condition classes	Different biomass estimate parameters for the different species of woody plants in each rangeland condition class												
		Plant density (no. ha^{-1})	LVOL	ETTE	LMAS	LM (<1.5m)	LM (<2m)	LM (<5m)	BTE	BTE (<1.5m)	BTE (<2m)	BTE (<5m)	CSI-1	CSI-2
C	**Moderate condition**													
1	***Acacia nilotica***	**52**	**50**	**99**	**23**	**9**	**16**	**23**	**91**	**36**	**66**	**91**	**0.7**	**0.0**
2	***Acacia fruticosa***	**4**	**6**	**12**	**3**	**1**	**3**	**3**	**11**	**4**	**11**	**11**	**0.2**	**0.0**
3	***Acacia mellifera***	**244**	**447**	**895**	**206**	**119**	**173**	**206**	**826**	**477**	**691**	**826**	**5.2**	**0.0**
4	***Acacia nubica***	**4**	**1**	**3**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**0.0**	**0.0**
5	***Acacia senegal***	**104**	**212**	**424**	**98**	**28**	**66**	**98**	**392**	**111**	**263**	**392**	**4.2**	**0.0**
6	***Acacia tortilis***	**220**	**320**	**640**	**147**	**44**	**95**	**147**	**590**	**177**	**379**	**590**	**6.2**	**0.6**
7	***Acalypha fruticosa***	**32**	**9**	**19**	**4**	**4**	**4**	**4**	**17**	**17**	**17**	**17**	**0.0**	**0.0**
8	***Aloe somaliensis***	**32**	**13**	**26**	**6**	**6**	**6**	**6**	**23**	**23**	**23**	**23**	**0.0**	**0.0**
9	***Aloe tricosantha***	**4**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**0.0**	**0.0**
10	***Balanites aegyptiaca***	**156**	**169**	**339**	**76**	**13**	**38**	**76**	**303**	**53**	**151**	**303**	**4.3**	**0.0**
11	***Cadaba forinosa***	**32**	**17**	**34**	**8**	**4**	**8**	**8**	**31**	**17**	**30**	**31**	**0.3**	**0.0**
12	***Grewia ferruginea***	**44**	**39**	**79**	**14**	**8**	**13**	**14**	**56**	**33**	**52**	**56**	**0.4**	**0.0**
13	***Salvadora persica***	**8**	**9**	**17**	**4**	**2**	**3**	**4**	**16**	**7**	**13**	**16**	**0.2**	**0.0**
14	***Sanseviera abyssinica***	**288**	**151**	**303**	**68**	**67**	**68**	**68**	**272**	**266**	**272**	**272**	**0.2**	**0.0**
	Total	**1228**	**1446**	**2891**	**657**	**307**	**493**	**657**	**2630**	**1228**	**1971**	**2630**	**21.9**	**0.6**

LVOL= Estimated true leaf volume (cm^3), ETTE= Evapotranspiration Tree Equivalent value (volume/500), LMAS= Estimated leaf Dry Mass (kg), LM< 1.5m= Estimated leaf Dry Mass below a browsing height of 1.5 m, LM< 2.0 m= Estimated leaf Dry Mass below a browsing height of 2.0 m, LM< 5m= Estimated leaf Dry Mass below a browsing height of 5 m, BTE= Browse Tree Equivalent ((leaf DM/250), BTE< 1.5 m= BTE-value for leaf DM below a browsing height of 1.5 m, BTE< 2.0 m= BTE-value for leaf DM below a browsing height of 2.0 m, BTE< 5 m= BTE-value for leaf DM below a browsing height of 5.0 m, CSI= The area spanned by the tree canopy (m^2)

APPENDIX 8 (CHAPTER 6)

Appendix Table 6.4 Biomass estimates for poor rangeland condition class of Hurso closed savanna of Shinile zone in Somali region

No	Species of woody plants by rangeland condition classes	Different biomass estimate parameters for the different species of woody plants in each rangeland condition class												
		Plant density (no. ha^{-1})	LVOL	ETTE	LMAS	LM (<1.5m)	LM (<2m)	LM (<5m)	BTE	BTE (<1.5m)	BTE (<2m)	BTE (<5m)	CSI-1	CSI-2
D	**Poor condition**													
1	***Acacia nilotica***	**72**	**80**	**160**	**37**	**10**	**22**	**37**	**147**	**41**	**86**	**147**	**1.4**	**0.0**
2	***Acacia melliffera***	**28**	**61**	**123**	**28**	**6**	**14**	**28**	**113**	**25**	**54**	**113**	**1.0**	**0.0**
3	***Acacia nubica***	**284**	**340**	**680**	**157**	**82**	**115**	**157**	**627**	**328**	**458**	**627**	**3.8**	**0.0**
4	***Acacia senegal***	**48**	**36**	**71**	**16**	**11**	**14**	**16**	**65**	**42**	**58**	**65**	**0.3**	**0.0**
5	***Acacia tortilis***	**88**	**91**	**181**	**41**	**12**	**27**	**41**	**166**	**48**	**109**	**166**	**1.5**	**0.0**
6	***Acalypha fruticosa***	**376**	**63**	**127**	**29**	**25**	**25**	**27**	**114**	**101**	**102**	**107**	**0.0**	**0.0**
7	***Aloe somaliensis***	**8**	**1**	**2**	**0**	**0**	**0**	**0**	**2**	**2**	**2**	**2**	**0.0**	**0.0**
8	***Aloe tricosantha***	**92**	**9**	**19**	**4**	**4**	**4**	**4**	**17**	**17**	**17**	**17**	**0.0**	**0.0**
9	***Balanites aegyptiaca***	**120**	**44**	**87**	**20**	**11**	**16**	**20**	**78**	**43**	**65**	**78**	**0.6**	**0.0**
10	***Blepharis edulis***	**20**	**2**	**4**	**1**	**1**	**1**	**1**	**4**	**4**	**4**	**4**	**0.0**	**0.0**
11	***Cadaba forinosa***	**56**	**12**	**24**	**5**	**5**	**5**	**5**	**21**	**20**	**21**	**21**	**0.0**	**0.0**
12	***Cadaba glandulosa***	**12**	**11**	**21**	**5**	**4**	**5**	**5**	**19**	**14**	**19**	**19**	**0.2**	**0.0**
13	***Gomphocarpus fruticosus***	**16**	**1**	**3**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**0.0**	**0.0**
14	***Grewia ferruginea***	**348**	**108**	**251**	**35**	**35**	**35**	**35**	**139**	**138**	**139**	**139**	**0.0**	**0.0**
15	***Grewia villosa***	**32**	**9**	**18**	**3**	**3**	**3**	**3**	**12**	**12**	**12**	**12**	**0.0**	**0.0**
16	***Lanthana camara***	**12**	**2**	**4**	**1**	**1**	**1**	**1**	**4**	**4**	**4**	**4**	**0.0**	**0.0**
17	***Salvadora persica***	**4**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**0.0**	**0.0**
18	***Solanum carinensis***	**8**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**0.0**	**0.0**
	Total	**1624**	**871**	**1742**	**383**	**211**	**288**	**381**	**1532**	**844**	**1153**	**1526**	**8.8**	**0.0**

LVOL= Estimated true leaf volume (cm^3), ETTE= Evapotranspiration Tree Equivalent value (volume/500), LMAS= Estimated leaf Dry Mass (g), LM< 1.5m= Estimated leaf Dry Mass below a browsing height of 1.5 m, LM< 2.0 m= Estimated leaf Dry Mass below a browsing height of 2.0 m, LM< 5m= Estimated leaf Dry Mass below a browsing height of 5 m, BTE= Browse Tree Equivalent ((leaf DM/250), BTE< 1.5 m= BTE-value for leaf DM below a browsing height of 1.5 m, BTE< 2.0 m= BTE-value for leaf DM below a browsing height of 2.0 m, BTE< 5 m= BTE-value for leaf DM below a browsing height of 5.0 m, CSI= The area spanned by the tree canopy (m^2)