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Rangeland condition and feed resources in Metema District, North Gondar Zone, Amhara Region, Ethiopia

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Table of Contents

List of Tables

List of Figures

Abbreviations

ADF	Acid Detergent Fibre
ADL	Acid Detergent Lignin
AEZ	Agro-ecological Zone
ANOVA	Analysis of Variance
ANRS	Amhara National Regional State
AOAC	Association of Official Analytical Chemist
BOA	Bureau of Agriculture
CACC	Central Agricultural Census Commission
CBFS	Cotton Based Farming System
CRs	Crop Residues
CSA	Central Statistic Authority
DCP	Digestible Crude Protein
DM	Dry Matter
FAO	Food and Agriculture Organization of the United Nations
GLM	General Linear Model
ha	hectare
HHC	Household Count
HH	Household
ILCA	International Livestock Center for Africa
ILRI	International Livestock Research Institute
IVDMD	Invitro Dry Matter Digestibility
LSM	Least square mean
masl	Metre above sea level
ME	Metabolizable Energy
MOA	Ministry of Agriculture
NDF	Neutral Detergent Fibre
OoARD	Office of Agriculture and Rural Development
OM	Organic Matter
PAs	Peasant Associations
SE	Standard error
SBFS	Sesame Based Farming System
SPSS	Statistical Package for Social Science
SSA	Sub-Saharan Africa
SRM	Society of Range Management
t	tonne
TLU	Tropical Livestock Unit

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Abstract

The study was conducted in 2006/07 in Metema district, North Gondar Zone of Amhara region, Ethiopia, with the objectives to characterize the existing rangeland and to determine the feed resources utilization practices, to assess the natural grazing land condition based on herbaceous, woody and soil condition and to evaluate the chemical composition of major livestock feed resources of the area. A single-visit formal survey, group discussions and visual observations are used to collect the primary information and secondary sources are also used in livestock feed resources assessment of the district. A total of 140 respondents from 7 *kebeles* were selected for interviewing by stratified random sampling techniques. To assess the range conditions, the samples were collected by classifying the district into cotton–livestock and sesame–livestock farming systems. Within a farming system, grazing lands were further stratified into three sampling areas: communal, road side and enclosure grazing areas. In each of the range sites a sampling block of 4 km × 1 km was demarcated and this was further stratified into four sampling plots of equal size. In each of the plot, a belt transects of 50 m × 4 m was laid out randomly. Then, the parameter used for (herbaceous, soil and woody) grass species composition, basal cover, litter cover, soil erosion, soil compaction, seedling count, age distribution and woody density enumeration, canopy cover and hedging were determined. For the height classes <0–1 m, >1–3 m, >3–4.5 m and >4.5 m was used. Feed samples were stratified by season and types and subjected to chemical analysis for determination of DM, ash, CP, ADF, ADL and IVDMD. About 83% of the inhabitants in the district practice mixed crop–livestock farming system. The mean family size is 5.31 ± 0.20 persons per household, while the average land holding is 6.78 ± 1.33 ha/household. The mean livestock holding per household is 12.52 ± 6.23 TLU, and is composed of cattle, goats, sheep, donkeys and camels. Natural pasture (55.7%), crop residues (20.7%), stubble (14.3%) and hay (9.3%) are the major feed resources for dry season whereas in the wet season only natural pasture serves as feed resource. The total estimated DM yield of grazing land and stubble is 780,750 and 51,954 t DM per annum, respectively. The total estimated available feed supply is 833,531.2 t DM per annum. Of the identified 33 herbaceous species, 14 and 19 are different grasses and non-grass species. From the non-grass species 6 legumes and 13 sedges and other species are recorded. Of the grasses, 23.07%, 38.46% and 30.77% are highly desirable, desirable and less desirable, respectively. Of the identified 20 woody species, 15%, 35%, and 50% are highly desirable, desirable and less desirable, respectively. The largest proportion of woody vegetation is contributed by different species of acacia (20%) and commbretum (10%). Trees and shrubs grouped within the height class of >1–3 m constituted 41.2% in communal grazing areas, 38.5% in road side grazing and 33.3%

in enclosures. Range condition assessment factors such as basal cover, litter cover, grass species composition, woody vegetation density, canopy cover, hedging effect, age distribution and total condition score are significant ($P<0.05$) in communal grazing areas of the sesame–livestock than in the cotton–livestock farming system. The communal grazing areas have significantly ($P< 0.05$) higher values of grass species composition, basal cover, litter cover, age distribution, and woody species density score, than the road side grazing areas and lower ($P<0.05$) than the enclosure grazing areas. The dry matter biomass of grass, highly desirable, desirable species of grasses and legumes and others obtained in the same farming system were significantly ($P<0.05$) higher than the road side grazing types and lower ($P<0.05$) in total grass biomass, highly desirable grass, and total biomass than enclosure areas. The total dry matter biomass, dry matter biomass of grass and highly desirable grasses, and legumes are significantly ($P<0.05$) higher in the enclosure followed by communal grazing and the road side grazing areas. In general, there is low feed resources conservation and utilization and very poor traditional grazing land management system in Metema. The abundant feed resources in the wet season are wasted. In the dry season, grasses are turned to ash by wild and man-made fire in the process of forest honey harvesting and crop land cleaning. As a result, the livestock populations seriously suffer from the critical feed shortage during the long dry season. The rangeland, species composition and biomass production are also affected by human, livestock and natural factors (biotic and abiotic factors). The human population of the district has increased due to settlement programs, investment induced settlers, expanding crop cultivation and have increased the pressure on the rangelands and natural grazing areas. Bush encroachment and overgrazing are also serious problems. Shifting cultivation practice is also contributing to the increased bush encroachment. The seasonal movement and transhumant livestock production by highlanders in adjacent districts also increases the grazing intensity. Absence of adequate baseline information about the rangeland resources, unsynchronized seasonal availability of feed resources and cropland encroachment to the rangeland are some of the main constraints of the district, and studies on rangeland management systems and improved livestock production should be initiated.

1 Introduction

Ethiopia, with its diverse climate and topography, is a country with wide resources and traditional skill and experience in livestock rearing (Ayana 1999). About 62% of the total land surface in the country is suitable for grazing (Mengistu 1998). In most developing countries, rangelands have contributed to the major portion of feed consumed by ruminants. In Ethiopia more than 90% of the ruminant livestock feed on natural pastures, which vary in composition depending on the agro-ecology (Alemayehu 2005). Rangeland is defined as land producing natural forage for animal consumption (Coppock 1994). Most rangelands are at best only marginally suitable for arable cropping, and in Ethiopia there are extensive areas where livestock raising on the natural vegetation is the only possible types of land use.

The lowlands of the country are found below 1500 metre above sea level (masl) and are estimated to cover about 78 million hectares, which is about 61–65% of the total land area of the country (Friedel et al. 2000). They are home for about 12% of the human and 26% of the livestock population (Beruk and Tafesse 2000). Pastoral communities dominate the lowland areas of the country. Low human population density and highly variable and uncertain rainfall characterize the lowland areas. In the pastoral community, grazing biomass is entirely determined by the amount, pattern and timing of rainfall.

The rangelands are presently undergoing extensive deterioration both in quantity and quality (Belaynesh 2006). The rangelands have limited capabilities in vegetative production and in providing reasonable animal sustenance and production due primarily to adverse environments including low and seasonal rainfall; moisture gathering winds; varying degrees of poor soil; soil erosion; lack of or inadequate forage and grazing management; and overstocking rates (Alemayehu 2005). Intensity of grazing and browsing and restriction of livestock mobility have more serious consequences on the rangelands than the number of animals owned by the pastoralists. Community structure is vastly altered when improper grazing continues for long periods (Holcheck et al. 1998). In seasonally dry environments, the main limitations to animal production are the lack of green feed for at least half of the year coupled with the low nutritive quality of forages during most of the active pasture growth period (Alemayehu 2005). The low nutritive quality of the forage during the growth period is mainly due to environmental stresses such as high temperatures and infertile soils (van Soest 1988). The major determinant of livestock productivity is dry-matter intake which, in turn, is influenced by the palatability, chemical composition and physical attributes of the diet, provided that the livestock are disease-free. The chemical composition of the fibre is important in providing indications of fermentation rates. However, interactions between the environment and plant physiology and growth are sufficient to render associations between fibre components and nutritive value unreliable (van Soest 1988).

The Amhara Regional State is located in the northwestern part of the Ethiopia. The region covers about one-eighth of the total area of the country and is home to about 27% of the total human and 35% of the total livestock population (BoA 1999; Befekadu and Berhanu 2000). The study area (Metema) district is one of the 104 districts of the Regional State, which is found in North Gondar Administrative Zone bordering the Sudan. The district is broadly characterized as lowland agro-ecology, and livestock production is an integral part of the land use system. Cattle and goat rearing is a common practice. The area has relatively high potential natural pasture during the wet season (IPMS 2005; Elias et al. 2007) According to Sisay (2006), the major livestock feeds available in the study areas are natural pasture, crop residues, crop aftermath and hay. Based on his estimation, the mean utilizable DM biomass of crop residues in the study areas was 3.68 t per household. Furthermore, the total ME (Metabolizable Energy), and DCP (Digestible Crude Protein) produced in the district were 76,636.81 MJ and 736.75 kg, respectively which could satisfy the nutrient requirements of the livestock owned per household. These results may hold true for the wet season because of the availability of extensive grazing land in the area as compared to the district's livestock population. Feed shortage in the dry season is becoming a serious problem and the situation of the area is changing very fast because of the current resettlement program and the large number of seasonal transhumant livestock movement from the neighbouring three highland districts (Chilga, Dembia and Gondar Zuria) into the district. The population pressure is undoubtedly increasing resulting in deforestation, encroachment of farmlands into forest areas, and diminishing grazing lands. The poor feed conservation practice of the community has also resulted in decline of the potential of the rangelands and has exacerbated the feed shortage, particularly during the dry season. According to Sisay (2006), the number of livestock and the available feed resources is not proportional to be beneficial for livestock rearing.

Absence of adequate baseline information about the rangeland resources is considered as one of the bottlenecks for development of rangelands in Ethiopia (Amsalu 2000). Thus, to ensure sustainable use and development, characterization of the rangeland condition, assessing and identifying the major feed resources of the area is imperative. This study was therefore undertaken to generate information on the rangeland resources, to characterize the existing rangeland, to assess the natural grazing land condition based on herbaceous, woody and soil condition, to determine the major feed resources, to evaluate their nutritive value and their utilization practices, and to forward suggestions for future sustainable management of the rangelands. A number of districts in Tigray and Amhara Regional States have similar agro-ecology to Metema, and the results of this study will have broader relevance to the large area of the lowlands of northwestern Ethiopia.

2 Background

2.1 Livestock resources in Ethiopia

Although statistical data on livestock in Ethiopia have never been consistent, the latest estimates indicated that Ethiopia has the largest livestock population and the highest draught animal population in the African continent. Data on Ethiopian livestock resources are presented in Table 1. Despite its huge numbers, the livestock subsector in Ethiopia is not as productive as compared to its great potential and the direct contribution to the national economy is very limited. The poor genetic potential for productive traits, in combination with the suboptional general management situation that the animals are exposed to are the main contributors to the low productivity.

Table 1. *Livestock population and regional distribution in Ethiopia*

Region	Thousand heads				
	Cattle	Sheep	Goats	Equines	Camels
Tigray	3103	1376	3107	476	32
Afar	473	403	801	26	171
Amhara	12,748	8987	6022	2438	50
Oromia	2245	9098	7439	3738	255
Somali	620	1162	283	96	24
Benishangul Gumuz	411	84	321	49	–
SNNPR	9263	3838	2626	732	–
Gambela	130	17	31	–	–
Harari	44	4	36	8	–
Dire Dawa	48	43	122	13	5
Ethiopia—Total	49,297	25,017	21,884	7209	759

Source: CSA survey (2008/09).

2.2 Rangelands of Ethiopia

Natural vegetation integration reflects the whole of the natural environment. If topography, geology and soil are not altered markedly, the change in vegetation usually reflects a change in rainfall (Alemayehu 2005; Abule et al. 2007a). Basically, the vegetation of an area is a product of the material available and the environmental conditions prevailing. The latter includes the environment, landform, soil, climate and factors such as fire and grazing and modification, circulation of minerals and plant decay. Furthermore, for a complete understanding of vegetation, it is necessary to consider the past as well as the present, for each sample of vegetation have a history and a background of plant colonization and succession. Often, of course, the present vegetation represents a stage of regression from a more highly developed or vigorous community that has been brought under stress, perhaps through overgrazing.

The pastoral rangelands of Ethiopia are located around the peripheral or the outer edge of the country, almost surrounding the central highland mass (Alemayehu 2004). The areas are classified as marginal arable and non-arable land and comprise about 62% (767,600 km[2]) of the country's land area. Most of these areas are below 1500 metres above sea level (masl) with the southwest and the southeastern areas having an altitude of around 1000 masl and the southeastern and southwestern rangelands rising up to 1700 masl (Kidane 1993). Climate in the lowlands includes arid (64%), semi-arid (21%) and subhumid (15%) zones largely defined by four rainfalls and temperature regimes. These zones vary markedly in terms of number of plant growing days per year, forage production, common plant associations, livestock and human carrying capacities and incidence of important livestock diseases. Ethiopia has over 70 million heads of livestock, and the lowlands are home to 12% of the human and 26% of the livestock population (CSA 2009). Various forms of pastoralism and agropastoralism dominate. Livestock depend upon rangelands consisting of native vegetation, with crop residues increasing in importance as livestock feed as annual rainfall increases. According to Coppock (1994), calculated for the lowlands overall, roughly six people/km^2 are dependent on 11 Tropical Livestock Units (TLUs), which are composed of cattle (49%), goats (16%), equines (16%), camels (12%) and sheep (7%). In contrast, the highlands support 72 people/km^2 and dependent on 44 TLUs/km^2 which are dominated by cattle (76%), equines (14%), sheep (8%) and goats (2%). Thus, although the lowlands comprise over 50% more land area than the highlands, the lowlands have only 40% as many TLUs at one-quarter the density.

2.3 Major livestock feed resources in Ethiopia

The major livestock feed resources in Ethiopia are natural grazing and browse, crop residues, improved pasture, and agro-industrial by-products (Alemayehu 2004). The feeding systems include communal or private natural grazing and browsing, provision of crop residues and cut-and-carry feeding. At present, stock are fed almost entirely on natural pasture and crop residues. Livestock are grazed on permanent pastures, fallow land and cropland aftermath (Alemayehu 2004; Abule et al. 2007a).

2.3.1 Feed availability and nutritive value of range forage

Feed availability

Natural pasture comprises the largest feed resource and estimates of its contribution to overall feed resource vary greatly. This is because the quantity and quality of native pasture varies with altitude, rainfall, soil and cropping intensity. Seasonal fluctuations of feed resources in the tropics also follow the pattern of vegetation growth which is modified by availability of rainfall. Alemayehu (1998) estimated that about 80–85% of the ruminant feed in Ethiopia comes from natural pasture. The total area of grazing and browsing is estimated at 62,280 million hectares, of which 12% is in the crop farming areas (with more than 600 mm rainfall) and the rest around the pastoral areas (Alemayehu 2005). Communal grazing is managed as a common property resource. Estimating carrying capacity, if calculated on plant availability, should allow a plant use of 30–50% (de Leeuw and Toothill 1993). Important principles of rangeland management that affect feed availability include stocking rate, rest, frequency of grazing, top hamper and litter cover (Alemayehu 2005; Abule et al. 2007a). Trees are an important component of the rangelands and serve for environmental conservation; provide fuel wood and building materials. They are also important source of feed for browsers and their value of tree litter as feed and shade to livestock should not be underestimated (Alemayehu 2005; Abule et al. 2007a).

Feed quality

Chemical analysis of range forage plants serves as a comparative measure of differences between species and changes with season. Chemical analyses are also useful for measuring differences on effect of stage of growth, and effect of site quality on chemical constituents**.** Simbaya (1998) reported that the quality of natural pastures is influenced by the absence of legume species in communal grasslands. This limits the nutritional quality of available fodder and animals are thus unable to meet their protein, energy and mineral requirements. As suggested by Osuji et al. (1993), poor nutrition is one of the major constraints to livestock productivity in sub-Saharan Africa. This is because animals thrive predominantly on high-fibre feeds (straws, stover and native pasture hay) which are deficient in nutrients (nitrogen, sulphur, minerals, phosphorus etc.) essential for microbial fermentation. Consequently, the digestibility and intake of digestible nutrients are unavoidably low. Data on chemical composition of major feed resources as affected by season in Metema district are presented in Table 2.

Table 2. *Nutritional quality of major feed resources in Metema district as influenced by season*

Feed types	Season	% chemical composition						
		DM	ASH	CP	ADF	ADL	NDF	IVDMD
Natural pasture	August	93.4	9.4	6.4	45.8	4.7	78.3	57.8
	October	94.1	10.3	5.7	47.8	5.5	78.5	56.9
Fodder	August	92.3	15.4	14.4	37.0	13.3	54.9	51.6
	October	92.9	8.6	13.2	40.6	13.2	54.5	47.9
Hay		94.5	10.5	7.2	41.2	4.8	76.8	54.3
Sorghum stover		92.4	7.9	3.1	44.9	6.3	75.5	46.9
Teff straw		93.2	8.9	4.3	46.9	8.0	76.0	41.0
Millet stover		92.4	9.8	4.2	44.2	5.9	72.3	52.8

Source: Sisay (2006).

Range forage varies in quality from time to time and from place to place. Plants are most nutritious during the growth stages. Once mature, plants are subject to leaching and dilution of nutrients and reduction in nutritive value. Declines in nutrient composition and leaching are especially serious in the case of herbaceous plants (Alemayehu 2006). As plants mature, contents of crude protein, readily digested carbohydrates and phosphorus decrease, while contents of fibre, lignin and cellulose increase (Osuji et al. 1993). Most grasses and tree leaves in arid environments are low in nutritive value because of high contents of lignin and relatively indigestible (compared with starch) cellulose and hemicellulose. The plants require such substances as an adaptation mechanism to protect themselves from high temperatures and evapotranspiration. Unfortunately, these substances reduce their nutritional content and digestibility (Mathur et al. 1991). The stage of growth, maturity of grasses and taste influence their nutritional value. Mathur et al. (1991) reported that cattle kept solely on grazing mature grass exhibited loss in body weight during the dry season. The use of some roughages is also limited by their low contents of protein and digestible energy (Ncube and Mpofu 1994), especially as the season progresses. Further problems are caused by secondary factors such as antinutritive or toxic constituents in the plants, which restrict acceptability of the diet (Osuji et al. 1993; Kumar and D'Mello 1995).

Crop residues are roughages that become available as livestock feeds after crops have been harvested. Residues can usually be grouped by crop type such as cereals, grain legumes, roots and tubers. Apart from being a source of animal feed, residues are also used as building, roofing and fencing materials, as fuel, and as fertilizer or surface mulch in cropland. Their value when used as feed depends on the demand from livestock owners, which varies with the overall supply and demand situation for feeds. This in turn depends on the livestock density and the supply of other feed resources, in particular forages and browse from natural vegetation (de Leeuw and Rey 1995). The supply of crop residues is a function of the proportion of land used for cropping and of the edible feed yields per unit of land, where consumable feed from the crop residues exceeds grazing from natural pastures (expressed in tonne of dry matter per hectare, t DM/ha). Depending on the production system, expansion of cropland may have a positive effect on overall feed supply

2.4 Causes of rangeland degradation

Rangeland degradation may be defined as the loss of utility or potential utility or the reduction, loss or change of features of rangeland ecosystem, which cannot be replaced (Chrisholm and Dumsday 1987). In general, rangeland degradation implies a reduction in rank or status, which includes a loss of topsoil, a change to a simple floral/

fauna composition or a transition from one organic form to a lower organic form, and continuous reduction of productivity/biomass of the ecosystem. Generally, a lower biological diversity is supposed to occur in a degraded rangeland.

2.4.1 Drought and shortage of rain

Prolonged drought including shortage and erratic rainfall can cause serious range degradation. Rainfall during drought is hardly adequate to allow grasses to grow and unable to fill the surface water ponds (Cossins and Upton 1988).

2.4.2 Bush encroachment

Overall, woody vegetation reduces grass cover through increasing competition for available water and nutrients and reducing light reaching the grass layer. In addition to competing with grasses, these noxious woody plants are commonly thorny and thicket forming and reduce the grazing capacity of the rangeland (Alemayehu 2004). From rangeland management perspective, understanding the factors that contribute to invasion process of undesirable woody vegetation is important. Many factors may be involved in bush encroachment. Overgrazing, including high stocking rates, is claimed to be the major problem and a high concentration of woody plants are found around water points where stocking densities and grazing intensities are relatively high (Cossins and Upton 1988). As reported by Archer (2003), the characteristics common to many woody species that increase in grazed environments include high seed production, seeds that persist in soil for many years, ability to disperse over long distances, ability to sprout following top removal, tolerance to low levels of water and nutrients and low palatability. A report by Alemayehu (2004) indicates that the ecological succession in the Borana rangelands of Ethiopia indicates that the potential of grassland is threatened by bush encroachment in many areas.

2.4.3 Over population and overstocking

Increase in human population necessitates the increase in livestock population in rangelands in order to maintain survival. In pastoral areas of Ethiopia, the animal and human populations are growing at an increasing rate, while the pasture resource on which they depend is limited or diminishing both in terms of grazing area and range productivity (Coppock 1994). These increases in population and over stocking are increasing the imbalances in the Borana range system and have already resulted in over grazing and range degradation (Alemayehu 2004). Gamedo (2004) also reported that overgrazing has been one of the major factors for rangeland degradation in Borana and the relatively good rangeland condition in ranches and *kalos* may show the fact that overgrazing has contributed to rangeland degradation.

2.5 Factors affecting rangeland vegetation

2.5.1 Climate and soil

Climate plays a primary role in determining the main types and growth responses of vegetation used for grazing (Alemayehu 2004; 2005). The amount and distribution of rainfall determine the form and productivity of the natural vegetation. Edaphic characteristics may substantially modify climatic factors in various ways. High natural soil fertility levels increase the vegetation's response to moisture while soil volume and water holding characteristics condition the soil water storage capacity. Surface characteristics determining run-off and infiltration of water, and subsurface characteristics determined the level of drainage. Over grazing can lead to bareness and loss of topsoil by erosion to such an extent that the vegetation assumes a drier appearance than the rainfall data suggests.

2.5.2 Animal management

Livestock grazing can have profound impact on vegetation. The general pattern of grazing-induced vegetation change is well documented (Alemyehu 2004; 2005). It is known that less palatable plants increase at the expense of more palatable species. Community structure is vastly altered when improper grazing continues for long period. The poor animal production experienced in rangelands has long been attributed to the poor quality of forage. This is generally confirmed by chemical analysis of the range plants. However, sampling of such material often overlooked selective grazing by animals between species and deferent parts of species and selectivity is of considerable importance (Holechek et al. 1994).

2.6 Factors influencing vegetation composition of the rangeland

The species composition of rangeland varies depending on topography, climate and soil types. Different grasslands contain various types of grasses, legumes, and other herbaceous species. The botanical composition of a plant community can change because of many factors, including altitude, grazing practices, burning, drought, and temperature effects, pest, and erosion. Depending on the nature of this compositional change, the productivity of an area (in terms of its capacity to support livestock) may change. A change in plant composition results because of the relative adaptability of different species to these influences (Alemyehu 2004; 2005).

2.6.1 Effects of grazing on vegetation composition

Natural pasture communities are very complex consisting of a large range of grasses, shrubs and herbaceous species among which only few species are palatable. Livestock are able to selectively graze a small proportion of the palatable herbage available and ignore the undesirable ones. The most palatable species are selected first and closely defoliated. If the grazing pressure is high, then a decline in the quality and productivity of rangeland occurs (Cossins and Upton 1985). This causes reduced vigour, less seed production and eventually plant death. Overgrazing can also lead to extensive sheet and gully erosion (Alemyehu 2005). Since the whole of plant organism, leaves, stems, and roots react to the degree of trampling or grazing which it receives, a weakening of the top growth results in a lighter short root system that dies back from the bottom. Grass roots continue normal growth when not more than about 40–50% of the vegetative parts are removed (grazed) during the period of active growth. Therefore, the effects of overgrazing can be overcome if rangelands are properly managed. According to Laze and Swain (1969), grasses naturally need certain rest periods to develop, to grow, to seed and to be able to build reserves for the next growing season.

2.6.2 Response of plants to grazing

The response to grazing by various plants is dependent on the reduced vigour of plants grazed repeatedly without the opportunity to replenish food reserves. It is also based on the high degree of selectivity exhibited by grazing livestock. Cattle prefer grasses, sheep prefer forbs, deer prefer browse. Within each category, there are ice-cream plants (decreasers), which the grazing animal will seek out. Repeated grazing will have the same effect as repeated clipping. A third factor independent of the plant–animal interaction is the presence or absence in the climax plant community. The classification of decreaser and increaser is based largely on the preference exhibited by the livestock. This is dependent on two major criteria: (1) the range site and (2) the livestock. The range site is important because it limits the selectivity available. This explains why some plants are decreasers on one site and increasers on another. In the first case they are the most palatable species, while in the second there are other plants that are more palatable. The kind of livestock will determine general categories of preference.'

2.7 Range condition assessment

Range condition is the present status of vegetation of a range site in relation to the climax (natural potential) plant community for that site. It is an expression of the relative degree to which the kinds, proportions, and amounts of plants in a plant community resemble that of the climax plant community for the site (SRM 1999).

According to Pratt and Gwynne (1977), range condition is the state and health of the range, which can be assessed on the basis of an area's vegetation composition, plant vigour, ground cover and soil status. The concept of 'condition' implies that an optimal or desired vegetation cover (in terms of quantity and composition) exists for each particular land system. However, since it will often be uncertain what the desired or 'optimum' condition is (particularly in areas which have undergone misuse for a considerable period of time), and since optimum range condition will differ according to the manner in which the range is used (e.g. cattle, sheep, wildlife), the comparison used should be clearly stated as well as whether this is based on actual measurements or whether it is assumed. As cited by Amaha (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 (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, and 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 (DuToit and Aucamp 1985) and to assess the rangeland condition (van der Westhuizen et al. 1999; 2001). Methods of classifying range condition have emphasized species composition, growth form composition, forage productivity, a combination of a number of different vegetation and soil attributes, such as cover, composition, vigour, palatability, litter and soil stability.

If overuse is excessive or continued over long periods of time, invaders or undesirable plants are found. The invader plants were thought to be absent in the original vegetation but through grazing pressure have replaced the decreaser and increaser plants. In favourable years invaders can provide considerable forage for a short period of time but sound range management cannot be based on this uncertain forage production.

The four classes of range condition are based on production percentages of decreaser and increaser plants present on the site as compared to the original vegetation. A site composed of decreasers and increasers indicates a high condition range. As decreasers on the site are replaced with increaser and invader plants, the site shows need of improvement. The four range condition classes are as follows:

Excellent condition: 76–100% of allowable vegetation is mixture of original highly palatable, desirable perennial decreasers and increasers. Legumes and desirable forbs may be present.

Good condition: 51–75% of vegetation is mixture of original highly palatable, desirable perennial decreasers and increasers. Some legumes and forbs may be present.

Fair condition: 26–50% of allowable vegetation is mixture of original highly palatable, desirable perennial decreasers and increasers. Some legumes may occur, but most forbs are increasers and invaders. Overall vegetation appearance is shorter and amount of bare ground is increasing.

Poor condition: less than 25% of all vegetation is composed of highly palatable, desirable perennial decreasers and increasers. Invader plants and unallowable increasers comprise majority of vegetation.

2.7.1 Estimating range condition

Range condition refers to the present ecological status in terms of productivity of a vegetation community relative to its natural potential for particular range site and types of land use (SRM 1999). In other words the concept 'condition' implies that an optimal or desired vegetation cover (in terms of quantity and composition) exists for each particular land system. Range condition is based on the species composition of the plant community as estimated by the percentage of the total annual air-dry weight of each species. Species must be classified as decreasers, increasers, or invaders. Each species has an allowable percentage that occurred in climax.

2.7.2 Range sites

Before range condition can be assessed the range sites must be located. Range sites are the basic unit of land for practical use. Ideally, each range site should respond in the same manner to climatic variation, have uniform topography and productivity and respond uniformly to experimental treatment (Alemayehu 2006).

2.7.3 Range trends

The direction of change in ecological status or resource value rating observed over time (SRM 1999). It describes the current health of the range, and then range trend indicates whether it is getting better, worse or staying the same. Consequently, range trend is the best single indicator of the success or failure of current management practices. It can be determined by two range condition determinations. However, changes in range condition can be fairly slow and the ability to properly estimate range condition has sufficient error to require that meaningful changes must be based on readings at least five years apart. This is too long; management must be evaluated over shorter periods of time. Indicators of trend are very useful tools.

2.7.4 Range condition classification

Range condition classification is often included in a range inventory. Changes in range condition scores overtime are usually the basis for monitoring management effectiveness. Range condition classification provides an induction of management inputs necessary. If ranges are in good or excellent condition, maintaining them in a stable condition may be the best management strategy. However, if they are in poor or fair condition, management, that is aimed at 'improvement' may be indicated. Generally, four or five condition classes are recognized: excellent, good, fair and poor. Sometimes a fifth category is added. Many approaches have been used to determine range condition on different range sites or habitat types. Dyksterhuis (1949 1958) developed the most familiar method. This approach is ecological, in that range condition is measured in degree of departure from climax. The approach assumes that climax can be determined for each range sites. Excellent class would represent climax, i.e. excellent (76–100); good (50–75); fair (26–50); and poor (0–25). Originally, species occurring on each site were classified, by their reaction to grazing, as decreasers, increasers, or invaders. Dcreasers are highly palatable plants that decline in abundance with grazing pressure. Plants classified as increaser I types are moderately palatable and 'serve as secondary forage plants'. They may increase slightly, or remain stable under moderate grazing condition and reaches fair condition, they also decline. Other plant species present in the climax vegetation but that are unpalatable may increase under grazing pressure or as site deterioration occurs. These species are classified as increaser II plants. Invaders are species that encroach on to the sites from adjacent sites in a later stage of deterioration. Type I invaders may eventually decrease if forced utilization occurs at later stages of deterioration; while type II invaders are generally unpalatable and increase even at the final stages of deterioration.

2.8 Biomass estimation methods

Biomass or standing crop usually refers to the weight of organisms present at one time (SRM 1999). Increases in biomass through growth process of photosynthesis over time are generally considered productivity estimates that include a time dimension. In the English system biomass is generally expressed in pound per acre, and in the metric system, kg per hectare. Productivity estimates would include a unit of time (e.g. annual per day, week, month etc.). Most estimates of plant biomass or standing crop include only that above the soil surface. This material is commonly available to larger herbivores. Below ground biomass is very important for plant functions, but is difficult to measure and generally not included in inventory or monitoring procedures. Direct harvesting is considered the most reliable method of determining above ground biomass. However, this method is too time-consuming to be of practical value for inventory or monitoring of extensive range areas. Several weight estimate techniques have been developed for rapid and fairly reliable determination of herbage weight. These procedures involve estimating herbage weight by species from small quadrates in the field. Training of observers in the field is necessary. This can be done easily by checking the estimates with clipped quadrate (Alemayehu 2005). The method is considered reliable enough to be used on detailed research studies. Weight estimates can be adjusted by clipping a portion of the quadrates that have been estimated.

3 Materials and methods

3.1 Description of the study area

3.1.1 Location, climate and topography

The study was conducted in Metema district, North Gondar Zone of Amhara Regional State (Figure 1). Metema is located between 12°40′00″ N and 36°8′00″ E. It is 925 km northwest of Addis Ababa and 180 km west of Gondar town. The district has an international boundary of more than 60 km long distance between Ethiopia and Sudan. It has 18 rural and 2 urban *kebeles*. According to IPMS (2005), out of the total 18 rural *kebeles* in the district, 16 are under moist *kola* and the remaining two *kebeles* are dry *kola*. Mean annual temperature ranges from 22°C to 28°C and daily temperature reaches as high as 43°C during the months of March to May. Mean annual rainfall ranges from 850 mm to 1100 mm (IPMS 2005) and has unimodal pattern. The rainy months extend from June to end of September. Altitudes range from 550 to 1068 masl.

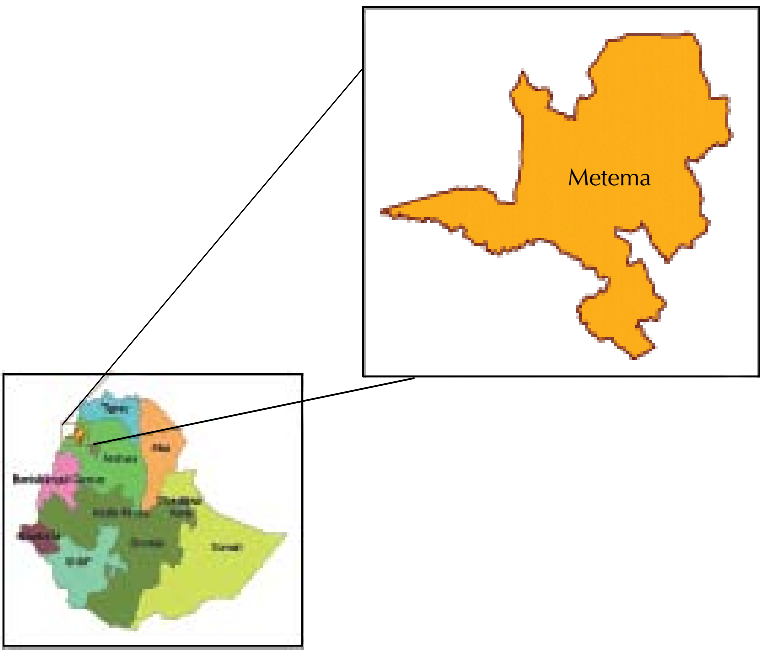

Figure 1. *Location of Metema* woreda *in Ethiopia.*

3.1.2 Human population and livestock resources

According to CSA (2005), the human population in the *woreda* is estimated at 76,084 rural (54.2% male) and 18,467 urban (50.0% male). The majority of the population (80%) lives in rural areas with farming as a major occupation. The original residents of the area are the Gumuz people. Until recently, they practised slash and burn and hunting wild animals. The area has been gradually populated by settlers from the highlands. According to OoARD (2007), through a new resettlement program, the government has settled a total of 33,159 people between 2003 and 2005.

Livestock production was an integral part of the land use system. Production of cattle for draught power, milk, and meat; small ruminants for income and meat and donkeys and camels for transport and poultry for income is a common practice. The livestock population is composed of 136,910 cattle, 32,024 goats, 1686 sheep, 7164 donkeys, 7127 poultry, 400 camels and 23,789 beehives (OoARD 2007). Transhumance production system was commonly practised by the highlanders. According to Azage et al. (2008), about 80% of the inhabitants of the highland Chilga, Dembia and Gondar Zuria districts trek their livestock to Metema in search of feed during the main rainy season from May to October. The major cattle breed of the study area is Fogera crossbred with other highland zebu cattle. Ruthana cattle originally from Sudan and Felata cattle from Niger and Nigeria also constituted smaller proportion of the cattle population. The main small ruminant resource is goat production. There is a small proportion of sheep population locally known as the 'Gumuz sheep'. Important livestock diseases include infectious diseases, internal and external parasites.

3.1.3 Land use and farming systems

According to OoARD (2007), land use pattern of Metema district is comprised of forest and rangelands 72.0% (312,300 ha), cultivated land 23.6%, (103,908 ha of which 71,324 ha, 13,908 ha and 18,676 ha are smallholder farms, commercial farms, and potential cultivable land, respectively), and uncultivable land 5% (23,877 ha). About 60% of the district is plain, and 20, 15, and 5% are sloppy, undulating and valley bottoms, respectively.

Cotton–livestock farming system

According to IPMS (2005), 4 out of the 18 peasant associations (PAs) belong to this farming system. They are Maka, Awlala, Genda Wuha and Kemechela. They are found in the northeastern part of the *woreda*. These PAs predominantly grow cotton followed by sorghum and sesame in few areas. The PAs in this farming system have some different features in terms of suitability for crop production and amount of rainfall received. These PAs are relatively cooler in temperature and have higher altitude and rainfall. Most of the area is flat with black Vertisol and have water logging problem. As a result, the area is suitable for growing cotton and rice. Farmers in these PAs practice slightly early planting of crops. Cotton is grown in bigger plots, while sorghum and sesame are planted in very smaller areas. The primary and secondary sources of income in this farming system were crops (97.7%) and livestock (97.6%). Off-farm activity was the third important source of income for 82% of the respondents.

Sesame–livestock farming system

Fourteen PAs belong to this farming system, and sesame, cotton and sorghum are the major crops produced (in order of importance). Altitude (550 to 700 masl) and rainfall (700 to 900 mm) in this farming system is lower than the cotton–livestock farming system. The underground water table is high, and in some places water could be obtained at less than 10 m depth. In addition, there are three rivers in this farming system that could be used for irrigated crop production and livestock rearing. Extensive grazing areas and natural gum and incense trees are found in this farming system. Sorghum is an important crop and it is the main food crop for all smallholder households and labourers in commercial sesame and cotton farms. The major sources of income in this farming system were crops (95.2%), livestock (84.8%) and off-farm (57.1%).

3.2 Selection of *kebeles* and farmers

A single-visit formal survey method (ILCA 1990) was used to collect information on livestock feed resources and rangeland utilization practices in the district. A total of 7 *kebeles* were selected randomly out of the total 18 *kebeles*. Then, a total of 140 respondents were selected using purposive sampling technique and interviewed for collection of primary data. A structured questionnaire was prepared as per the objective of the study and was pre-tested. In addition, observations, group discussions with elders, development agents and key informants were undertaken. Secondary data were reviewed and browsed to consolidate the information.

3.3 Rangeland condition assessment

3.3.1 Range sites selection and sampling procedures

Discussions were made with the community members, elders and agricultural experts about the locations and conditions of major grazing areas in the two farming systems. Short visits were made to these sites for assessment. The number of sites was then decided based on proportions of the available grazing land within farming system. Categories of the grazing lands were further stratified into three sampling areas: communal grazing, road side and enclosure using the systematically stratified random sampling technique.

Enclosures used as benchmark was selected from protected areas in schools and government protected acacia wooded grass land for sesame–livestock farming system. The road sides were selected 200 metres away form the main road to avoid any edge effect. Road side grazing lands were selected because they are exposed to continuous grazing and trampling by transhumants and inhabitants.

In each site, a sampling block of 4 km × 1 km, considered homogenous and representative of the vegetation cover under investigation, was demarcated. This was further stratified into four sampling plots of equal size (1 km × 1 km each) in order to encompass vegetations of herbaceous and woody layers. In each plot, a belt transects of 50 m × 4 m was laid out randomly. A total of 68 composite samples (24 from communal and 24 from road side) for herbaceous and 21 composite samples for woody vegetation were collected from both farming systems. In enclosure areas, 8 and 12 sampling units were used in cotton–livestock and sesame–livestock farming systems, respectively. The numbers of quadrates laid in the composite sampling units differed according to the proportion of the grazing areas and the factors assessed. For grass species composition, three and four quadrates per one composite unit were used in the cotton–livestock and sesame–livestock farming systems, respectively. For woody vegetation assessment three belt transects per one composite sampling unit was used in both farming systems. For biomass estimation four quadrates per one composite sampling unit was employed in both farming systems. Compass and GPS were used to measure the transect locations and coordinates. Sampling was done from 10 August to 10 September 2007 when almost all the pasture plants were fully-grown with over 50% at flowering stage.

3.3.2 Species composition assessment

At each sample site, the composition of herbaceous species was assessed by harvesting three or four quadrates of 1 m × 1 m area (depending on the homogeneity and heterogeneity of the range sites) randomly by throwing a quadrate each time towards the back and the herbaceous species within the quadrates and this was cut to ground level. The sample was weighed immediately using a spring balance and was transferred into properly labelled paper bag and fasten at the top. Samples were kept under a shade until sampling for the day was completed. Each of the sample in the paper bag was then hand separated into different species and separately weighed again. Subsequently, samples were sun dried. Dry matter (DM) of each species was determined in an oven (60ºC for 72 hours) at the ILRI laboratory Addis Ababa and the percent composition of each species were determined on DM weight basis (ILCA 1990).

3.3.3 Identification of plant species

For identification of species, representative plants with flowering head and other vegetative parts from each species were collected and dried in presses. After drying, the specimens were mounted. Very few common species were identified right in the field (Azene et al. 1993) and specimens were coded and transported to the National Herbarium of Addis Ababa University for final identification.

3.3.4 Range condition assessment

The rangeland condition was assessed considering the three layers (grass, woody, and soil factors) based on the suggestion made by Friedle (1991). For grass and soil layer factors, the criteria developed in South Africa (Tainton 1981) and adapted to fit semi-arid and subhumid environments by Baars et al. (1997) was used. Woody vegetation layer was assessed using density enumeration based on the suggestion of Pratt and Gwynne (1977) for east African rangelands. The assessment factors were based on the composition of the grass layer, basal cover, litter cover, soil erosion, soil compaction, and woody vegetation density (Appendix Table 1) summing up to a total of 50 points, the overall rating of vegetation was interpreted as excellent (65–58.5 points), good (47.5–41 points), fair (40–33.5 points), poor (32.5–26 points), very poor (≤ 25 points) (Baars et al. 1997).

3.3.5 Herbaceous species composition

For herbaceous (mainly grasses) species composition, 1 to 10 points were considered. Grass species were divided into desirable species likely to decline with heavy grazing pressure (deceasers), intermediate species likely to increase with heavy grazing pressure (increasers), and undesirable species likely to invade with heavy grazing pressure (invaders), according to the succession theory (Abule et al. 2007). Classification of grass species into these three categories was done by conducting detailed interview with members of the local community about the palatability and distribution of each identified grass species in relation to the intensity of grazing, and cross checking with the list of grasses from the literature.

3.3.6 Basal and litter cover

For basal and litter cover a score rating of 0 to 10 points were considered as indicated in Appendix Table 1. A representative sample area of 1 m^2 was selected for detail assessments of basal and litter cover. For the surface of basal cover of tufted grasses, the distribution was assessed as follows: The 1 m^2 was divided into halves, one of which was again divided into eighths. All plants in the selected 1 m^2 were removed and transferred to the eighth to facilitate visual estimation. Only basal cover of living parts was considered. The rating of basal cover for tufted species was considered excellent if the eighth was completely filling (12.5) or very poor if the cover becomes less than 3%.

3.3.7 Number of seedlings and age distribution

The number of seedlings was counted in three randomly selected areas, each the size of an A4 paper (30 cm × 21 cm) (Appendix Table 1). An A4 paper was dropped from an approximate height of 2 metre above the ground and the number of seedlings within the paper was counted. The category: 'no seedlings', was given 0 point, and more than 4 seedlings were given the maximum score of 5 points. Similarly, if all age categories, i.e. young, medium and old plants of the dominant species are present, a maximum score of 5 points was given. If there were only young plants, then the minimum score of 1 was given (Appendix Table 1).

3.3.8 Woody vegetation layer

In woody vegetation assessment, species composition, density, canopy cover, plant height and hedge effect were considered. All species in the belt transect of 50 m × 4 m were recorded and identified. The desirability and palatability of each species was recorded based on group discussion with livestock owners with respect to the woody plants sensitivity to grazing, abundance and preference by livestock as feed. This discussion was supported by literature (Azene et al. 1993). The criteria developed by Kuchar (1995) were used for scoring the percent of canopy cover of woody species. Height of a particular species in the belt was measured using calibrated poles of appropriate sizes for different woody species and five height classes (>0.5–1 m, >1–2 m, >2–3 m, 3–4 m and >4–5 m) were employed (Amaha 2006). The density of woody species were enumerated from each belt transect of 200 m^2 area. Only live woody plants regardless of being single or multiple stemmed were counted and recorded to estimate the woody vegetation density.

The number of trees/shrubs per plot area was determined and the lowest score (0 point) was given for the highest density: i.e. 0 = > 5000/ha, 1 = 4001–5000/ha, 2 = 3001–4000/ha, 3 = 2001–3000/ha, 4 = 1001–2000/ha, and 5 = 0–1000/ha (Abule 2003). The percent canopy cover of the species in the belt transect was measured using a tape meter. The ratio was computed as the measured canopy area by the remaining tape length and the result percentage canopy cover was rated by the criteria developed by Kuchar (1995).

The rates given for cover in the range of 1–5 points, for woody covers of >45%, 36–45%, 26–35%, 15–25% and <15% points of 5, 4, 3, 2, and 1 were given, respectively. Hedging was estimated visually based on the state of palatability of the species. The rating of hedging effect for woody species (1–5 points) was based on criteria developed by Kuchar (1995).

3.3.9 Soil erosion and compaction

Soil erosion was evaluated based on the amount of pedestals (higher parts of soils kept together by plant roots, with eroded soil around the tuft) and in severe cases the presence of pavements (terraces flat soil, normally without basal cover, with a line of tufts between pavements). Soil compaction was assessed based on the amount of capping (crust formation) scoring of 0–5 points (Appendix Table 1).

3.4 Evaluating the quality of major feed resources

3.4.1 Sample preparation

Representative samples of the major feed resources were collected. The samples were stratified based on type and season. For each season, samples of the same feed type were bulked and then thoroughly mixed and subsampled. Finally the subsamples were oven dried at 65ºC for 72 h, and ground in Willey mill to pass through 1 mm sieve and were kept in air tight containers pending analysis for chemical composition (van Soest 1988).

3.4.2 Laboratory analysis

Feed samples were analysed for DM and ash using the method of AOAC (1990). Nitrogen (N_2) is determined by micro-Kejeldhal method, and then CP (crude protein) was calculated as N × 6.25. Neutral detergent fibre (NDF) and acid detergent lignin (ADL) were analysed by the method of van Soest et al. (1991). The method of Tilley and Terry as modified by van Soest and Robertson (1985) was used to determine IVDMD.

3.5 Statistical analysis

Data on various aspects of livestock feed resources were analysed using Statistical Packages for Social Sciences (SPSS 2003). Descriptive statistics (mean, percentage, range, standard error of means) were calculated. For range condition assessments, 68 composite samples for herbaceous species and 21 composite sample units respectively, and all in all 89 composite sample units (Table 3) were subjected to analysis using the General Linear Model (GLM) procedure of SPSS version 12. One-way analysis of variance (ANOVA) was used for variables of range condition. Correlation analysis was used to test if there were relationships between rangeland degradation, biomass production and vegetation variables.

Table 3. *Experimental units used for analysis in each composite sample site*

	Farming system	Grazing type			
		Communal	Road side	Enclosure	Subtotal
Herbaceous layer	CLFS	12	12	8	32
	SLFS	12	12	12	36
	Total	24	24	20	68
Woody layer	CLFS	4	4	2	10
	SLFS	4	4	3	11
	Total	8	8	5	21

Composite samples = 89; SLFS = sesame–livestock farming system, CLFS = cotton–livestock farming system.

4 Results and discussion

4.1 Socio-economic conditions

4.1.1 Household characteristics

Sex, ethnic group, education, and major occupation of respondents under the two farming systems in Metema district are presented in Table 4. Overall, 87.1% of the respondents are male, 10% spouses, 1.4% sons and 1.4% are daughters. From overall respondents, 88.6 and 11.4% are male and female, respectively. There were five ethnic groups in the districts. Of these, the Amhara dominate in both farming systems, being 76.3% in the sesame–livestock and 60% in cotton–livestock system. Overall, 86.4% are Amhara, 10% Tigre 5% Gumuz, 3% Agew and 1% are others.

Table 4. *Sex, ethnic group, education, and major occupation of respondents in the cotton–livestock and sesame–livestock farming systems in Metema district*

Variables	CLFS		SLFS		Overall	
	HHC	%	HHC	%	HHC	%
Respondent status	N = 80		N = 60		N = 140	
Husband	67	83.8	55	91.7	122	87.1
Spouse	10	12.5	4	6.7	14	10.0
Son	1	1.3	1	1.7	2	1.4
Daughter	2	2.5			2	1.4
Sex of household head						
Male	68	85.0	56	93.3	124	88.6
Female	12	15.0	4	6.7	16	11.4
Ethnic group of household						
Amhara	61	76.3	60	100	121	86.4
Agew	3	3.8			3	2.1
Tigre	10	12.5			10	7.1
Gumuz	5	6.3			5	3.6
Other	1	1.3			1	0.7
Education status of household						
Illiterate	33	41.3	35	58.3	68	48.6
Read and write only	29	36.3	18	30.0	47	33.6
Grade 1–3	7	8.8	3	5.0	9	6.4
Grade 4–6	9	11.3	2	3.3	9	6.4
Grade 7–9	2	2.5	2	3.3	7	5.0
Major occupation						
Trade	4	5.0			4	2.9
Livestock rearing only	3	3.8	1	1.7	4	2.9
Crop production only	10	12.5	2	3.3	12	8.6
Mixed farming	61	76.3	55	91.7	116	82.9
Others	2	2.5	2	3.3	3	2.1

SLFS = sesame–livestock farming system, CLFS = cotton–livestock farming system, HHC = household count.

The overall educational status of the respondents indicate that 48.6% are illiterate; being higher in sesame–livestock (58.3%) than in the cotton–livestock (41.3%) farming system. Similar findings were also reported for pastoralist communities in South Omo (Admasu 2006) and Bale Zones (Teshome 2006) of Ethiopia. The findings may suggest that this situation could impede technology uptake. About 33.5% of the respondents could read and write. About 5% of the respondents had grade 7 to 9 education; which is the highest among the total respondents.

The majority of the households (82.9%) are farmers and practised crop and livestock mixed farming system. This could be due to the fact that most of the settlers came to the district from highland and medium altitude areas of Gondar, Wollo, North Shoa and Gojjam Zones of the Region, which practised predominantly mixed farming system. The native Gumuz people still practice hunting and wild plant gathering with some farming (IPMS 2005).

4.1.2 Age and family size

The overall mean age of respondents is 40.16 ± 0.84 (Table 5). This result was lower than the mean average age of 44.3 years reported by (Teshome 2006) in Fogera district of the Amhara region, whereas it was in agreement with the mean average age of 41.2 ± 0.65 years reported by (Tesfaye 2008) for Metema district.

Table 5. *Family size, age of respondents and family members in Metema district*

Variables	CLFS	SLFS	Overall
	Mean ± SE (N = 60)	Mean ± SE (N = 80)	Mean ± SE (N = 140)
Age of respondents, years	41.05 ± 1.43	39.49 ± 1.01	40.16 ± 0.84
Age of family members			
> 60 years	3.00 ± 1.00	2.00 ± 0.00	2.44 ± 0.44
16 to 60 years	2.74 ± 0.17	3.13 ± 0.19	2.97 ± 0.13
6 to 15 years	3.29 ± 0.26	2.89 ± 0.24	3.09 ± 0.18
< 6 years	2.46 ± 0.22	2.28 ± 0.14	2.35 ± 0.13
Family size			
Male	5.47 ± 0.34	5.32 ± 0.32	5.41 ± 0.24
Female	6.02 ± 1.32	4.98 ± 0.25	5.44 ± 0.65
Total	5.37 ± 0.28a	5.26 ± 0.27a	5.31 ± 0.20a

SLFS = sesame–livestock farming system, CLFS = cotton–livestock farming system.
Means with same superscript within the same row do not differ significantly (P<0.05).
SE = standard error.

The mean family size is 5.37 ± 0.28 and 5.26 ± 0.27 persons per household in the cotton–livestock and sesame–livestock farming systems, respectively; the overall being

5.31 ± 0.20 persons per household. This mean family size was similar to the national average of 5.2 (CACC 2002), but lower than the values of 6.6 ± 0.31 reported by Sisay, (2006) for the same district and 7.3 for Hamer and Bena-Tsemay by Admasu (2006). The age structure showed that 50% are within the productive workforce age of 16 to 60 years. Only 2.5% are above 60 years of age. The remaining 30.1% are between 6–15 years of age, while 17.4% are children of less than 6 years of age. In rural Ethiopia, all people above 10 years of age are involved in agricultural and related activities (CSA 2003).

4.2 Land holding and land use pattern

Data on land holding and land use pattern of the respondents are presented in Table 6. The overall average land holding per household is 6.78 ± 1.33 ha; being slightly higher ($P>0.05$) in the cotton–livestock (7.53 ± 1.53 ha) than in the sesame–livestock (6.21 ± 1.17 ha) farming system. The possible reason may be associated with the time of settlement in both areas. According to the group discussion with key informants, the settled inhabitants in the cotton–livestock farming system arrived earlier (by their own and government), benefited from less controlled open access land and are therefore well established. The majority of the inhabitants in the sesame–livestock system are relatively new settlers and only 1–2 ha of farm land is allocated per settler (OoARD, Settlement Desk, personal communication). According to Sisay (2006), this is greater than the average landholdings of the highland districts of Debark (1.66 ha) and Layarmachiho (2.03 ha). As reported by IPMS (2005), previously settled and the indigenous people officially own about 5 ha of land, but many farmers cultivate more than this.

According to the respondents, about 91.4% of the land is used for annual crop production; while 0.8% is covered by perennial crops, 3.1% is left for private grazing and 4.7% fallowed (Table 6). The trend was similar to the result reported by Sisay 2006. This fallow land was associated with the widely practised shifting cultivation in the area as a means of soil fertility improvement measure. Based on the group discussion held with elders, some 10 years back, fallowing of farmland was practised for about 5–8 years and was a common practice in the district. The trend has been decreasing, and currently, land is left for fallow for about 2 to 4 years due to the increase in human population and the use of extensive areas for private investment.

Table 6. *Mean ± SE land holding and land use pattern in Metema district*

Variables	CLFS		SLFS		Overall	
	HHC	%	HHC	%	HHC	%
Land holding						
1–5 ha	21	42.9	38	52.8	64	50.4
5.1–10 ha	15	30.6	23	31.9	38	29.9
10.1–15 ha	10	20.4	11	15.3	22	17.3
>15 ha	3	6.1	0	0.0	3	2.4
Mean (SE)	55	7.53 ± 1.53a	72	6.21 ± 1.17b	127	6.78 ± 1.33b
Land use						
Annual crops	51	89.5	66	93	117	91.4
Perennial crops	–	–	1	1.4	1	0.8
Private grazing	–	–	4	5.6	4	3.1
Fallow	6	10.5	–	–	6	4.7

HHC = household count, CLFS = cotton–livestock farming system, SLFS = sesame–livestock farming system. Means with different superscripts differ significantly (P<0.05).

4.3 Livestock holdings

Data on livestock holdings of the respondents by farming system are presented in Table 7. The average cattle holding per household that was 6.34 ± 0.59 TLU per household in the sesame based farming system was significantly (P<0.05) different than mean cattle holding in the cotton based farming system cattle holding that was 6.24 ± 0.45 TLU per HH. Goat, sheep, donkey, and camel were 0.43 ± 0.6, 0.11 ± 0.03, 0.31 ± 0.04 and 0.06 ± 0.04, respectively, are greater than the cotton based farming system of 0.36 ± 0.04, 0.01 ± 0.1, 0.34 ± 0.03, and 0.00 for goat, sheep, donkey and camel respectively. The difference between the two may be because of the availability of more free grazing area in sesame based farming favoured to have large number of livestock than the cotton based farming. The over all mean livestock holding per household in the district was 12.52 ± 6.23, 0.80 ± 0.40, 0.13 ± 0.07, 0.65 ± 0.32 and 0.07 ± 0.04, cattle, goat, sheep, donkey and camel respectively (Table 5). The total livestock holding per household was 27.58 ± (13.72) TLU (Table 5). This finding was comparable in number with the reports of IPMS (2005) and Sisay (2006) 9.41 ± 0.03, 9.4 ± 0.33, 0.3 ± 0.33, and 0.9 ± 0.08 for cattle, goat, sheep and donkey for the same area. With regard to livestock composition of the area, cattle were dominant followed by goat, donkey, sheep and camel in that order. The result is also similar with the findings reported by the above mentioned authors.

Table 7. *Livestock holdings in TLU of the sampled households in Metema*

Species	CLFS	SLFS
	Mean ± SE	Mean ± SE
Cattle	6.24 ± 0.45	6.34 ± 0.59
Goats	0.36 ± 0.04	0.43 ± 0.60
Sheep	0.01 ± 0.1a	0.11 ± 0.03b
Donkey	0.34 ± 0.03	0.31 ± 0.04
Camel	0.00a	0.06 ± 04b
Poultry (No.)	15.7a	17.2b

CLFS = cotton–livestock farming system; SLFS = sesame–livestock farming system; TLU = Tropical Livestock Unit.
Means followed by different superscripts differ significantly (P<0.05).

4.4 Livestock herd/flock structure

The livestock herd structure by farming system is presented in Table 8. Mean cattle holding per household is higher in the sesame–livestock (16.34 ± (0.59) TLU/hh) than in cotton–livestock (6.25 ± (0.45 TLU/hh) farming system. This is due to the better access to extensive gazing area in sesame livestock farming system. In both farming systems, cows dominate followed by calves, oxen, heifers, and steers, respectively. Female animals are highly valued than males and are a manifestation of wealth and prestige. Oxen are purchased for farming activities and sold immediately after the ploughing season. Young bulls (locally called 'shelba'*)* are highly demanded in the Sudan market.

With regard to goat flocks, the structure that was also in a similar trend, was revealed as that of she-goats population followed by kids and he-goats respectively (Table 8). The number of he-goats is smaller than she-goats because he-goats are either sold at relatively younger age for cash or used for household consumption, while she-goats are retained as breeding stock. Ownership of camels and sheep were small in number as compared to other species of livestock. Male camels are purchased from Afar Region and Sudan and are mainly used for sesame oil extraction (locally called 'ansara'). Male donkeys are the third largest populated stock in Metama because they are in high demand for the heavy burden of donkey cart ('caroo') and transportation activities.

Table 8. *Livestock herd structures in surveyed households by farming system in Metema*

Variables	Mean ± SE	Mean ± SE
	CLFS	SLFS
Cattle		
Oxen	1.19 ± 0.09	1.06 ± 0.15
Cow	2.04 ± 0.19	2.08 ± 0.26
Heifer	1.02 ± 0.13	1.17 ± 0.15
Steer	0.71 ± 0.13	0.73 ± 0.11
Calves	1.30 ± 0.13	1.30 ± 0.18
Total	6.24 ± 0.45	6.34 ± 0.59
Goats		
He-goat	0.03 ± 0.01	0.01 ± 0.01
She-goat	0.23 ± 0.03	0.22 ± 0.03
Kids	0.11 ± 0.02	0.20 ± 0.04
Total	0.36 ± 0.04	0.43 ± 0.60
Sheep		
Male	0.01 ± 0.01	0.06 ± 0.02
Female	0.0	0.01 ± 0.01
Lambs	0.01 ± 0.0	0.04 ± 0.01
Total	0.01 ± 0.1	0.11 ± 0.03
Donkeys	0.34 ± 0.03	0.31 ± 0.04
Camels	0.0	0.06 ± 0.04
Total	13.60 ± 0.9a	14.11 ± 1.24b
Poultry (No.)	15.7a	17.2b

CLFS = cotton–livestock farming system; SLFS = sesame—livestock system; SE = standard error.
Means followed by different superscripts differ significantly (P<0.05).

4.5 Major feed resources

The major feed resources for different species of livestock are presented in Table 9 by farming system and season of the year. In the wet season natural pasture is the sole sources of livestock feed, while in the dry season, natural pasture (55.7%), crop residues (20.7%), stubble grazing (14.3%) and grass hay (9.3%) are the major feed resources for cattle, 73.6%, 12.1%, and 14.3% respectively for sheep, 72.9% and 27.1% natural pasture and crop residues for goats, and crop residues (65.7%), natural pasture (17.9%) and crop residues (16.4%) respectively for donkeys. Among the major feed resources described above, natural pasture and crop residues rank as the first and second largest source of livestock feed. Natural pastures support animal productivity in the rainy season, while in the dry season these pastures can hardly maintain the animals as most of the feed resources are less available and of poor nutritional quality. This could be due to the poor practices of feed conservation and flash burning of the feed resources during the dry season. Other studies have reported similar results (Simbaya 1998; Alemayehu 2006; Sisay 2006; Elias et al. 2007).

Table 9. *Major livestock feed resources and feeding systems in Metema district*

Feeding system and major feed sources	CLFS				SLFS				Overall			
	Wet		Dry		Wet		Dry		Wet		Dry	
	HHC	%	HHC	%	HHC	%	HHC	%	HHC	%	HHC	%
Major feeds for												
Cattle:	60											
– Natural pasture		100.0	30	50.0	80	100.0	48	60.0	140	100.0	78	55.7
– Crop residues			14	23.3			15	18.8			29	20.7
– Aftermath			9	15.0			11	13.8			20	14.3
– Hay			7	11.7			6	7.5			13	9.3
Goat	60											
– Trees and shrubs		100.0	45	75.0	80	100.0	57	71.3	140	100.0	102	72.9
– Crop aftermath			15	25.0			23	28.8			38	27.1
Sheep	60											
– Natural pasture		100.0	41	68.4	80	100.0	62	77.5	140	100.0	103	73.6
– Crop residues			8	13.3			9	11.3			17	12.1
– Crop aftermath			11	18.3			9	11.3			20	14.3
Donkey	60											
– Natural pasture		100.0	13	21.7	80	100.0	12	15.0	140	100.0	25	17.9
– Crop residues			35	58.3			57	71.3			92	65.7
– Crop aftermath		–	12	20.0			11	13.8			23	16.4
Feeding system												
Cattle	60											
– Tethering	6	10.0	2	3.3	4	5.0	4	5.0	10	7.1	6	4.3
– Free grazing	54	90.0	58	96.7	68	85.0	73	91.3	122	87.1	131	93.6
– Cut-and-carry	–	–	–	–	8	10.0	3	4.8	8	5.7	3	2.1
Goat	60											
– Tethering	13	21.7	–	–	11	13.8	–	–	24	17.1		
– Free browsing	47	78.3	60	100.0	69	86.3	80	100.0	116	82.9	140	100
Sheep	60											
– Free grazing	60	100.0	60	100.0	80	100.0	80	100.0	140	100.0	140	100
Donkey	60											
– Tethering	14	23.3	39	65.0	15	18.8	49	61.3	29	20.7	88	62.9
– Free grazing	46	81..7	21	35.0	65	81.3	26	32.5	111	79.3	47	33.6
– Cut-and-carry							5	6.3			5	3.5

HHC = household count, CLFS = cotton–livestock farming system, SLFS = sesame–livestock farming system.

4.6 Feed management and utilization practices

Three types of feeding systems were practised in the district (Table 9). In the cotton–livestock farming system, 90 and 96.7% of the respondents practised free grazing for their cattle during the wet and the dry season, respectively; while the respective values were 85 and 91.3% in the sesame–livestock farming system. Overall, 87.1, 5.7 and 7.1% of the respondents use free grazing, cut-and-carry and tethering during the wet season, respectively, while 93.6, 4.3 2.1% respectively practice these feeding management systems during the dry season. Variations in labour shortage, number of animals kept by herders and area covered by crops contribute to seasonal differences in herd management.

Overall, about 82.9% of the respondents allowed their goats to browse while 17.1% tethered them. Sheep production is based on free grazing. There were some variations in feeding management between the two farming system. Donkeys are important animals in the district, and particularly male donkeys are bought from the neighbouring highland districts for the purpose of transportation services. Most of the respondents (62.9%) tethered their donkeys while some (33.6%) practised cut-and-carry system. This is because donkeys work hard during the day and are left to graze at night. Unlike the highlands, hyenas are not found in the district, making night time grazing possible.

During the wet season, natural pasture is the sole feed resource for all species of livestock (Table 9). In the cotton–livestock farming system, the major feed resources for cattle during the dry season are natural pasture (50%), crop residues (23.3%), crop aftermath (15%) and grass hay (11.7%). Whereas, in the sesame–livestock farming system, the use of natural pasture is higher (60%; $P<0.05$), while the contributions of crop residues (18.8%), crop aftermath (13.8%) and grass hay (7.5%) are lower ($P<0.05$) than the cotton–livestock farming system. This is attributed to the fact that most of the communal grazing areas are found in the sesame–livestock farming system. Feed conservation practices and crop residue utilization are better in the cotton–livestock than in the sesame–livestock farming system.

4.7 Availability of natural pasture

Data on availability of natural pasture during the wet and dry seasons are presented in Table 10. About 62 and 65% of the respondents in the cotton–livestock and sesame–livestock farming system, respectively, indicated that availability of natural pasture for cattle is inadequate during the dry season. Contrary to this, availability of feed for goats was rated as adequate by 75 and 70% of the respondents in the cotton–livestock and sesame–livestock farming systems, respectively.

During the wet season, availability of livestock feed in both farming systems is rated as adequate and abundant by 50 and 42.9% of the respondents, respectively. According to IPMS (2005), out of the total land area of the district, estimated at 440,085 ha, about 71% (312,300 ha) is natural pasture and forest land. In addition, fallow lands and private grazing lands (not clearly known) are major sources of natural pastures in the district, as confirmed by earlier reports (Alemayehu 2006; Sisay 2006; Elias et al. 2007).

Table 10. *Percentage response of respondents on availability of feed resources in Metema*

Variables	CLFS		SLFS		Overall	
	HHC	%	HHC	%	HHC	%
Availability of feeds			Dry season			
Cattle:						
Adequate	23	38.3	28	35.0	51	36.4
Inadequate	37	61.7	52	65.0	89	63.6
Goat						
Adequate	45	75.0	56	70.0	115	82.1
Inadequate	15	25.0	24	30.0	39	27.9
Sheep						
Adequate	33	55.0	45	56.3	78	55.7
Inadequate	27	45.0	35	44.8	62	44.3
Donkey						
Adequate	51	85.0	62	77.5	113	80.7
Inadequate	9	15.0	18	22.1	27	19.3
Availability of feeds			Wet season			
Adequate	28	48.3	42	52.5	70	50.0
Inadequate	10	16.7			10	7.1
Abundant	22	36.7	38	47.5	60	42.9
Quality of the feeds						
Very good	48	80.0	70	87.5	118	84.3
Average	12	20.0	10	12.5	22	15.7

N = 60 for CLFS; N = 80 for SLFS, CLFS = cotton–livestock farming system, SLFS = sesame–livestock farming system, HHC = household count.

4.7.1 Hay making

According to the information gathered from group discussion with elders, hay making started only recently. About 10 years ago, there was no feed shortage during the dry season because bamboo trees were abundant and they shed leaves during the dry season and these leafy foliages were the principal sources of livestock feed. After the disappearance of the bamboo forest about 10 years ago, communities were forced to collect and conserve grass hay due to increased human and livestock population and drought. Hay making is practised from end of October up to November and curing takes place for a period of two week to one month. The quality of hay is often poor and is bleached by the strong sunshine in the area. Farmers have not received any training on good practices of hay making by the extension service. This poor hay making practice was also reported by Sisay (2006) who estimated hay production per household was only 0.77 t DM/ha. Tesfaye (2008) also reported the percentage of households that practice hay making is lower in the sesame–livestock (70.9%) than in the cotton–livestock (86.0%) farming system.

4.7.2 Crop residues production and utilization

In the cotton–livestock farming system, the main crops grown are cotton, rice, sorghum, maize, sesame, finger millet and fruits, while in the sesame livestock farming system, sesame, cotton, sorghum, maize, soya bean, teff, chickpea, groundnut and fruits are grown. Sorghum is the most important cereal crop grown in the district and constitutes about 90% of the total crop residues produced in the area. Crop residues from maize (8.4%), teff (1.3%), finger millet (0.14%), rice (0.25%), soya bean and chickpea make up for the difference (Table 11). Next to natural pastures, crop residues are other main sources of livestock feed during the dry season. In the cotton–livestock farming system, 23.3, 13.3 and 58.3% of the crop residues are used for cattle, sheep and donkeys, respectively, while in the sesame–livestock farming system the respective values are 18.8, 11.3 and 71.3%. Overall, out of the total amount of crop residues produced in the district, 20.0, 12.1 and 65.7% are used for cattle sheep and donkeys, respectively. The value of crop residues produced in a particular area depends on the amount and type of crops grown in the area.

Table 11. *Estimates of grain and crop residues production for major crops grown in Metema*

Types of crops	Cultivated (ha)	Grain produced (Qt)	Crop residue (CR) (t)	G:CR ratio	Sources	% Share
Teff	1005	8033	12.1	1.5	MOA (1984)	1.3
Finger millet	365	2555	1.3	2.04	Awassa, Bako	0.14
Sorghum	15,820	329,056	822.6	2.5	Jhanke (1982)	89.5
Maize	1809	40,143	80.3	2.0		
Chickpea	86	344	0.41	1.2		
Rice	117	2,340	2.34	1	Devendra (1997)	0.25
Soya bean	15.5	93	0.09	1	Devendra (1997)	
Total			919.1			

Sources: OoARD (2006).
Means with different superscripts differ significantly (P<0.05).

4.7.3 Stubble grazing

The proportion of respondents using stubble grazing in the two farming systems is presented in Table 12. Stubble grazing is an important feed resource and is practised soon after the crops have been harvested from October to early December. Livestock are allowed to graze stubbles of sorghum, maize, teff, peanut and millet fields. Stubble grazing contributes to about 14.3% of the basal diet of cattle; being slightly higher in the cotton–livestock (15%) than in the sesame–livestock farming system (13.8%). The proportion of stubble as feed for goats (25%) and sheep (18.3%) is slightly lower in the cotton–livestock than in the sesame–livestock (28.8%) farming system, while the reverse was true for sheep (18.3% vs. 11.3%), respectively. The differences in stubble grazing usage between the two farming systems could be associated with the types and size of cereal crop production. In the cotton–livestock system cereals like sorghum are extensively produced, while in the sesame–livestock system sesame is the dominant crop and herbicides are extensively used to control important weeds and forbs minimizing stubble grazing. This finding agrees with the reports of Sisay (2006).

Table 12. *Percentage of respondents using stubble grazing by farming system in Metema*

Species	CLFS		SLFS		Overall	
	HHC	%	HHC	%	HHC	%
Cattle	9	15.0	11	13.8	20	14.3
Goat	15	25.0	23	28.8	38	27.1
Sheep	11	18.3	9	11.3	20	14.3
Donkey	12	20.0	11	13.8	23	16.4

CLFS = cotton–livestock farming system; SLFS = sesame–livestock farming system, HHC = household count.

4.7.4 Supplementary feeding

The types and the amount of supplementary feeding for livestock are summarized in Table 13. Crop residues, sesame oil by-products ('embaze'), noug cake, hay, wheat bran and local brewery by-product ('atela') are the major supplementary feed used in the dry season. More number of respondents (28.3%) in the cotton–livestock farming system use crop residues as supplementary feed than those in the sesame–livestock farming system (20.0%). This could be due to the more availability of residues and experiences of the farmers in collecting and utilization of residues in the cotton–livestock farming system. As expected, the use of embaze as a supplementary feed is higher in the sesame–livestock (26.3%) than the cotton–livestock farming system (6.7%), due to availability and easy access in the former system.

Amount of supplementation

Data on the amounts of supplementary feed offered to livestock are presented in Table 13. Most of the respondents (53%) provide 1 kg of supplementary feed per cattle per day, and this is slightly higher in the cotton–livestock (55%) than in the sesame–livestock (51.25%) farming system. About 22 and 19% of the respondents also indicated that they provide 1.5 and 0.5 kg per cattle per day, respectively. About 66 and 31% of the respondents also indicated that they provide 1 kg and 1.5 kg of supplementary feed per donkey per day, respectively. This indicates that donkeys are important assets to the household and the community at large in Metema.

Table 13. *Percentages of respondents showing the types and amount of supplementation of feeds in the two farming systems in Metema*

Variables	CLFS (N = 60)		SLFS (N = 80)		Overall (N = 140)	
	HH	%	HH	%	HH	%
Types of supplementation						
Cattle						
Crop residues only	17	28.3	16	20.0	31	12.9
Crop residues + embaze	10	16.7	12	15.0	22	15.7
Embaze (sesame cake)	4	6.7	21	26.3	25	17.7
Noug cake	9	15.0	7	8.8	16	11.4
Grass hay	8	13.3	10	12.5	18	12.9
Wheat bran	5	8.3	9	11.3	14	10.0
Atela	3	5.0	–		5	3.6
Atela + hay	4	6.7	5	6.3	9	6.4
Donkey						
Crop residues	20	33.3	29	36.3	49	35.0
Hay only	4	6.7	7	8.8	11	7.9
Grains	36	60.0	44	55.0	80	57.1
Amount of supplementation, kg/animal per day						
Cattle						
2	4	6.7	9	11.3	13	5.4
1.5	15	25.0	6	7.5	31	22.1
1	33	55.0	41	51.3	74	52.9
0.5	6	10.0	20	25.0	26	18.6
0.75	2	3.3	4	5.0	6	4.2
Donkey						
2	1	1.7	4	5.0	5	3.6
1.5	19	31.7	24	30.0	43	30.7
1	40	66.7	52	65.0	92	65.7

Crop residues only = 1 kg/animal per day; Crop residues + Embaze = 1.5 kg/animal per day; embaze (sesame cake) = 0.5 kg/animal per day; noug cake = 0.75 kg/animal per day; Grass hay = 2 kg/animal per day.

The amount of wheat bran, atela and atela plus hay offered are not estimated due to small quantity offered to animals. During the field work it was also noted that the amount of supplementary feeds offered, especially sesame cake, noug cake and wheat bran was very small, and the major purpose of supplementation is not to increase productivity, but is focused to those animals that are susceptible to diseases, weak animals, suckling cows and calves.

4.7.5 Feeding calendar and seasonal availability of feed resources

Seasonal availability of feed resources in the study area, as obtained from group discussion and observation during the field work is presented in Table 14. The pattern of feed resources availability in the district is influenced by season as in the highland areas (Ahmed 2006) and the trend followed similar pattern with the findings of Sisay (2006).

Table 14. *Availability of different feed resources by month in the district*

Type of feed	Month											
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Natural pasture	*	*	*	*	*	*	-----	----	-----	----	-----	-----
Crop residues									*	*	*	*
Stubble grazing					----	*	*	*				
Hay									*	*	*	*
Supplementation										---	*	*
Fodder trees	*									*	*	*

----- = Availability of few green browse species and dry grasses; * = Abundant

4.7.6 Chemical composition of the major feed resources

The effect of species on chemical composition

Chemical composition of different species of feed resources is given in Table 15. Comparison of the chemical composition of the three major grass species (*Pennisetum spheslatum*, *Cenchrus ciliaris* and *Pterocarpus lucens)* indicated that there is a species difference in nutrient contents.

Table 15. *Chemical composition (Mean ± SE) of different feeds in the study districts*

Chemical composition,%	Species		
	P. spheslatum	*C. ciliaris*	*P. lucens*
DM	90.2 ± 0.14a	89.9 ± 0.14ab	89.0 ± 0.14b
Ash	20.1 ± 2.54a	15.3 ± 2.54ab	7.7 ± 2.54b
OM	79.9 ± 2.54ab	84.7 ± 2.54ab	92.3 ± 2.54a
CP	6.3 ± 0.43ab	6.4 ± 0.43ab	15.8 ± 0.43a
NDF	69.3 ± 0.64b	74.6 ± 0.64a	58.2 ± 0.64c
ADF	45.8 ± 0.55a	45.9 ± 0.55a	43.1 ± 0.55b
ADL	8.1 ± 0.74ab	5.9 ± 0.74ab	21.3 ± 0.74a
IVDMD	45.9 ± 1.18b	39.3 ± 1.18c	47.8 ± 1.18a

Means with different superscripts in a row differ significantly (P<0.05).

The mean DM and ash contents in *P. spheslatum* were significantly (P < 0.05) higher than in *P. lucens* and *C. ciliaris* and also mean ADF and ADL contents in *P. spheslatum* were significantly (P < 0.05) higher than in *P. lucens*. The DM, ash, NAF and ADF contents of *P. lucens* were significantly (P<0.05) lower than the mean DM, ASH, NAF and ADF contents of *C. ciliaris*. The mean OM and CP contents in *C. ciliaris* were higher than in *P. spheslatum*. Contents of NDF and ADF in *C. ciliaris* were significantly (P<0.05) higher than in *P. spheslatum* and *C. ciliaris*. Mean OM, CP and IVDMD contents in *P. lucens* were significantly (P < 0.05) higher than the other two species. The differences in nutrient content between species could be associated with their inherent nature, i.e. fodder trees contain more protein than grass species. As reported by Mathur et al. (1991) most grasses and tree leaves in arid environments are low in nutritive value because of high contents of lignin and relatively indigestible (compared with starch) cellulose and hemicelluloses.

The effects of season on chemical composition

Data on the effect of season on chemical composition of dominantly growing two grass and one fodder species are given in Table 16. The DM, OM, NDF, ADF and ADL contents of feeds were significantly (P < 0.05) higher in October than in August. Whereas, the percentages of ash, CP, IVDMD of the feeds were significantly (P < 0.05) lower in October than in August. This may be associated with the temperature, the stages of growth and the plant species that influenced the quality of feeds. This finding agrees with earlier reports (Alemayehu 2006; Sisay 2006), that the structural constituents of plant materials (lignin, cellulose and hemicelluloses) increase with maturity. During the growth stage, plants are most nutritious. Once mature, plants are subject to leaching and dilution of nutrients and reduction in nutritive value. Declines in nutrient composition and leaching are especially serious in the case of herbaceous plants. As the plant matures, the contents of crude protein, the more readily digestible carbohydrates and phosphorus decrease and that of fibre, lignin and cellulose increase. The decline in nutritive value of these feeds in October indicates that feed conservation practised by the communities between mid October and November is not appropriate time and should be done earlier than in mid October.

Table 16. *Effect of season on chemical composition (Mean ± SE) of composite samples of dominant feed species in Metema*

Chemical composition, %	Season	
	Wet (August)	Dry (October)
DM	88.9 ± 0.11^{b}	90.5 ± 0.11^{a}
ASH	18.2 ± 2.07^{a}	10.5 ± 2.07^{b}
OM	81.8 ± 2.07^{b}	89.5 ± 2.07^{a}
CP	10.8 ± 0.35^{a}	8.2 ± 0.35^{b}
NDF	60.8 ± 0.52^{b}	73.9 ± 0.52^{a}
ADF	$40.3 \pm 0. 45^{a}$	49.6 ± 0.45^{a}
ADL	10.1 ± 0.60^{b}	13.5 ± 0.60^{a}
IVDMD	50.7 ± 0.96^{a}	37.9 ± 0.96^{b}

Means with different superscripts in a row differ significantly (P<0.05).

4.7.7 Feed balance

The estimate of the total available feeds in terms of dry matter (calculated from grazing land, cultivated land (crop residues and stubble), and forest land) is presented in Table 17. The total estimated annual DM from crop residues, grazing land and stubble is 827.16, 780,750.0 and 51,954.0 t; totalling 833,531.16 t. The total livestock population in TLU (tropical livestock unit) is estimated at 103,190. Daily DM requirement for maintenance of one TLU is estimated as 2.5% of the body weight (ILCA 1990) that is, 250 × 2.5% = 6.25 kg DM per day and (6.25 × 365 = 2280 kg) per annum. Therefore, the total DM requirement for maintenance per annum is estimated at 235,273.2 t. Based on this calculation, the estimated feed balance in the district is 598,258 t DM. This finding is in agreement with the estimates of Sisay (2006) who reported that the nutrient balance in Metema is sufficient to support the livestock holdings per household. However, the quality of the feed is poor.

Table 17. *Estimates of feed balance in Metema district*

Livestock species	A (TLU)	B	A × B	C	C – (A × B)	D
Cattle	95,837	2.28	218,508.4			
Goat	3202	2.28	7300.6			
Sheep	169	2.28	385.3			
Donkey	3582	2.28	8167.0			
Camel	400	2.28	912.0			
Total	103,190		235,273.3	833,531.2	598,257.9	0.00

A = Livestock number in the district (TLU), B = Feed requirement of per animal (t Dm/year), A × B = Total feed requirement of all animals (t DM/year), C = Estimate of available feed resources (t DM/year), C–(A × B) = Estimated feed balance of the district, D = Deficit (if any).

4.7.8 Water resources

Availability of water in grazing areas is a good opportunity for livestock and human beings living in a lowland agro-ecology like Metema district. Based on respondents and observations made during the study, the major sources of water in the district (Table 18) are rivers (64.3%), springs (21.4%) and ponds (10.7%). Rivers are equally important sources of water in both farming systems. There are three large continuous rivers passing through the district and used for livestock and irrigation activities. Ponds are more important sources of water in the cotton–livestock (18.3%) than in the sesame–livestock (5%) farming system, while springs are more important in the sesame–livestock (28%) than in the cotton–livestock (13.3%) farming system. IPMS (2005) also reported that farmers and agriculturists believe that the underground water table is high and in some places sufficient amount of water could be obtained at less than 10 m depth. The majority of the respondents (69.3%) water their animals once a day, while about 31% water twice a day (Table 18). This result is in agreement with Teshome (2006).

Table 18. *Sources of water and watering frequency by farming system for cattle in Metema (percentage of respondents)*

Parameter	CLFS		SLFS		Overall	
	N	%	N	%	N	%
Sources of water						
River	39	65.1	51	63.7	90	64.3
Pond	11	18.3	4	5.0	15	10.7
Spring	8	13.3	22	27.5	30	21.4
Wells	2	3.3	3	3.8	5	3.6
Watering frequency						
Once a day	37	61.7	60	75.0	97	69.3
Twice a day	23	38.3	20	25.0	43	30.7

CLFS = cotton–livestock farming system; SLFS = sesame–livestock farming system.

4.7.9 Major constraints to livestock production

The major problems associated with livestock production as perceived by the respondents are presented in Table 19. About a quarter of the respondents indicated livestock theft as their major problem in both farming systems. During group discussions, elders reported that at times up to 90 heads of cattle are stolen. The trend appears to be escalating from time to time. The location of the district encourages theft as there is an extensive area bordering the Sudan making it easier for cattle rustlers to trek the animals across the boarder.

Table 19. *Percentage of respondents showing major problems to livestock production in Metema*

Variables	CLFS (N = 60)		SLFS (N = 80)		Overall	
	HH	%	HH	%	HH	%
Feed shortage	4	15.0	4	5.0	8	5.7
Biting insects	8	13.3	10	12.5	18	12.9
Livestock diseases	10	16.7	15	18.8	25	17.9
Labour shortage	4	6.7	5	6.3	9	6.4
Drought	5	8.3	7	8.8	12	8.6
Livestock theft	14	23.3	19	23.8	33	23.6
Conflict with highlanders	5	8.3	8	10.0	13	9.3
Crop land encroachment	7	11.7	8	10.0	15	10.7
Shortage of crop residues	3	5.0	4	5.0	7	5.0

HH = Households, CLFS = cotton–livestock farming system, SLFS = sesame–livestock farming system.

Livestock diseases (16.7%) and biting insects (13.3%) were the secondly and thirdly prioritized constraints in both CLFS and in the SLFS, respectively. About 11% of the respondents indicated that crop land encroachment is affecting livestock production. The possible causes of the crop land encroachment might be due to the human population pressure through continuous settlement program by government, increasing number of voluntary settlers and settler's relatives from the neighbouring highland districts and the natural increase in population.

Conflict between transhumants and the local inhabitants for livestock feed resources was not a major problem and was reported by about 9% of the respondents. Feed shortage, drought and shortage of crop residues were minor concerns and were reported by only 5.7, 8.6 and 5% of the respondents, respectively. During the group discussion, it was noted that there are two major varieties of sorghum grown by farmers. These are 'wodiaker' and 'zole', and the former is highly preferred by livestock. The residue from the later variety is left as mulch or burned in the field. Farmers also reported that the productivity of wodiaker variety is declining at an alarming rate due to loss of soil fertility, while the zole variety grows well on less fertile soil and is more productive than the wodiaker variety. This could contribute to feed shortage during the long dry season. An alternative dual purpose sorghum variety suitable for the agro-ecology should be developed in the future.

4.8 Floristic composition

4.8.1 Herbaceous species composition

A total of 33 herbaceous species were recorded, and out of these, 14 (42.4%) were grasses, 6 (18.2%) were legumes, and 13 (39.4%) were sedges and others (Table 20; Appendix Table 6). Of the grass species identified, 23.1% were categorized as highly desirable, 38.5% desirable and 30.8% less desirable. This might be due to the gradual disappearance of highly desirable species through over use and disturbance by livestock and human beings. From the discussion held with the farmers, it was understood that the major factors that cause the decline in the abundance of highly desirable species were drought followed by overgrazing due to the increase in grazing pressure, invader plants have replaced decreaser and increaser plants. Furthermore, overgrazing reduces ground cover, plant height, forage quality and productivity, changes are induced in the dominant growth forms of herbaceous plants; tall perennial bunch grass species give way to shorter rhizomatous and sotoloniferous perennial grasses which are replaced by annual grass and forbs species (Herlocker 1999; Abule et al. 2007a). Besides, overgrazing tends to reduce perennial grassland vegetation types and allows invasion by annual forbs and grasses. Drought and overgrazing could be the causal factors for the decline in plant species composition and diversity of plants over time (Admasu 2006; Alemayehu 2006; Amaha 2006; Abule et al. 2007a).

Table 20. *Common and dominant grass species identified by farming systems and different grazing types in Metema*

Grasses	Category	CLFS			SLFS		
		CG	RS	EN	CG	RS	EN
C. ciliars	DS	D	C	C	C		C
P. sphacelatum	DS	C		C	D	C	C
Setaria pumila	DS	C	C	C		C	C
Brachiaria lata	DS	C					C
Urochloa fatamensis	LD		C	C			
Rhamphicarpa fistulosa	LD	C	C			C	
Temeda triandria	HD			D			
Cynodon dyctlon	HD			C			
Cyprus spp.	DS		C				C
Eleusine floccifolia	LD		D			D	C
Hyparrhenia rufa	HD			D			D
Panicum coloratum	HD						D
Sporobolus pyramidialis	DS						C

HD = highly desirable; DS = desirable; LD = less desirable; CG = communal grazing; RS = road side; EN = enclosure; P = present (<5% of DM); C = common (>5% and <20% of DM), D = dominant (>20% of DM).

4.8.2 Woody species composition

A total of 20 woody species were identified in the study district (Table 21; Appendix Table 5), and 15, 35, and 50% are highly desirable, desirable and less desirable, respectively. The highest proportion of the woody vegetation is composed of different species of acacia (20%) and commbretum (10%). Species such as *Anogeissus leiocarpus, P. lucens,* and *Ziziphus spina-christi* are highly desirable and they are dominant in enclosure areas. Besides different species of acacia, *Balanites aegyptiaca, Boswelia papyrifera, Combretum collinum, C. mole, Dichrostachys cinerea, Ficus sycomorus, Fluegea virosa, Gardenia ternifolia, Grewia villosa, Stereospermum kunthianum, Terminalia laxiflora* and *Ximenia Americana* are commonly found woody species (Table 21). In sesame based framing system, *Acacia polyacantha, A. seyal, Balanites aegyptiaca* and *B. papyrifera* were the dominant species in communal grazing areas and *A. tortilis, A. leiocarpus, A. senegal, C. collinum, C. mole, D. cinerea, F. sycomorus, F. virosa, P. lucens,* and *Z. spina-christi,* were common species. In road side grazing areas, *A. polyacantha* and *D. cinerea* dominated and *A. seyal, B. aegyptiaca, B. papyrifera, T. laxiflora, C. collinum, C. mole* and *X. Americana* were common species found. From this result, the grazing land in the district could be characterized as acacia dominated wood land and the woody vegetation were the important sources of feed for ruminant animals in the area.

Table 21. *Common and dominant woody species and their percentage composition by farming system in different grazing areas in Metema*

Woody species	Category	CLFS			SLFS		
		CG	RS	EN	CG	RS	EN
G. ternifolia	LD	C					
A. polyacantha	DS	D	D	C	D	D	
T. laxiflora		C		C		C	
A. tortilis	DS	C	D		C	C	C
A. seyal	DS	D	C	D	D	C	C
D. cinerea	DS		D		C	D	
A. leiocarpus	DS	C	C	D	C		D
P. lucens	HD	C		D	C		D
F. sycomorus	DS	C			C		
C. collinum	LD				C	C	C
X. Americana	LD	C					
S. kunthianum	DS	C					
B. aegyptiaca	DS	C		C	D	C	C
G. villosa	LD						C
Z. spina-christi	HD	C	C	D	C		D
Piliostigma toningii	DS						
F. virosa	LD	C			C		
B. papyrifera	UD	C	C	C	D	C	D
A. senegal	DS	D		C	C		C
C. mole	LD				C	C	

CLFS = cotton–livestock farming system; SLFS = sesame–livestock farming system; CG: communal grazing; RS: road side; EN: enclosure; C = common (>10% and <20% density); D = dominant (>20% density).

According to the result obtained from group discussions, *P. lucens* is one of the most important fodder trees in the district. After the long dry season during the on set of the main rain season, the community practised to search *P. lucens* to heal their emaciated animals. The communities take care of this tree species by their own against destruction unlike other species. Thus, woody plants contribute significantly to the sources of livestock feed in the district. The finding is agreed with the report suggested that woody species are important source of food, fodder, fuel wood, medicine, fibre and gums (Herlocker *1*999; Alemayehu 2006; Abule et al. 2007b).

Height classes of woody vegetation

The height class distribution of trees and shrubs in the farming systems are presented in (Table 22). There is no difference in height class category of < 0–1 m between grazing types found in both farming systems. The highest percentage of distribution of trees and shrubs is found in height class category of > 1–3 m in both farming systems and are also comparable. Generally, most height classes of the vegetation could be considered at browsing height of the animals. According to Tainton (1999) height of 1.5 m represents the mean browsing height for goats.

Table 22. *Percentage of height class (metres) distribution of trees and shrubs in Metema*

Height class	CLFS			SLFS		
	CG	RS	EN	CG	RS	EN
< 0–1 m	22.6	25.0	21.1	20.6	23.1	20.8
> 1–3 m	45.2	33.3	42.1	41.2	38.5	33.3
>3–4.5 m	19.4	16.7	15.8	26.5	23.1	12.5
> 4.5 m	12.9	25.0	21.1	11.8	15.4	33.3

CLFS = cotton–livestock farming system; SLFS = sesame–livestock farming system; CG = communal grazing; RS = road side grazing, EN = enclosure.

Hence, these reachable heights of different woody browse species make the area favourable to raise browsing animal species such as goats and at the same time maintain the balance between the woody and herbaceous species. Studies suggested that integration of grazers and browsers having different feeding habitats makes more efficient use of natural vegetations. According to Taylor (1985), when cattle were partly replaced by goats and/or sheep, individual cattle performance increased because forage demand for the grass component was reduced. Likewise, production of ewes increased when some sheep were replaced by cattle and goats because grazing pressure on the forbs component declined. Herd diversification through increasing the number of browsers such as camels and goats would also contribute towards efficient resource utilization and decreases woody plant encroachments in rangelands (Gemedo 2004).

4.8.3 Vegetation in the cotton–livestock farming system

Herbaceous species composition

From a total of 24 herbaceous species recorded in the cotton–livestock farming system, 50, 20.8 and 29.2% are different species of grasses, legumes and sedges (Table 23). Among the grass species identified, 25% are highly desirable, 33.3% are desirable and 41.7% are less desirable, respectively. The ratios of the herbaceous species (grasses:legumes:sedges) is 12:5:7. *Bracheria lata, P. spheslatum, R. fistulosa* and *Seteria pumila* are the common grass species. In the communal grazing areas, *C. ciliaris* is the dominant grass species, while *Cyprus spp, Eurochloa fatamensis fistulosa, R.* and *S. pumila,* are the common grass species. In the road side grazing areas, *E. flocifolia* is dominant. The enclosure areas have a relatively higher percentage of highly desirable grass species than the communal and road side grazing areas. In the enclosure areas, *C. ciliaris, Cyprus spp, E. fatamensis, P. spheslatum* and *S. pumila,* are the common species, while *Themeda teriandra* and *H. rufa* are dominant. This could be attributed to a better management practice and a lower livestock impact in the enclosure areas. This result is in agreement with earlier reports (Admasu 2006; Amaha 2006; Teshome 2006).

Table 23. *Herbaceous species composition (% DM biomass) and their desirability by grazing type in cotton–livestock farming system in Metema*

Grazing types	Herbaceous species	Category	% composition	Remark
Communal	*C. ciliaris*	DS	21.2	Grasses
	P. sphacelatum	DS	5.8	
	S. pumila	DS	10.4	
	B. lata	DS	6.2	
	U. fatamensis	LD	1.4	
	R. fistulosa	LD	16.66	
	Urochloa cf. brchyura	LD	1.2	
	T. triandria	HD	2.6	
	C. dyctlon	HD	1.4	
	Ahiya abish (local name)	UD		Legumes
	Alysicarpus quartinianus	LD		
	Vigna membranacea	LD		
	Chamaecrista mimosoides (L)	UD		
	Euphhorbia indica	UD		Sedges
	Spermacoce sphaerostima	UD	1.3	
	Hygrophilla schulli	UD	10.4	
	Kedrostis foetidissima	LD	0.63	
	Commelina subula	UD	0.5	
Road side	*C. dyctlon*	HD	3.4	Grasses
	Cypres spp.	LD	6.7	
	C ciliaris	DS	14.9	
	S. pumila	DS	17.2	
	U. fatamensis	LD	5.3	
	R. fistulosa	LD	5.2	
	E. floccifolia	LD	23.6	
	Ahiya abish (local name)	UD	13.2	Legumes
	A. quartinianus	LD	8.0	
	V. membranacea	DS		
Road side	*Cyanotis barbata*	UD		Sedges
	H. schulli	UD		
	S. sphaerostima	UD		
	Bidens setigera	UD		
	K. foetidissima	LD		
	Zennia elegans Jaquin.	UD		

Grazing types	Herbaceous species	Category	% composition	Remark
Enclosure	*P. sphacelatum*	DS	6.1	Grasses
	C. ciliaris	DS	6.5	
	S. pumila	DS	5.2	
	B. lata	DS	1.9	
	U. fatamensis	LD	5.2	
	T. triandra	HD	22.6	
	H. rufa	HD	24.4	
	C. dyctlon	HD	5.8	
	Indigofera spicata	DS		Legumes
	A. quartinianus	LD		
	Dismodium dichotomum (Klein)	DS		
	Hibiscus articulatus	HD		Sedges
	C. barbata	UD		
	C. subula	UD		
	H. vitifolius L.	DS		

HD = highly desirable, DS = desirable, LD = less desirable.

Woody vegetation

A total of 17 woody species were recorded (Table 24), and 17.7, 41.2, 35.3 and 5.9% are highly desirable, desirable, less desirable and undesirable species, respectively. *A. polyacantha*, *A. seyal, A. senegal* and *B. papirefera* are the dominant species whereas, *A. tortolis, A. leiocarpus, B. aegyptiaca, F. sycomorus, G. ternifolia, P. lucens, T. laxiflora* and *Z. spina-christi* are commonly found in communal grazing areas. In road side grazing areas, *A. polyacantha*, *A. tortilis* and *D. cinerea* are the dominant species, while *A. seyal, A. leiocarpus, A.* senegal, *B. papyrifera, Z. spina-christi* are common. In the enclosure grazing areas, *A. leiocarpus, P. lucens, A. seyal* and *Z. spina-christi* are dominant woody plant species and *A. polyacantha, B. aegyptiaca, B. papyrifera*, *A. senegal,* and *T. laxiflora* are common. The proportion of desirable species in this farming system is considerably higher than the highly desirable and less desirable species. This could favour raising browsing livestock species like goats and camels.

4.8.4 Vegetation in the sesame–livestock farming system

Herbaceous species

Herbaceous species obtained in sesame based farming system and their percentage composition is presented in (Table 25).

Table 24. *Woody species and percentage composition in different grazing system in cotton–livestock farming system in Metema*

Grazing types	Woody species	Category	% composition
Communal	*T. laxiflora*	LD	0.9
	G. ternifolia	LD	24.8
	A. polyacantha	DS	1.5
	A. tortilis	DS	12.1
	A. seyal	DS	8.5
	D. cinerea	LD	5.5
	A. liocarpus	HD	15.2
	P. lucens	HD	7.0
	F. sycomorus	DS	2.4
	C. collinum	LD	1.2
	S. kunthianum	DS	0.6
	X. americana	LD	0.9
	Blanites aegyptyca	DS	5.5
	Z. spina-christi	HD	1.8
	P. toningii	LD	5.2
	B. paperiferra	UD	0.6
	A. senegal	DS	3.9
Road side	*G. ternifolia*	LD	21.0
	A. polyacantha	DS	1.1
	A. tortilis	DS	14.8
	A. seyal	DS	2.3
	D. cinerea	LD	15.3
	A. liocarpus	HD	2.8
	P. lucens	HD	5.7
	F. sycomorus	DS	14.8
	C. collinum	LD	1.1
	S. kunthianum	DS	1.7
	X. americana	LD	9.1
	B. aegyptyca	DS	7.5
	Z. spina-christi	HD	1.1
	P. toningii	LD	
Enclosure	*T. laxiflora*	LD	31.0
	A. liocarpus	HD	3.4
	A. polyacantha	DS	10.3
	A. seyal	DS	20.7
	P. lucens	HD	6.9
	B. aegyptyca	DS	13.8
	Z. spina-christi	HD	5.7
	B. paperiferra	UD	3.4
	A. senegal	DS	2.8

D = desirable, HD = highly desirable; UD = undesirable; LD = less desirable.

Table 25. *Herbaceous species composition (% DM biomass) and their desirability by grazing type in sesame–livestock farming system in Metema*

Grazing types	Herbaceous species	Category	% composition	Species types
Communal	*U. fatamensis*	LD	2.6	Grasses
	P. sphacelatum	DS	22.0	
	U. bracyra	LD	3.2	
	T. triandra	HD	2.9	
	C. ciliaris	DS	16.5	
	E. floccifolia	LD	18.3	
	Ahiya abish	UD		Legumes
	A. quartinianus	LD		
	I. spicata	DS		
	C. barbata	UD		Sedges
	E. indica	UD		
	S. sphaerostima	UD		
	C. subul	UD		
	H. schulli	UD		
Road side	*P. sphacelatum*	DS	8.5	Grasses
	S. pumila	DS	17.4	
	C. dactylon	HD	3.6	
	R. fistulosa	LD	9.2	
	E. floscifolia	LD	23.1	
	Ahiya abish	UD		Legumes
	C. mimosoides (L)	UD		
	E. indica	UD		Sedges
	H. schulli	UD		
	S. sphaerostima	UD		
	B. setigera	UD		
	Z. elegans Jaquin.	UD		
	C. subula	UD		
Enclosure	*P. sphacelatum*	DS	6.4	
	T. triandra	HD	2.6	
	S. pumila	DS	5.2	
	B. lata	DS	8.3	
	P. coloratum	HD	20.5	
	H. rufa	HD	25.1	
	S. pyramidialis	DS	5.1	
	E. flocifolia	LD	5.6	
	I. spicata	DS		Legumes
	A. quartinianus	LD		
	H. articulatus	HD		
	V. membranacea	DS		
	Corchorus trilocularis L	DS		Sedges
	B. setigera	UD		
	C. barbata	UD		

D = Desirable, HD = highly desirable; UD = undesirable; LD = Less desirable.

A total of 25 herbaceous species are recorded in this farming system, and the majority (56%) are grass species, followed by sedges (24%) and legumes (20%). In the communal grazing areas, 13 herbaceous species are identified, out of which 6 (46.2%) are grass species, and 3 (23.1%) and 4 (30.8%) are legumes and sedges/others species, respectively. From the grass species recorded, 16.7, 33.3 and 50.0% are highly desirable, desirable, and less desirable, respectively. In road side grazing area, out of the recorded 5 species of grasses, 20, 40 and 40% are highly desirable, desirable, and less desirable, respectively. In enclosure grazing area, 8 species of grasses, 4 species of legumes and 2 species of sedges are recorded. From the grass species identified, 37.5% are highly desirable, 50% desirable and 12.5% less desirable. In road side grazing areas, the less desirable species of *Eleunine flocifolia* is dominant (23.1%), followed by the desirable species of *S. pumila* (17.4%) and *P. spheslatem* (9.2%). Highly desirable species accounted for 14.28, 42.86, and 42.86% for the desirable and less desirable *R. fistulosa* species of grasses. In enclosure areas, the highly desirable grass species of *H. rufa* (25.1%) and *P. coloratum* (20.5%) are the dominant specie. There is a relatively high percentage of highly desirable (decreasers) grass species in the enclosure followed by communal and the road side grazing areas. This might suggest that the highly desirable species are replaced by less desirable and unpalatable species as the grazing pressure increased.

Woody vegetation in sesame based farming system

A total of 18 woody species are identified in the sesame–livestock farming system (Table 26). These are composed of highly desirable (16.7%), desirable (38.9%), and less desirable (44.4%) species. In the communal grazing areas, *A. tortolis*, *A. leiocarpus, B. egyptica, P. lucens*, *T. laxiflora*, *X. Americana*, and *Z. spina-christi* are the common species, while *A. polyacantha*, *A. seyal, A. senegale* and *B. papirefera* are the dominant species. In the road side grazing areas, the frequency of *A. polyacantha*, *A. tortolis, A. seyal* and *D. cinerea* was dominant, and *A. senegal, A. leiocarpus*, *B. papyrifera, Z. spina-christi* are common species. In the enclosure areas, highly desirable species like, *A. leiocarpus, P. lucens, Z. spina-christi* and the desirable species of *A. seyal* are dominant. *A. Balanites egyptica, B. papirefera*, *A. senegal, A. polyacantha,* and *T. laxiflora* are common species.

The proportion of desirable tree species in the communal and road side is lower than in the enclosure areas, probably due to the influence of people and animals. For instance, group discussions revealed (confirmed during the field work) that about 10 years ago, almost all of the district was covered by bamboo tree species, and the remains of bamboo trees were observed on steep slope areas and undisturbed remote *kebeles* of Shimele Gara, Kemechela, Zebach Bahir and Lemlem Terara. *A. polyacantha* was found in very low density a decade ago, but currently it is the dominant species. This result agrees with the suggestion of Alemayehu (2006).

Table 26. *Woody species in the sesame based farming system by grazing type in sesame–livestock farming system (SLFS)*

Woody species	Category	SLFS		
		CG	RS	EN
A. polyacantha	DS	C	D	
T. laxiflora	LD	P	C	
A. tortilis	DS	C	C	C
A. seyal	DS	D	C	C
D. cinerea	DS	C	D	P
A. leiocarpus	DS	C	P	D
P. lucens	HD	C	P	D
F. sycomorus	DS	P		P
C. collinum	LD	C	P	C
X. Americana	LD	P	–	–
B. aegyptiaca	DS	C	C	C
G. villosa	LD	P	–	C
Z. spina-christi	HD	C	C	D
P. toningii	DS	P	P	
F. virosa	LD	C		
B. papyrifera	UD	C	C	D
A. senegal	DS	C	P	C
C. mole	LD	C	C	

CG: communal grazing; RS: road side; EN: enclosure; P: Present (<10% density); C: common (>10% and <20% density); D: dominant (>20% density).

4.9 Range condition assessment

4.9.1 Effect of farming systems on rangeland condition

Communal grazing areas

In the communal grazing areas, basal cover, litter cover and grass species composition were significantly ($P<0.05$) higher in sesame–livestock than in the cotton–livestock farming system (Table 27). This may be associated with grazing intensity and disturbances of the grazing land in the cotton–livestock farming system to be relatively higher than the sesame–livestock farming system. Different literature also suggested that the frequency and intensity of grazing influences the rate of live biomass accumulation on a site thereby affecting the rate of competitive displacement in a multi species community. Additionally, grazing affects the amount of plant litter at the soil surface with important indirect effects on patterns of germination and seedling establishment (Belaynesh 2006; Teshome 2006; Lishan 2007). Productivity of most rangelands has been reduced by human and livestock pressure and natural hazards. Because vegetation integrates all environmental factors acting on a site, knowledge on its type may be used to make inference about prevailing environmental patterns (Herlocker 1999). Major causes of changes in rangelands are excessive grazing by domestic and/or wildlife animals, cultivating for cropping and harvesting resources like firewood, foods and building materials (Teshome 2006; Lishan 2007).

Table 27. *Range condition score (Mean ± SE) of communal grazing areas by farming system in Metema*

Parameter	CLFS	SLFS
Grass species composition score	4.64 ± 0.31b	6.62 ± 0.31a
Basal cover	4.80 ± 0.25a	5.20 ± 0.25a
Litter cover	4.62 ± 0.37a	5.15 ± 0.37a
Soil erosion	3.11 ± 0.30a	2.77 ± 0.30a
Soil compaction	2.79 ± 0.28a	3.33 ± 0.28a
Age distribution of grasses	2.36 ± 0.27a	3.25 ± 0.27a
Seedling distribution	2.91 ± 0.34a	3.22 ± 0.34a
Woody density score	2.25 ± 0.27a	1.50 ± 0.27a
Canopy cover score	8.92 ± 0.77a	6.97 ± 0.77a
Hedging	1.90 ± 0.25a	2.15 ± 0.25a
Total range condition score	38.32 ± 1.21a	40.22 ± 1.21a
Range condition	Fair	Fair
Woody density	3354.17 ± 292.28a	4137.52 ± 292.28a
Canopy cover	146.55 ± 15.98a	179.1 ± 15.98a

CLFS: cotton–livestock farming system; SLFS: sesame–livestock farming system.
Means with different superscripts in a row differ significantly (P<0.05).

Soil erosion and compaction did not differ between farming system. Soil erosion and compaction depend on a number of man made and natural factors including vegetation cover, soil type, intensity and pattern of rainfall, degree of wind erosion, high percentage value of bare ground and grazing management systems in an area.

The woody vegetation density, canopy cover, hedging effect, age distribution and total condition score in the sesame–livestock farming system was significantly (P<0.05) higher than the cotton–livestock farming system (Table 27). The possible reason for the differences between the two could be the disturbance of grazing areas in cotton–livestock farming system by humans and livestock. Based on density value (plants/ha), the most common and/or dominant woody species in the communal grazing areas of cotton–livestock farming are *A. polyacantha (*3050*), A. tortolis (*1450*), A. seyal (*1250*), A. senegal (*800), *A. liocarpus (*1800*), B. aegyptyca (*1050*), B. paperiferra (*650*), P. lucens (*1150*), F. sycomorus (400) S. kunthianum (*150*), X. Americana (*300*)* and *Z. spina-christi (*1550). Studies in Borana area have shown that when the woody plant density is greater than 2400 plants per hectare, the area is moving towards bush encroachment (Gemedo

2004). Based on the results of this study, the communal grazing areas are affected by bush encroachment.

Woody vegetation reduces grass cover through increasing the competition for available water and nutrients and reduces the light reaching the grass layer. In addition to competing with grasses, these noxious woody plants are commonly thorny and thicket forming and the grazing capacity of the rangeland may be extremely reduced (Alemayehu 2004). Factors regulating the balance between graminoid and woody plant life-forms include climate, soils, disturbance (e.g. grazing, fire), and their interactions. Changes in one or more of these factors may enable woody plants to increase in abundance. Characteristics common to many woody species that increase in grazed environments include high seed production, seeds that persist in soil for many years, ability to disperse over long distances, ability to sprout following top removal, tolerance to low levels of water and nutrients and low palatability (Archer 2003). These authors also suggested that as climate changes occur over time, undesirable woody species vigorously spread out on communal grazing lands. In semi-arid ecosystems, drought, absence of fire and overgrazing are some of the major factors that cause conversion of grasslands to woodlands (Coppock 1994; Archer 2003). The increase in woody plant encroachment, loss of palatable grass cover and increase of unpalatable forbs are the main threats to the communal grazing areas in Metema. The result of this study revealed that the condition of the communal grazing lands is in fair condition, and this implies that there is need to take measures to improve the rangelands. Herd diversification through increasing the number of browsers such as camels and goats will contribute towards efficient resource utilization and decrease encroachment of woody plants.

Road side grazing areas

The mean range condition scores for herbaceous species variables considered are presented in (Table 28). Grass species composition, basal cover and litter cover were significantly ($P<0.05$) higher in the sesame–livestock than in the cotton–livestock farming system. This could possibly be associated with the grazing pressure exerted by livestock and climate changes that favour the replacement of most palatable tall and erect species such as (*H. rufa, T. triandra* and *P. coloratum)* by creeping, spreading and grazing resistant species such as *C. dactylon* and less palatable *E. floccifolia* grass species which cover the soil. Similar studies made in Borana (Ayana 1999), Middle Awash (Amsalu 2000; Abule et al. 2007a), Bena-Tsemay (Admasu 2006), Somali Region (Lishan 2007) and Bale Zone (Teshome 2006) in Ethiopia revealed that the percent of cover decreased as the condition of the range decline, due to the replacement of tall and erect species with low growing and spreading species.

Table 28. *Range condition score (Mean ± SE) for road side grazing areas found in different farming systems of the study district*

Parameters	CLFS	SLFS
Grass species composition	4.43 ± 0.22b	5.62 ± 0.22a
Basal cover	4 ± 0.52a	4.25 ± 0.52a
Litter cover	3.51 ± 0.39a	4.87 ± 0.39a
Soil erosion	2.40 ± 0.26a	2.0 ± 0.26a
Soil compaction	2.32 ± 0.27a	2.49 ± 0.27a
Age distribution of grasses	2.25 ± 0.32a	2.71 ± 0.32a
Seedling distribution	1.96 ± 0.38a	2.18 ± 0.38a
Woody density score	2.75 ± 0.27a	2.5 ± 0.27a
Canopy cover score	3.02 ± 0.79a	1.9 ± 0.79a
Hedging	1.25 ± 0.29a	2.10 ± 0.29a
Total range condition score	27.92 ± 1.42a	30.65 ± 1.42a
Range condition	Poor	Poor
Woody density	2678.33 ± 196.34a	2795.85 ± 196.34a
Canopy cover	68.38 ± 13.04a	75.40 ± 13.04a

CLFS: cotton–livestock farming system; SLFS: sesame–livestock farming system.
Means with different superscripts in a row differ significantly (P<0.05).

The mean density of woody plants along the road side grazing lands is 2678.3 ± 13.04/ha in the cotton–livestock farming system and 2795.9 ± 13.04/ha in the sesame–livestock farming system. Based on density value (plants/ha), the woody species in the road side grazing areas of the cotton–livestock farming system identified as common and/or dominant are *A. tortilis,* (1600), *A. seyal,* (350); *B. egyptica*, (1300), *D. cinerea* (1655), *G. ternifolia,* (1150), *P. toninngii* (300), while *A. syal* (2200), *B. egyptica*, (1350), *B. periphera*, *C. collinum*, (300), *T. laxiflora* (750), (1660), and *Z. spina-christi* (1850) are identified as common and/or dominant in the sesame–livestock farming system. Similar to the communal grazing areas, the road side grazing areas are also encroached by bush. The density of woody plants as well as the total range condition scores indicated that the riverside grazing areas are in poor condition, and it is imperative to improve the condition of the rangeland.

Enclosure

In the enclosure areas, the grass species composition, basal cover, litter cover, woody density and canopy cover scores are significantly (P < 0.05) higher in the sesame–livestock than in the cotton–livestock farming system. This could be attributed to the variation in land use pattern of the sites and the response of the species to protection from grazing. Studies indicated that knowledge of the land use history of a site is imperative (Fleischner 1994). In addition to this spatial scale, e.g. plant distribution patterns in an enclosures plot may be caused by different processes than patterns found at the landscape scale; short temporal scales (the initial response of a community to protection or release from grazing may not represent the long-term response) and the pool of species that are present or able to disperse to the protected area. There was no significant ($P < 0.05$) difference in the soil erosion, compaction, age distribution, seedling count, and hedge effects between the two farming systems (Table 29). Generally, these parameters suggested that the condition of the enclosure sites is in a good condition. The number of livestock that graze in the enclosure areas limits the grazing pressure and had a positive effect on rangeland condition. This is considered as a means to protect and conserve local resource under threat from increasing human and livestock population pressure and interventions.

Table 29. *Range condition score (LSM ± SE) in enclosure grazing areas by farming system in Metema*

Parameter	CBFS	SBFS
Grass species composition score	7.80 ± 0.61a	8.11 ± 0.50a
Basal cover	6.91 ± 0.46a	7.03 ± 0.37a
Litter cover	6.0 ± 0.33a	7.05 ± 0.27a
Soil erosion	3.88 ± 0.16b	4.89 ± 0.20a
Soil compaction	4.93 ± 0.38a	3.64 ± 0.31a
Age distribution of grasses	3.70 ± 0.44a	3.67 ± 0.35a
Seedling distribution	4.0 ± 0.21a	4.64 ± 0.17a
Woody density score	3.5 ± 0.28a	3.0 ± 0.23a
Canopy cover score	2.75 ± 0.61a	3.46 ± 0.50a
Hedging	2.20 ± 0.41a	2.43 ± 0.33a
Total range condition score	46.65 ± 0.78a	46.93 ± 0.63a
Range condition	Good	Good
Woody density	2316.7 ± 244.68a	2340.0 ± 199.78a
Canopy cover	64.05 ± 7.27a	71.93 ± 3.44a

CLFS: cotton–livestock farming system; SLFS: sesame–livestock farming system.
Means with different superscripts in a row differ significantly ($P<0.05$).

The woody vegetation density in the enclosure areas did not differ between the two farming systems (Table 29), and the overall mean density of woody vegetation is 1029.9 plants/ha. Based on density value (plants/ha) the common/dominant species in the cotton–livestock farming system are *A. leiocarpus* (300), *A. senegal* (540), *B. aegyptiaca* (500), *B. papyrifera* (500), *P. lucens* (400), and *Z. spina-christi* (1540). In the sesame–livestock farming system, *A. polyacantha* (650), *A. tortilis* (500), *A. seyal* (2250), *A. leiocarpus* (600), *A. senegal* (1550) *B. aegyptiaca* (1480), *B. papyrifera* (3200), *G. villosa* (450), *C. mole* (100), *P. lucens* (2200), *S. kunthianum* (300) and *Z. spina-christi* (1540) are identified as the common and/or dominant species.

The enclosure areas in the two farming systems have different range condition class. In general, the condition of the rangeland in the enclosure areas is good, and implies that establishing enclosures is an alternative method of improving the rangelands. A similar observation was made by Ayana (1999); Amsalu (2000); Admasu (2006); Amaha (2006); Teshome (2006); Lishan (2007) who reported that good range condition class in enclosure areas in Bale, Somali, Borana, Rift valley, Somali and Hamer and Bena-Tesmay areas of Ethiopia, respectively.

4.10 Biomass production

4.10.1 Dry matter biomass production in different grazing types by farming system

Communal grazing areas

Data on dry matter biomass production of highly desirable, intermediate and less desirable grasses in the communal grazing areas are presented by farming system in Table 30.

Table 30. *Dry matter biomass (kg/ha) of the communal grazing areas by farming system in Metema district*

Parameters	CLFS	SLFS
	Mean ± SE	Mean ± SE
Total grasses	2396.6 ± 370.17a	3282.2 ± 598.77b
Highly desirable	143.3 ± 22.14a	145.1 ± 27.46a
Intermediate	1562.8 ± 242.38a	1929.0 ± 352.6b
Less desirable	690.2 ± 106.61a	1206.5 ± 221.29b
Legumes	699.2 ± 56.69a	923.3 ± 213.74b
Others	488.7 ± 128.09a	802.1 ± 163.14b
Total biomass	3584.4 ± 403.34a	5007.6 ± 664.25b

CLFS = cotton–livestock farming system, SLFS = sesame–livestock farming system.
Means with different superscripts in a row differ significantly ($P<0.05$).

The dry matter biomass from grasses and legumes and the total dry matter biomass production are higher in the sesame–livestock than in the cotton–livestock farming system, and these differences may be attributed to the higher grazing intensity and anthropogenic disturbance of the cotton based farming system. Studies on soil erosion and soil compaction generally found out that exposure to livestock grazing compacts soil and this again increases with grazing intensity (Fleischner 1994). Therefore, compaction is directly related to soil productivity, because it reduces water and air movement into and through the soil and reduces water and air availability to the root system of plants.

Soil compaction also directly restricts root growth because as soils become compacted only fewer large pores are present and so there is little space for roots to enter (Amaha 2006). In semi-arid rangelands, under similar rainfall conditions, soil type will have an effect on plant biomass production. Plant biomass and standing crop are affected by species composition and density (Alemayehu 2005).

Road side grazing areas

In the road side grazing areas, dry matter biomass production of total grass, legumes, others and total biomass production are significantly (P<0.05) higher in the sesame–livestock than in the cotton–livestock farming system (see Table 31). The difference could be associated with the increasing grazing intensity and anthropogenic disturbances applied in the cotton–livestock farming system where heavy and continuous grazing pressure resulted in decreased biomass production. There was, however, no significant (P<0.05) difference in the dry matter biomass of legumes between the two farming systems. Grasslands are able to tolerate a moderate degree of grazing intensity before changing in composition, diversity, or productivity. However, as grazing intensity increases or becomes continuous, tall and medium grasses eventually give way to short-stature perennial grasses, which, in turn, gives way to annuals and unpalatable perennials with a concomitant loss of primary and secondary productivity, diversity, cover, and soil. Different reports on Ethiopian rangelands indicated that decline in perennial grass and increase in unpalatable forbs and annual grass cover influenced types of grazing management, rainfall and livestock population pressure where overgrazing coupled by a high population of livestock and prolonged drought may lead to reduction of dry matter biomass production and aggravate rangeland deterioration (Ayana 1999; Amsalu 2000; Gemedo 2004; Amaha 2006; Abule et al. 2007a, b, c).

Table 31. *Dry matter biomass (kg/ha) of the road side grazing areas by farming system in Metema*

Parameters	CLFS	SLFS
	Mean ± SE	Mean ± SE
Grasses	1631.6 ± 370.17a	1963.7 ± 598.77b
Highly desirable	79.3 ± 18.99a	114.8 ± 35.85b
Intermediate	751.9 ± 170.60a	822.8 ± 250.88b
Less desirable	798.7 ± 181.19a	1026.2 ± 312.92b
Legumes	422.1 ± 106.45a	497.7 ± 72.21a
Others	288.7 ± 52.98a	712.9 ± 225.98b
Total biomass	2342.5 ± 403.34a	3174.2 ± 664.25b

CLFS = cotton–livestock farming system, SLFS = sesame–livestock farming system.
Means with different superscripts in a row differ significantly (P<0.05).

Enclosure

In the enclosure areas, total dry matter biomass, dry matter biomass of grasses and legumes are significantly higher ($P < 0.05$) in the sesame–livestock than in the cotton–livestock farming system (Table 32). This may be associated with the presence of more dominant herbaceous species in the sesame–livestock system that may have contributed to the higher biomass production. Some literature suggested that the most dominant species contributed the highest amount of biomass (Kamau 2004). The total dry matter biomass value obtained for the enclosure areas in this study is much higher than those reported by Amsalu (2000), Amaha (2006), and Lishan, (2007) for the arid and semi-arid rangelands of Middle Awash Somali Region of Ethiopia. This implies that the productivity of enclosure areas in Metema is better than other rangelands in Ethiopia and can support livestock population provided that good management practice is applied.

Table 32. *Dry biomass (kg/ha) of enclosure grazing areas by farming system in Metema*

Parameters	CLFS	SLFS
	Mean ± SE	Mean ± SE
Grasses	4814.9 ± 453.36a	8438.6 ± 598.77b
Highly desirable	3343.0 ± 259a	5161.0 ± 367.21b
Desirable	1165.2 ± 15.55a	2676.7 ± 198.9b
Less desirable	305.7 ± 23.51a	599.1 ± 42.51b
Legumes	697.1 ± 164.73a	1071.3 ± 116.27b
Others	375.6 ± 116.27a	1186.0 ± 203.98b
Total biomass	5887.6 ± 493.9a	10695.8 ± 664.2b

CLFS = cotton–livestock farming system, SLFS = sesame–livestock farming system.
Means with different superscripts in a row differ significantly ($P<0.05$).

4.11 Correlation among variables studied for range condition assessment

Among the different variables correlated, only the most important ones were presented (Appendix Tables 5–10). Correlation analysis showed that grass species composition was positively correlated with basal cover, total dry matter biomass and total condition score. Similarly, grass species composition was negatively correlated with soil erosion, soil compaction, woody density and canopy cover. Basal cover was highly and positively correlated ($P \leq 0.05$) with grass species composition and total dry matter biomass and also positively correlated with total condition scores. These finding were in agreement with the report of Gemedo (2004) from the Borana rangelands.

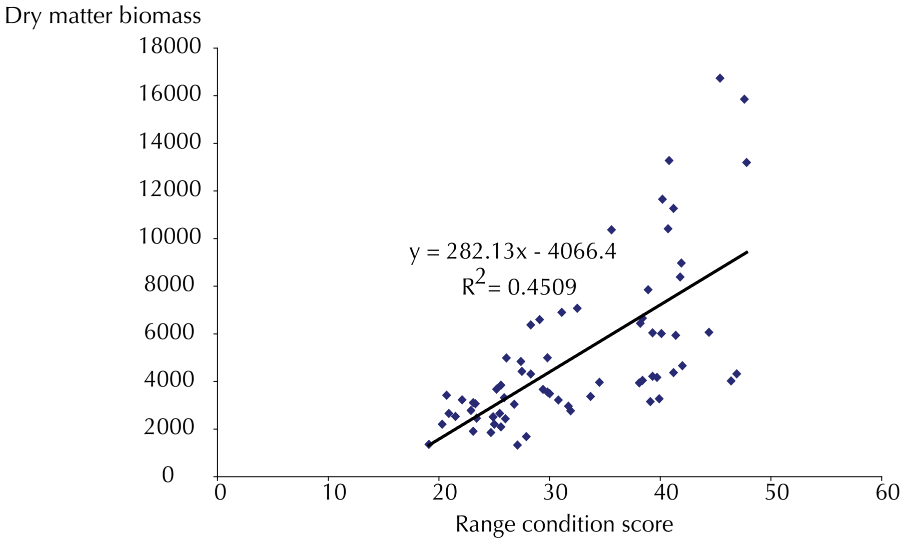

Figure 2. *Regression graph of dry matter biomass and range condition.*

There were positive and significant correlations between basal cover and grass species composition ($P \leq 0.01$); between grass species composition and age distribution ($P \leq 0.01$) whereas strong negative correlations were noted among basal cover, soil erosion, soil compaction, woody density and canopy cover. Total dry matter biomass was also negatively correlated with soil erosion, soil compaction, woody density and canopy cover in the communal grazing areas found in the two farming systems. Similarly, the total dry matter biomass was positively correlated with age distribution, basal cover and grass species composition in the road side grazing areas (Appendix Tables 5–10).

In the enclosure grazing areas, correlation analysis showed that woody density and canopy cover were negatively correlated ($P \leq 0.05$) with basal cover, total dry matter biomass and positively correlated ($P \leq 0.05$) with soil erosion and soil compaction. On the other hand, density of woody vegetation and canopy cover were positively correlated ($P \leq 0.05$) with each other (Appendix Tables 5–10). Similarly, total dry matter biomass production was negatively correlated ($P \leq 0.05$) with soil erosion, soil compaction, woody vegetation density and canopy cover. Besides, the total dry matter biomass was positively correlated ($P \leq 0.05$) with basal cover and grass species composition.

5 Conclusion and recommendations

5.1 Conclusion

This study was conducted in Metema district, North Gondar Zone, Amhara National Regional State of northwestern Ethiopia. The aims of the study were to characterize the existing rangeland, to determine the available feed resources and utilization practices, to assess the natural grazing land based on herbaceous and woody biomass and soil condition and to evaluate the chemical composition of major livestock feed resources of the area. The feed resources utilization practice of the district was assessed through interviewing 140 households using a semi-structured questionnaire, group discussions and personal observations. For the study of rangeland condition, the district was classified into cotton–livestock and sesame–livestock farming systems and three grazing types (communal grazing, enclosure and road side grazing areas). Data on grass species composition, basal and litter covers, age distribution, soil erosion, soil compaction and woody species density, tree height class, canopy cover and hedging effect were collected.

In Metema, the mean family size is 5.31 ± 0.20 persons and the level of education is low. Smallholder crop–livestock mixed farming is dominant and is the main occupation of the people. The mean land holding is 6.78 ± 1.33 ha per household, and the land use pattern includes annual cropping, perennial cropping, communal grazing, fallowing and private grazing. Cattle are the dominant livestock followed by small ruminant (goats and sheep), donkeys and camel. The mean total livestock holding per household is 27.58 ± 13.72 TLU, and is composed of 12.52 ± 6.23 TLU cattle, 0.80 ± 0.40 TLU goats, 0.13 ± 0.07 TLU sheep, 0.65 ± 0.32 TLU donkeys and 0.07 ± 0.04 TLU camels. Female stocks of cattle and goats are dominant in both farming systems because male stocks are sold at earlier ages and females are retained as replacement breeding stock. In addition, ownership of large number of cows is considered as prestige and wealth ranking by the community.

The major livestock feed resources in Metema are natural pasture, crop residues, crop aftermath and fallow land. Natural pasture is the major sources of livestock feed, and contributes to 59.3, 72.9, 72.1 and 42.1% of the diets of cattle, goat, sheep and donkeys, respectively. Although there is surplus feed during the rainy season, these pastures can hardly maintain animals in the dry season due to limited availability and very low nutritive value. Free grazing, tethering and cut-and-carry feeding systems are the commonly practised feeding systems in both farming systems. Animals are allowed to graze in communal grazing land, forest land and fallow lands (privately owned land) during the wet season and from October onwards. From the total area of the district, i.e. 312,300 ha, about 71% is natural pasture and forest land indicating the existence of extensive grazing land resources. The abundantly available feeds in the wet season are mostly wasted because of poor feed conservation practices. Farmers make hay late in the season between mid-October and end of November, when the herbaceous species are lignified and low in nutrient quality.

Crop residues are the second major feed resources. Sorghum is the most important cereal crop grown in Metema next to sesame and cotton, and accounts for about 90% of the total crop residues produced in the district. Crop residues of maize, teff, finger millet and rice make up for the difference. As observed during the field work, there is no proper collection, handling, storage and utilization of crop residues. The total mean crop residues utilization as livestock feed is low, and most of it is either burned in the field or left as mulch. Generally, the feed balance estimate of the district on DM basis is sufficient to support the maintenance requirement of livestock per household, but the quality of the feeds is very poor.

In the rangelands, a total of 32 herbaceous and 20 woody species were recorded. Among the herbaceous species, 41.9% are different grasses and 58.1% are non-grass species. The non-grass species are comprised of five species of legumes, seven species of sedges and six species of forbs. Of the grass species, 23.1% are highly desirable, 38.5% desirable and 30.8% are less desirable. *P. spheslatum* (Jingra) and *C. ciliaris* (Zemen) are the dominant and desirable grass species found in the communal grazing areas of the sesame–livestock and cotton–livestock farming system, respectively. Of the identified woody species, 15, 35, and 50% are highly desirable, desirable and less desirable, respectively. The largest proportion of the woody vegetation is made up of different species of acacia (20%) and commbretum (10%), hence the rangeland can be categorized as an acacia dominated grazing land. *P. lucens* (C*haria*) is a very important fodder tree used as a main livestock feed during the onset of the main rainy season. The woody vegetation falls within the height class of >1–3 m in about 41% of the communal grazing areas, 39% of the road side grazing land and 33% of the enclosure areas, indicating that most of the vegetation is at the browsing height of the animals.

In cotton–livestock farming system, a total of 24 herbaceous and 17 woody species are recorded. Among the herbaceous species, 50% are different grass species, 20.8% legumes and 29.2% sedge species. Among the woody species, 17.7, 41.2, and 35.3% are highly desirable, desirable and less desirable, respectively, while 5.9% are undesirable. In the sesame–livestock farming system, 25 herbaceous and 18 woody species were identified. Among the herbaceous species, 56% are grasses, 20% legumes and 24% sedges species. About 17% of the grass species are highly desirable, while 38.9 and 44.4% are desirable and less desirable, respectively. In the communal grazing areas, basal cover, litter cover and grass species composition are significantly ($P<0.05$) higher in the sesame–livestock than in the cotton–livestock farming system. Higher soil erosion and compaction is observed in the cotton–livestock than in the sesame–livestock farming system. The woody vegetation density is higher ($P<0.05$) in the sesame–livestock than in the cotton–livestock farming system. Grass species composition, basal cover and litter cover of road side grazing is significantly ($P<0.05$) higher in sesame–livestock than in the cotton–livestock farming system. Total dry matter biomass production is significantly ($P < 0.05$) higher in enclosure areas followed by the communal and road side grazing areas.

In general, there is low feed resources conservation and utilization and very poor traditional grazing land management system in Metema. The abundant feed resources in the wet season are wasted. In the dry season, grasses are turned to ash by wild and man-made fire (forest honey harvesters and crop land cleaning). As a result, the livestock population seriously suffer from critical feed shortage during the long dry season. The rangeland, species composition and biomass production are also affected by human, livestock and natural factors (biotic and abiotic factors). The human population of the district has increased due to settlement programs, investment induced settlers, expanding crop cultivation and have increased the pressure on the rangelands and natural grazing areas. Bush encroachment and overgrazing are also serious problems. Shifting cultivation practice is also contributing to the increased bush encroachment. The seasonal movement and transhumant livestock production by highlanders in adjacent districts also increases the grazing intensity.

5.2 Recommendations

- The rangelands in the lowlands of northwestern Ethiopia are important resources for the country and beyond. They are rich in biodiversity, have huge economic importance and play an important ecological buffering role between the Sahel and the highlands of Ethiopia and should be managed properly.
- The rich biodiversity of incense and gum trees is critically important. The fast disappearing species such as *B. paperiferra and Acacia* spp. should be restored through fast propagation and multiplication and aggressive planting campaigns. The excessive and indiscriminate burning of important species of trees and bushes for fire wood should be regulated.
- The livestock resources are enormous and should be properly utilized.
- Conservation of grass hay, which otherwise is burned down during the dry season, should be averted and could be developed as a marketable commodity to the adjacent highland *woredas*, where feed shortage is crucial.

- Transhumance production system is increasingly leading to poor rangeland management and social conflicts over feed resources between the highlanders and lowlanders. Balance has to be established between the two systems.
- Settlers and investors or any new comers to the region should be educated ahead of time about the ecological and economic importance of the natural resources base and should be regulated in terms of utilization. There should be regular campaigns of tree planting.
- Absence of adequate baseline information about the rangeland resources, unsynchronized seasonal availability of feed resources and cropland encroachment to the rangeland are some of the main constraints of the district. Studies on rangeland management systems and improved livestock production should be initiated.
- The deteriorating condition of the rangelands in Metema should be reversed through rangeland rehabilitation, proper management and clearly demarcated land use system of the natural grazing lands.
- Provision of integrated extension service is required on range management, feed resources development and management and training on feed collection, storage, and proper feeding systems.
- Balancing grazer and browser livestock species is essential in order to keep ecological balance as well as to increase livestock productivity.
- Introduction of dual purpose food–feed crops such as sorghum species should be considered.
- The influence of different sub-habitats of woody plants (under canopy, between canopies) on herbaceous species composition and diversity, biomass production and their influence on livestock productivity should be studied.

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Appendices

Appendix Table 1. Criteria for the scoring of the different factors determining range conditions (Herbaceous vegetation and soil condition)

Score	Grasses spp composition	Basal cover	Number of seedlings	Litter cover	Soil erosion	Soil compaction	Age distribution
10	91–100% decreaser	> 12%, no bare areas		> 12%, no bare areas			
9	81–90% decreaser	–		–			
8	71–80% decreaser	>9% evenly distributed		>9% evenly distributed			
7	61–70% decreaser	>9% occasional bare spots		>9% occasional bare spots			
6	51–60% decreaser	>6% evenly distributed		>6% evenly distributed			
5	41–50% decreaser	>6%, bare spots	>4 seedlings on A4 paper	>6%, bare spots	No sign of soil erosion	No compaction	Young, medium ,old
4	10–40% decreaser and >30% increaser	>3%, mainly perennials	4 seedlings on A4 paper	>3%, mainly perennials	Slight sand mulch	Isolated capping	Two size categories
3	10-40% decreaser and <30% increaser	>3%, mainly annuals	3 seedlings on A4 paper	>3%, mainly annuals	Weak-side pedestals	>50% capping	Only old
2	< 10% decreaser and > 50% increaser	1–3%	2 seedlings on A4 paper	1–3%	Steep-sided pedestals	>75% capping	Only medium
1	<10% decreaser and <50% increaser.	<1%	1 seedling on A4 paper	<1%	Pavement	Almost 100% capping	Only young
0		0%	No seedlings	0%	Gullies		

Source: Baars et al. (1997).

Appendix Table 2. Criteria for the scoring of the different factors determining range conditions

Parameters	Value	Total point	Descriptions
Hedging	3	5	Highly palatable and palatable shrubs share dominance
			Most hedge able plants are lightly to moderately hedged
			Few or no decadent plants
	2	3	Palatable plants dominant. Hedgeable plants moderately to
			Heavily hedged
			Some shrubs decadent due to hedging
	1	2	Palatable and less palatable plants dominant
			Hedge able plants heavily to very heavily hedged Considerable numbers of decadents' shrubs present
			Some may be dead due to hedging
	0	1	Less palatable and unpalatable shrubs dominant
			Some normally unhedgeable shrubs are hedged
			Hedge able shrubs very heavily hedged the crowns often reduced to
Canopy cover	3	5	>45% cover
	2	4	36–45% cover
	1.5	3	26–35%
	1	2	15–25%
	0	1	<15% cover
Density		5	0–1000/ha
		4	>1000–2000/ha
		3	>2000–3000/ha
		2	>3000–4000/ha,
		1	>4000/ha

Source: Kuchar (1995).

Appendix Table 3. Common and/or dominant woody species and their percentage composition in the farming system of different grazing areas

Woody species	Category	CLFS			SLFS		
		CG	RS	EN	CG	RS	EN
G. ternifolia	LD	C	–	P	–	–	–
A. polyacantha	DS	D	D	C	C	D	
T. laxiflora		C	P	C	P	C	
A. tortilis	DS	C	D	–	C	C	C
A. seyal	DS	D	C	D	D	C	C
D. cinerea	DS		D	–	C	D	P
A. leiocarpus	DS	C	C	D	C	P	D
P. lucens	HD	C	P	D	C	P	D
F. sycomorus	DS	C	P	–	P		P
C. collinum	LD	P	–	–	C	P	C
X. Americana	LD	C		–	P	–	–
S. kunthianum	DS	C	P	–	–	P	
B. aegyptiaca	DS	C	P	C	C	C	C
G. villosa	LD	–	–	–		–	C
Z. spina-christi	HD	C	C	D	C	C	D
P. toningii	DS	P			P	P	
F. virosa	LD	C	–	–	C		
B. papyrifera	UD	C	P	C	C	C	D
A. senegal	DS	D	P	C	–	P	C
C. mole	LD	–			C	C	

CLFS: cotton livestock farming system; SLFS: sesame livestock farming system; CG: communal grazing; RS: road side; EN: enclosure; P: Present (<10% density); C: common (>10% and <20% density); D: dominant (>20% density).

Appendix Table 4. Herbaceous species identified in different farming system and grazing types of the district

Botanical name	Local name	Category	CLFS			SLFS		
Grasses:			CG	RS	EN	CG	RS	EN
Eriochloa fatamensis (Hochst. and Steud.)	Metruqe	LD	P	C	C	P		
P. sphacelatum (Nees)	Jingra	DS	C	C	C	D	C	C
Urochloa cf. brachyura (Hack.) Stapf	Metruq	LD	P			P		
T. triandra	Chechewa	HD	P		D	P		P
C. ciliaris	Zemen	DS	D	C	C	C		
E. floccifolia	Ahya dagusa	LD		D		C	D	C
S. pumila (Poir.) R. and S.	Dimemo	DS	C		C		C	C
C. dyctlon	Serdo	HD	P	P	C		P	
R.fistulosa (Hochst.) Benth.	Ejargew	LD	C	C			C	
B. lata (Schumach.) C. E. Hub	Mashilo	DS	C		P			C
P. coloratum L.	kok sar	HD			D			D
H. rufa	Topas	HD						D
S. pyramidialis	NA	DS						C
Cyprrus Spp.	Gicha	LD		C				
Legumes:								
I. spicata Forsk.	Kola maget	DS		C		C		C
A. quartinianus A. Rich	Adoye	DS	C		C	C		D
C. mimosoides (L) Greene)	Koina	UD	P	C			p	
-------------------	Yeahiya abish	UD	C	D		D	D	
V. membranacea	Yeayit guaya	DS	C	P	C			C
D. dichotomum (Klein ex W)	Aborida		P		D			
Sedges and others:								
C. barbata	Mech mesel	UD		P		P		C
E. indica	Na	UD	C	C		C	D	
S. sphaerostima	wuha ankur	UD	C	P			C	
H. schulli	Amakela	LD	P					

Botanical name	Local name	Category		CLFS			SLFS	
K. foetidissima	Hareg ressa	UD	P	P				
C. subula	Yekola mech	UD	D	D	C	C	P	
H. articulatus Hoccht.	Abo hareg	HD	P		D			C
B. setigera (Sch. Bip.) Sherff	Yebereha adey	UD	C	C			C	C
Phyllanthus rotundifolius Willd.		UD	p	p				
C. trilocularis L	Amirra	DS						p
H. vitifolius L.	Gimel waika	DS	p		P	p		
Z. elegans Jaquin.	Adey abeba	UD	C	C		C	C	

Appendix Table 5. Correlation matrix among variables studied in the communal grazing areas of CLFS

	fs	spc	bc	lc	se	sc	ag	sed	wds	ccs	heg	tor	wd	cc
Fs	1													
Spc	0.767**	1												
Bc	0.758**	0.540**	1											
C	0.526**	0.383	0.548**	1										
Se	0.571**	0.315	0.744**	0.576**	1									
Sc	0.388	0.387	0.335	0.126	0.135	1								
Ag	0.462*	0.575**	0.243	0.017	–0.14	0.132	1							
Sed	0.234	–0.023	0.179	0.338	0.118	0.228	–0.087	1						
Wds	–0.203	–0.323	–0.056	–0.314	0.491	–0.691	–0.240	–0.612	1					
Ccs	0.664	0.728*	0.312	–0.103	0.121	0.188	0.383	–0.046	0.172	1				
Heg	0.887**	0.737**	0.856**	0.383	0.353	0.555	0.716*	0.118	–0.058	0.616	1			
Tor	0.666**	0.593**	590**	0.468*	0.497	0.383	0.196	0.345	–0.169	0.649	0.902**	1		
Wd	0.612	0.859**	0.490	0.511	0.033	0.807*	0.515	0.219	–0.611	0.410	0.489	0.731*	1	
Cc	0.507	0.351	0.303	0.254	0.374	–0.180	0.088	–0.196	0.237	0.576	0.304	0.417	0.170	1

** Correlation is significant at 0.01 levels;* Correlation is significant at 0.05 levels.

Fs: farming system; Spc: species composition; Bc: basal cover; Lc: litter cover; Se: soil erosion; Sc: soil compaction; Ag: age distribution; Sed: seedling count; Wds: woody density score; Ccs: canopy cover score; Heg: hedging effect; Tor: total range condition score; Wd: woody density; Cc: canopy cover.

Appendix Table 6. Correlation matrixes among variables studied in the road side grazing areas of CLFS

	fs	spc	bc	lc	se	sc	ag	sed	wds	ccs	heg	tor	wd	cc
Fs	1													
Spc	0.707**	1												
Bc	0.497*	0.226	1											
Lc	0.406*	0.288	0.040	1										
Se	–0.073	–0.058	–0.057	0.321	1									
Sc	0.080	0.108	–0.240	0.021	0.014	1								
Ag	0.132	0.138	–0.070	0.507**	0.128	0.197	1							
Sed	0.330	0.060	0.426*	0.137	–0.070	–0.154	–0.248	1						
Wds	0.460	0.246	0.127	–0.038	0.060	0.185	–0.183	0.395	1					
Ccs	–0.220	–0.196	0.488	0.025	0.017	0.334	–0.201	0.141	–0.003	1				
Heg	0.482	0.306	–0.083	–0.073	0.119	0.030	–0.200	0.198	0.792*	–0.275	1			
Tor	0.462*	0.523**	0.222	0.418*	0.167	0.271	0.434*	0.235	0.380	0.457	0.199	1		
wd	0.142	0.036	0.156	0.150	0.453	–0.295	0.149	0.240	0.392	–0.446	0.374	0.138	1	
Cc	–0.071	–0.331	0.472	0.445	0.331	0.111	0.061	0.753*	–0.002	0.298	–0.310	0.469	–.203	1

**= correlation is significant at 0.01 levels,*= correlation is significant at 0.05 levels.

Fs: farming system; Spc: species composition; Bc: basal cover; Lc: litter cover; Se: soil erosion; Sc: soil compaction; Ag: age distribution; Sed: seedling count; Wds: woody density score; Ccs: canopy cover score; Heg: hedging effect; Tor: total range condition score; Wd: woody density; Cc: canopy cover.

Appendix Table 7. Correlation matrixes among variables studied in the enclosure areas of CLFS

	Fs	spc	bc	lc	se	sc	ag	sed	wds	ccs	heg	tor	wd
Fs	1												
Spc	0.339	1											
Bc	0.439	0.595**	1										
Lc	0.302	–0.229	0.027	1									
Se	0.202	0.342	0.089	–0.294	1								
Sc	0.013	0.411	–0.050	–0.034	0.197	1							
Ag	–0.258	–0.494*	–0.323	0.235	–0.548*	–0.213	1						
Sed	–0.146	–0.347	–0.066	0.467*	–0.115	–0.261	0.214	1					
Wds	–0.968**	–0.289	0.009	–0.639	–0.045	–0.069	–0.163	–0.362	1				
Ccs	–449	–219	0.747	–0.575	–0.349	–0.170	–0.265	0.180	0.509	1			
Heg	–425	0.509	–0.071	–0.702	0.730	0.697	0.041	–0.886*	0.360	0.304	1		
Tor	–0.241	0.198	–0.022	–0.621	0.250	0.155	–0.193	0.105	0.896*	0.360	0.304	1	
wd	0.043	–0.405	–0.754	0.631	–0.399	–0.354	0.885*	0.459	–0. 247	–0.603	–0.185	–0.107	1

**= correlation is significant at 0.01 levels;*= correlation is significant at 0.05 levels.

Fs: farming system; Spc: species composition; Bc: basal cover; Lc: litter cover; Se: soil erosion; Sc: soil compaction; Ag: age distribution; Sed: seedling count; Wds: woody density score; Ccs: canopy cover score; Heg: hedging effect; Tor: total range condition score; Wd: woody density; Cc: canopy cover.

Appendix Table 8. Correlation matrix among variables studied in the grazing areas of CLFS

	spc	bc	lc	se	sc	ag	sed	wds	ccs	heg	tor	wd
Grt	1											
Spc	0.665**	1										
Bc	0.611**	0.671**	1									
Lc	0.583**	0.697**	0.714**	1								
Se	0.642**	0.644**	0.582**	0.586**	1							
Sc	0.592**	0.600**	0.626**	0.386**	0.521**	1						
Ag	0.579**	0.689**	0.802**	0.654**	0.620**	0.648**	1					
Sed	0.790**	0.720**	0.477	0.715*	0.820**	0.701*	0.669*	1				
Wds	0.124	0.048	–0.087	–0.235	–0.056	0.092	–0.139	0.147	1			
Ccs	769**	0.693**	0.426	0.788**	0.866**	0.503	0.669*	0.902**	–0.159	1		
Heg	0.757**	0.790**	0.747**	0.764**	0.723**	0.660**	0.801**	0.878**	0.043	0.826**	1	
Tor	–0.281	–0.140	0.112	–0.068	–0.406	–0.096	–0.056	–0.540	0.151	–0.309	–0.233	1
wd	0.214	–0.080	0.137	–0.078	–0.268	–0.216	0.043	–0.490	0.522	–0.299	–0.137	0.657*

**= correlation is significant at 0.01 levels; *= correlation is significant at 0.05 levels.

Fs: farming system; Spc: species composition; Bc: basal cover; Lc: litter cover; Se: soil erosion; Sc: soil compaction; Ag: age distribution; Sed: seedling count; Wds: woody density score; Ccs: canopy cover score; Heg: hedging effect; Tor: total range condition score; Wd: woody density; Cc: canopy cover.

Appendix Table 9. Correlation matrixes among variables studied in the grazing areas of SLFS

	Spc	bc	lc	se	sc	ag	sed	wds	ccs	heg	tor	wd
Spc	1											
Bc	0.631**	1										
Lc	0.718**	0.718**	1									
Se	0.652**	0.615**	0.728**	1								
Sc	0.833**	0.602**	0.807**	0.641**	1							
Ag	0.689**	0.0.470**	0.734**	0.617**	0.732**	1						
Sed	0.568**	0.784**	0.714**	0.458**	0.699**	0.437**	1					
Wds	0.247	0.484	0.516	0.545	0.291	0.052	0.395	1				
Ccs	0.143	0.219	–0.019	0.182	0.049	0.125	0.023	–0.624*	1			
Heg	0.633*	0.574	0.563	0.718*	0.572	0.401	0.582	0.556	–0.240	1		
Tor	0.846**	0.634**	0.811**	0.672**	0.819**	0.685**	0.663**	0.307	0.336	0.591	1	
wd	0.162	–0.114	–0.147	–0.054	0.038	0.124	–0.168	–0.835**	0.828**	–0.271	0.117	1

**= correlation is significant at 0.01 levels,*= correlation is significant at 0.05 levels.

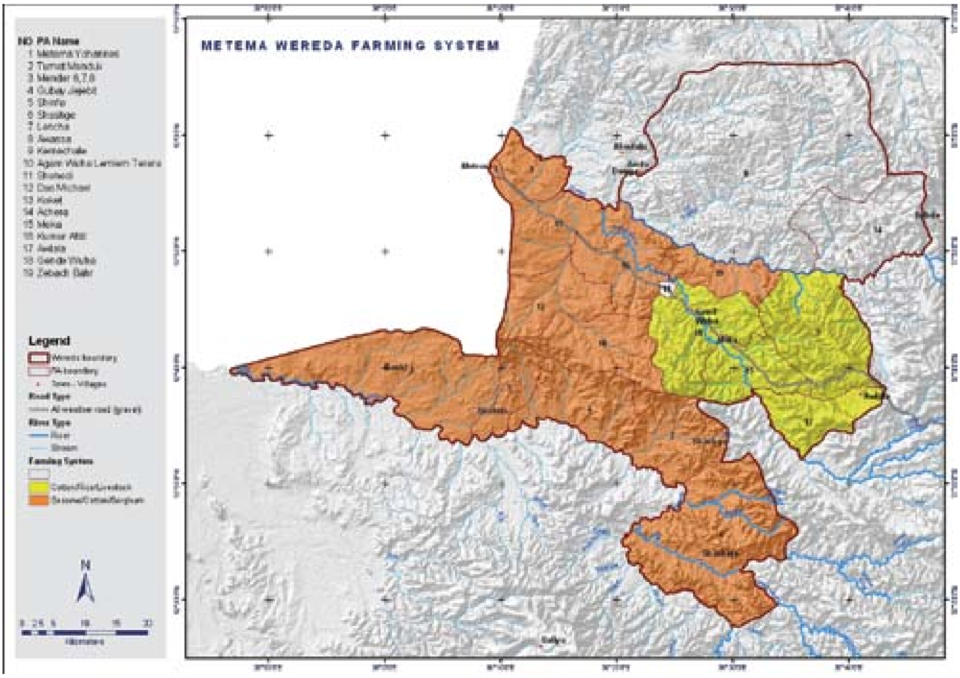
Fs: farming system; Spc: species composition; Bc: basal cover; Lc: litter cover; Se: soil erosion; Sc: soil compaction; Ag: age distribution; Sed: seedling count; Wds: woody density score; Ccs: canopy cover score; Heg: hedging effect; Tor: total range condition score; Wd: woody density; Cc: canopy cover.

Appendix Table 10. Correlation matrix among variables studied and their interactions in range condition assessment in Metema

	Fs	Grt	spc	bc	lc	se	sc	ag	sed	wds	ccs	heg	tor
FS	1												
Grt	0.078	1											
Spc	0.509**	0.345**	1										
Bc	0.443**	0.473**	0.726**	1									
Lc	0.306**	0.451**	0.690**	0.727**	1								
Se	0.247*	0.323**	0.630**	0.677**	0.739**	1							
Sc	0.192	0.454**	0.704**	0.634**	0.703**	0.603**	1						
Ag	0.157	0.328**	0.615**	0.549**	0.682**	0.513**	0.628**	1					
Sed	0.207	0.576**	0.588**	0.733**	0.772**	0.577**	0.669**	0.571**	1				
Wds	–0.086	0.799**	0.418	0.556**	0.406	0.590**	0.520*	0.411	0.523*	1			
Ccs	0.117	–0.678**	0.173	0.169	0.005	0.041	0.040	0.060	–0.024	–0.359	1		
Heg	0.285	0.536*	0.719**	0.677**	0.529*	0.702**	0.734**	0.515*	0.633**	0.737**	–0.142	1	
Tor	0.282*	0.440**	0.797**	0.745**	0.732**	0.773**		0.679**	0.756**	0.634**	0.205	0.770**	1

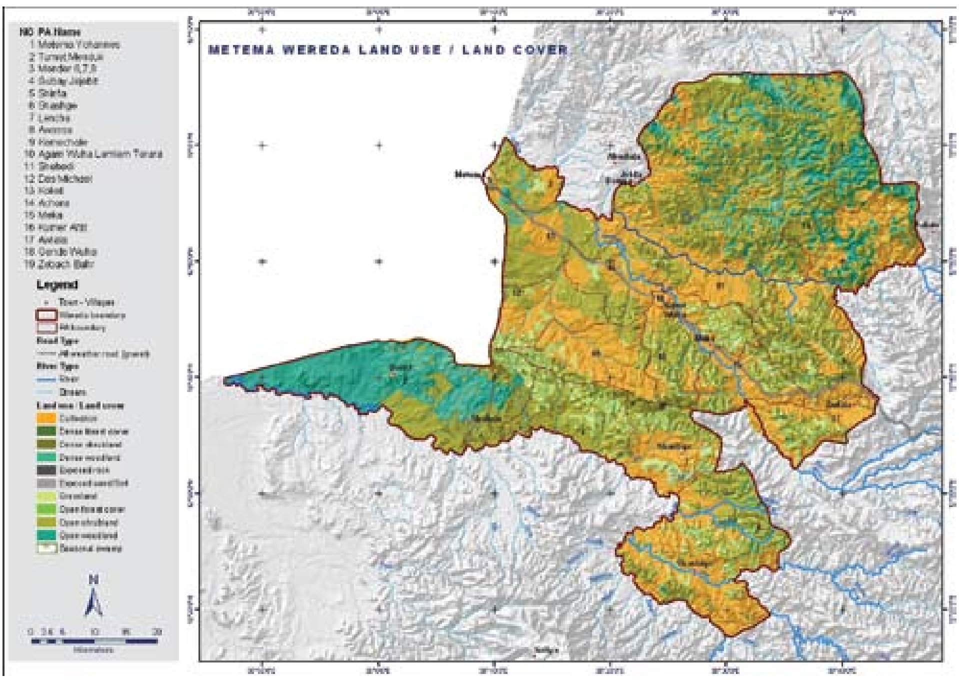
**= correlation is significant at 0.01 levels';*= correlation is significant at 0.05 levels.

Fs: farming system; Spc: species composition; Bc: basal cover; Lc: litter cover; Se: soil erosion; Sc: soil compaction; Ag: age distribution; Sed: seedling count; Wds: woody density score; Ccs: canopy cover score; Heg: hedging effect; Tor: total range condition score; Wd: woody density; Cc: canopy cover.



Source: IPMS (2005).

Appendix Figure 1. Metema district farming systems.



Source: IPMS (2005).

Appendix Figure 2. Land use and land cover of Metema district.

Appendix Figure 3. The view of communal grazing lands at the dry season prior to flash burning.

Appendix Figure 4. The view of communal grazing lands at peak dry season.

Appendix Figure 5. Partial view of communal grazing lands in the sesame-based farming system.

Appendix Figure 6. Hay storage in open field.

Appendix Figure 7. *P. spheslatum* grass dominated communal grazing land at SLFS.

Appendix Figure 8. Part of an enclosure site in the sesame–livestock farming system (Agam wuha).

Appendix Figure 9. Communal grazing land after flash burning.

Appendix Figure 10. *H. rufa* grass dominated wood land (Guange river side areas).

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