Effect of Altitudinal Gradient on Herbaceous Species Composition, Herbaceous Biomass and grassland Condition in North-Eastern Ethiopia

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Abstract

Species composition, biomass yield and grassland condition of four grazing land types (both communally and privately owned grazing areas; riverside grazing sites and grazing reserves, as bench mark areas) were studied along three altitudinal gradients (highland: >2600, medium altitude: 2300-2600, and bottomland: 1900-2300 meter above sea level) in north-eastern highlands of Ethiopia. Grassland condition assessment was based on grass layer composition, basal and litter covers, number of seedlings, age distribution of grasses and soil erosion according to previously developed methodologies. A total of 32 species were identified, of which 18 grasses, 7 legumes and 7 forbs. Benchmarks and private grazing areas had higher number of desirable grasses but the riverside and communal grazing areas dominated by undesirable grasses during the study. Similarly, benchmarks and private grazing areas were found in good and fair grassland condition, respectively, whereas the riverside and communal grazing areas were found in poor condition. Moreover, benchmark areas had a higher biomass yield of herbaceous species compared to the heavily grazed riverside and communal grazing areas. Our results confirmed that species composition, biomass yield and grassland condition in the benchmark areas were found in good condition, whereas riverside and communal grazing areas were highly deteriorated in the Ethiopian highlands, and resulted in severe soil and vegetation degradation. We suggested appropriate grazing land policy, destocking and pasture improvement technologies to improve the condition of the grasslands on the heavily grazed riverside and communal grazing areas in the north-eastern highlands of Ethiopia.

Keywords: *Herbaceous species; Dry matter yield; Grass species; Grazing pressure; Grassland condition class; Soil erosion*

Introduction

In Ethiopia, 85% of the population depends on agriculture for their livelihood. Agriculture is the basis for the entire socio-economic development, provides about 80% of total employment, and the source of 85% of earnings from export (EEA 2002). Livestock is an integral component for most of the agricultural activities in the country. The livestock sector has a share of 12-16% of the total Gross Domestic Product (GDP), and 30-35% of the agricultural GDP (Ayele et al. 2002; EEA 2002). In general, livestock contributes 60-70% of the livelihoods of the Ethiopian population (Abebe 2008). However, the productivity of livestock subsector is extremely low compared to other African countries due to the shortage of feed both in quantity and quality through-out the year (Yeshitila et al. 2008a, b).

Natural pasture is the predominant form of ruminant feeding in most parts of the crop-livestock farming systems in the country (Getachew 2002; Solomon 2004). About 80% of the livestock feed in the highlands of Ethiopia comes from natural pasture (Yeshitila et al. 2008a, b). Continuous grazing and stall-feeding mixed with crop residues are the common feeding systems in the highlands. Moreover, some rotational grazing under the control of herders in privately owned natural pasture land is also practiced in addition to fallow land and stubble grazing. There are different types of grazing land types in the highlands of Ethiopia such as privately owned grazing, communal grazing areas, river and roadside grazing areas, and some permanently protected pasture lands reserved for dry season grazing (Amsalu and Baars 2002; Tessema 2005). However, the increase in human population and the decline in the productivity of arable lands forced the conversion of grasslands into crop production. There is a high competition of land for grazing and crop cultivation in the highlands of Ethiopia. As a result of this and other factors, the disappearance of palatable herbaceous species as well as land degradation, as explained by indicators of soil and vegetation degradation, is the major constraints limiting the productivity of grazing lands in the highlands of Ethiopia (Tessema et al. 2002; Adane and Birhan 2005).

Increased grazing pressure due to large number of domestic animals may drastically affect the species composition and biomass production of the natural pasture and this can in turn change the current conditions of the pasture (Abule et al. 2005; Angassa and Oba 2010; Hoshino et al. 2009; Tessema et al. 2011). Grassland condition indicates the change in vegetation composition, productivity and stability of the grazing areas over time, and it is the most important concept in pasture management (De Leeuw and Tothill 1990; Tainton 1999). According to Trollope et al. (1990) grassland condition is defined as the state of the health of pasture in terms of its ecological status, resistance to soil erosion and potential for producing forage for sustained optimum livestock production. Effective pasture management requires knowledge and information about the relationships of the current grassland condition with its long term potential (Friedel 1991; Kuchar 1995). Grassland condition can be assessed in terms of one or more ecological characteristics of the vegetation in the pasture such as species composition of the herbaceous layer, basal and litter covers, soil erosion and biomass yield (Danckwerts 1982; Friedel 1991; Baars et al. 1997; Tainton 1999). The grassland condition is expressed in grassland condition classes as poor, fair, good, very good and excellent (Wilson and Tupper 1982; Baars et al. 1997; Tainton 1999).

The majority of grazing areas in the highlands of Ethiopia are severely affected by soil and vegetation degradation due to both biotic and abiotic factors. Accordingly, the species composition, herbaceous biomass and grassland condition are affected by factors other than livestock grazing (Bilotta et al. 2007; Ayana 2016). There might be altitudinal patterns in species composition, herbaceous biomass and grassland condition due to differences in climate and soil factors (Dahlberg 2000; Ayana 2016), as species composition (species richness) either show a decrease along altitudinal gradients or a humped-back relationship with peak species richness at intermediate altitudes (Anderson et al. 2010; Speed et al. 2013). Although grazing by livestock is an important form of land use in grasslands, but how grazing affects the species composition, herbaceous biomass and grassland condition along altitudinal gradients is not clear. Moreover, the impact of livestock grazing on grasslands along altitudinal gradients is hard to predict as herbivores are more selective at a range of spatial scales (Nogues-Bravo 2008; Speed et al. 2013). Hence, information that affect the species composition, productivity and condition of the major grazing land types, is very crucial for proper pasture management and development in the highlands of Ethiopia. Therefore, the objectives of the study were to assess the species composition, herbaceous biomass and grassland condition of the major grazing land types along three altitudinal gradients, and to validate the existing grassland condition assessment procedures developed for dryland areas to local conditions in the north-eastern highlands of Ethiopia.

Materials and Methods

Description of the study area

The study was conducted in Kutaber district in south Wollo administrative zone, located 493 km east of Bahir Dar, the capital of Amhara regional state, and 420 km north east of Addis Ababa, the capital of Ethiopia (Figure 1). Kutaber is bordered on the south by Dessie Zuria, on the west by the Adila River which separates it from Tenta, on the north by the Walano which separates it from Ambasel, and on the east by Tehuledere district. The Kutaber district covered about 990,286 km^2 (BOARD 2005).The climate of the district was characterized by cold temperature (6-20°C). The rainfall was bimodal in distribution, with short rainy season (from March-April) and main rainy season (from June-September). The mean annual rainfall of the district was between 731-1068 mm, and was highly variable. The main rai8y season accounts 70% of the total rainfall of the district, with the highest rainfall in July and August. The human and livestock (cattle, small ruminant and equines) population of the district was 24,445 and 229,192, respectively.

Selection of sampling sites

Before the actual field study, reconnaissance survey and visual field observations were made throughout the study district in order to have a general overview of the nature and distribution of the major grazing areas. Then the district was stratified into 3 altitudinal gradients: highland (>2600m), medium altitude (2300-2600m), and bottomland (1900-2300m) for this study. Within each altitude, the grazing lands were stratified into 4 grazing areas: privately owned grazing areas (PGAs), communal grazing areas (CGAs), riverside grazing areas (RGAs), and benchmark (BM) areas. The BM grazing areas were permanently protected from livestock grazing for several years to conserve pasture for dry seasons either in the form of hay or standing biomass (standing hay) and it was lightly grazed by livestock, and used for comparison (as a control) for other grazing land types. The PGAs were owned by individual farmer, which were seasonally grazed by livestock, and had an intermediate grazing pressure during the study. The RGAs and CGAs were grazing throughout the year and all were heavy grazing pressures. The number of sampling sites in PGAs, CGAs, RGAs and BM areas were 10, 9, 6 and 2, respectively based on the proportion of area covered by each grazing land type in the district. Finally, within each sampling site, 4 quadrats were randomly selected, yielding a total of 124 observations for the whole study.

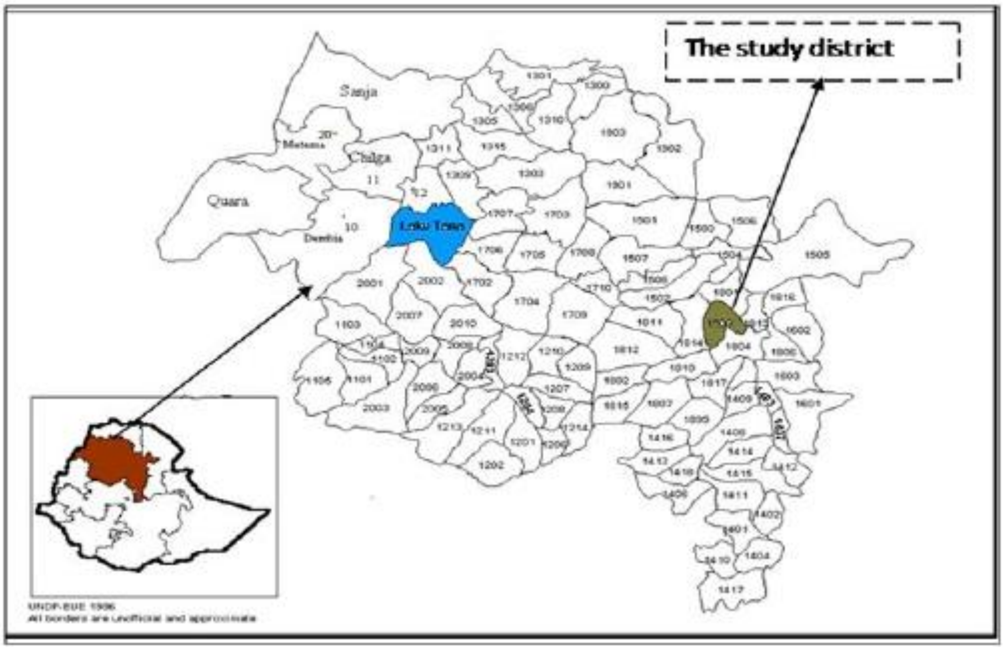

Figure 1. Location of the study area, Kutaber district in south Wollo zone, Amhara National Regional State of Ethiopia

Sampling of herbaceous vegetation

Species composition, biomass yield and grassland condition studies were carried out from September to October of 2008, when most of the herbaceous species were flowering. All herbaceous species were listed, recorded and identified based on their morphological, structural and floristic characteristics. For those species that were difficult to identify in the field, herbarium samples were collected, and transported to the National Herbarium of Addis Ababa University. Plant nomenclature follows Cufodontis (1953-1972), Fromann and Persson (1974); Edwards et al. (1995, 1997, 2000), Hedberg et al. (2003), Hedberg and Edwards (1989, 1995). The herbaceous species were classified into grasses (annual or perennial), herbaceous legumes and forbs within each quadrat and the contribution of each species were determined based on number of occurrence (frequency) within the quadrat. Classification of grasses into desirable species (species likely to decrease with heavy grazing pressure, decreasers), intermediate species (species likely to increase with heavy grazing pressure, increasers), and undesirable species (species likely to invade the pasture land with heavy grazing pressure, pioneers or invaders) according to plant succession theory (Dyksterhuis 1949; Tainton 1999). In case of doubt, the opinion of herdsmen on desirability or palatability of a particular species was considered during classification. Woody species were not included in this study.

Assessment of grassland condition

The factors and criteria considered for grassland condition assessment was based on the composition of the herbaceous layer, basal cover, litter cover, relative number of seedlings, age distribution of grasses and soil erosion (Tainton, 1981; Baars et al., 1997). The maximum possible score was 50 points and the rating was interpreted as excellent (41-50 points), good (31-40), fair (21-30), poor (11-20), and very poor (3-10 points) (Table 1).

Herbaceous species composition, 1 to 10 points were considered based on the contribution of grasses only. At each sample site, 1 m x 1 m (1-m^2) quadrant was cut, and its fresh and dry weight of each individual species was determined. Three levels of species occurrence, based on the dry matter weight, were distinguished: (i) present ≤5% of the dry matter weight of the herbaceous biomass; (ii) common = 5-20%; and (iii) dominant ≥20%. Basal cover (0-10 points) and litter cover, 0 to 10 points were considered. A representative sample area of 1-m^2 was selected for detailed assessments. The surface of basal cover of tufted grasses and their distribution was assessed as follows. One square metre was divided into eight equal parts. All basal covers of plant in the selected 1-m^2 were transferred (drawn) to one of the eighths in order to facilitate visual estimations of only basal covers of living parts. The rating of basal cover for tufted species was considered excellent (10 points), if the eighth was completely filled (corresponding to 12.5% basal cover of the original square metre). Classes of <3%, 3-6%, 6-9%, 9-12% were distinguished. The basal cover was considered very poor (0, 1 or 2 points) if the basal cover was <3%. The maximum score was given to creeping grass species because of higher basal cover.

The rating for litter cover within the 1-m^2 was considered excellent when it exceeded 40%, moderate from 11-40% and poor at <10% litter cover. Number of seedlings, 0 to 5 points was considered. The number of seedlings was counted using three areas, with a distance of approximately 10 m between the areas, equal to the size of an A4 sheet of paper chosen at random. The sheet was dropped from a height of 2 m above the ground. The category 'no seedlings' was given 0 points, 1 seedling 1 point etc., and more than 4 seedlings was given the maximum score of 5 points. Age distribution (1-5 points), when all age categories, young, medium aged and old plants of the dominant grass species were present, the maximum score of 5 points was given. Young and medium aged plants were declined as having approximately 20% and 50%, respectively, of the biomass of old and mature plants of the dominant species. When there were only old, medium aged or young plants, the scores were 3, 2 or 1 point, respectively. Soil erosion (0 to 5 points) was based on the amount of pedestals (higher parts of soils, held together by plant roots, with eroded soil around the tuft), and in severe cases, the presence of pavements (terraces of flat soil, normally without basal cover, with a line of tufts between pavements) (5 points = no signs of erosion, 4 = slightly sand mulch, 3 = weak pedestals, 2 = steep-sided pedestals, 1 = pavements, 0 = gullies).

Biomass yield of herbaceous vegetation

Dry matter (DM) yield of the herbaceous layer was determined by harvesting the whole fresh biomass within 1 m x 1 m (1-m^2) quadrat at ground level, and oven dried at 70^{o}C for 48 h and weighing until constant weight (ILCA 1990).

Table 1. Criteria for the scoring of the different factors determining pasture condition

Score	Grass composition	Basal Cover	Litter cover	Number of seedling	Age distribution	Soil erosion
10	91-100% decreasers	>12% no bare areas	>40%			
9	81-90% decreasers	_	_			
8	71-80% decreasers	>9% evenly distributed	11-40% evenly distributed			
7	61-70% decreasers	>9% occasional bare spots	_			
6	51-60% decreasers	>6% evenly distributed	11-40% unevenly distributed			
5	41-50% decreasers	>6% bare spots	_	>4 seedlings on A4 paper	Young medium and old	no soil movement
4	10-40% decreasers >30% increasers	>3% mainly perennials	3 -10% mainly grasses	4 seedlings on A4 paper	two size category present	slight- sand mulch
3	10-40% decreasers <30% increasers	>3% mainly annuals	_	3 seedlings on A4 paper	only old	slope- side pedestals
2	<10% Decreasers >50% increasers	1-3%	3-10% weeds tree leaves	2 seedlings on A4 paper	only medium	steep- sided pedestals
1	<10% decreasers >50% Increasers	<1%	_	1 seedling on A4 paper	only young	Pavements
0		0%	<3%	no seedling		gullies

Source: Baars et al. (1997)

Data analyses

The dry matter yield and grassland condition score data were subjected to analysis of variance (ANOVA) using the Generalized Linear Model (GLM) procedures of SPSS (version 16). The model included the effect of altitude, grazing land types and their interaction. Means were compared using the least significant difference (LSD).

Results

Herbaceous species composition

A total of 32 herbaceous species were identified in the study areas, of which 18 were grass species, 7 were herbaceous legume species and 7 were forbs species. *Andropogon abyssinica* and *Andropogon pratensis* were dominant in the bench marks in all the three altitudinal gradients. *Sprobolous africanus* were dominant in the PGAs and RGAs, while *Eleusine floccifolia, Pennisetum macrorum* and *Pennisetum schimperi* were dominant in the CGAs in all the attitudinal ranges (Table 2). Out of the 18 grass species identified, 14 grass species were found in the highlands, whereas 12 and 9 grass species recorded in the medium and bottom lands, respectively in all grazing land types (Table 2). The total number of grass species recorded in the BM areas, PGAs, RGAs and CGAs were 12, 11, 10 and 9, respectively. The BM areas and PGAs had relatively higher number of grass species compared to the RGAs and CGAs in the present study.

Grassland condition

The lightly grazed BM areas had a higher grassland condition (31.4 points out of 50 points) followed by the PGAs compared to the heavily grazed RGAs and CGAs (26 points out of 50 points) in all altitudinal ranges (Table 3). The extreme excellent grassland condition score did not occur in all the grazing areas in the present study. The highland (>2600m) showed a higher grassland condition (23 points out of 50 points) compared to the medium altitude (2300-2600m) and bottomland (1900-2300m) with 21 and 20 points out of 50 points, respectively. The excellent and the good grassland condition scores did not occur in all altitude ranges, and all the altitude ranges were found in fair grassland condition (Table 3). The condition of BM areas in all altitude ranges showed a good grassland condition and the PGAs were in fair condition. The heavily grazed RGAs and CGAs had a poor grassland condition scores, with 17.5 and 11 scores, respectively. However, the CGAs in the bottom lands were very poor in grassland condition. The overall condition score of the PGAs was 78% (range: 75-83%) of the BM areas. The overall grassland condition score of the heavily grazed RGAs and CGAs were found to be 57% and 38% (range: 50-59% and 31-42%) of the BM areas, respectively. The condition score for species composition of the BM areas and PGAs were high and quite different from the heavily grazed RGAs and CGAs. Similarly basal cover and litter cover as well as number of seedlings and age distribution showed the highest scores in the BM areas, intermediate scores in the PGAs, and lower scores in the RGAs and CGAs in all altitudinal ranges (Table 3).

Table 2: Herbaceous species composition with their percentage of occurrence (% of dry matter) from four grazing areas in three altitudinal ranges in the highlands of Ethiopia

Scientific name			Highland (>2600 m)				Medium altitude (2300-2600 m)				Bottom land (1900-2300m)			
			BM	RGA	PGA	CGA	BM	RGA	PGA	CGA	BM	RGA	PGA	CGA
Andropogon abyssinicus	P	D	28.9	16.6	18.4	1.5	27.8	11.7	23.1	1.5	26.6	18.8	25.1	-
Andropogon pratensis	P	D	25.6	-	17.1	2.6	20.1	-	25.9	0.2	-	-	-	-
Andropogon chrysostachyus	P	D	-	-	-	-	-	-	-	-	9.4	-	-	-
Aristida adoensis	A	I	-	-	-	-	-	-	-	-	5.2	19.7	13.2	21.2
Bothriochloa radicans	P	D	-	-	-	-	-	-	-	-	21.3	-	11.3	-
Eleusine floccifolia	A	P+	6.2	-	3.5	24.3	5.5	22.1	-	24.4	-	-	-	-
Eragrostis tenuifolia	A	P+	-	17.2	6.1	4.0	-	10.3	6.2	9.2	-	-	-	-
Harpachne schimperi	A	I	-	4.5	-	-	-	-	-	-	-	-	-	-
Hyparrhenia tuberculata	P	I	-	3.0	-	-	-	0.7	-	-	-	-	-	-
Hyparrhenia filipendula	P	I	-	2.9	-	-	-	1.2	-	-	-	2.9	0.6	-
Hyparrhenia rufa	P	I	19.1	-	3.2	-	8.1	-	-	-	5.7	-	-	-
Pennisetum adoensis	P	I	-	-	2.4	0.5	0.9	-	12.5	-	-	-	-	-
Pennisetum macrorum	P	I	P	-	18.3	27.7	5.0	20.3	22.5	21.6	-	-	-	-
Pennisetum schimperi	P	I	P	22.3	4.2	22.8	3.2	-	-	23.3	-	8.5	19.5	29.1
Microchloa nubica	A	I	-	1.8	-	-	-	-	-	-	-	-	-	-
Setaria pumila	A	D	-	-	-	-	-	-	-	0.4	5.8	0.8	-	12.3
Sporobolus africanus	P	I	6.1	25.3	21.1	-	5.3	21.4	-	-	11.8	27.5	25.4	-
Themeda triandra	A	D	5.8	-	-	-	-	-	-	-	-	-	-	-

BM = benchmark; PGA = private owned grazing areas; RGA = riverside grazing areas; CGA = communal grazing areas; D = decreaser; I = increaser; P+ = pioneer grass species; P = perennial; A = annual; - = species not present

Table 3: Least square means ± (SE) of grassland condition scores of four grazing areas in three altitude ranges in the highlands of Ethiopia

	Grazing land types			
	Benchmarks	Private grazing	Riverside grazing	Communal grazing
Bottomland (1 900–2 300m)				
Species composition	8.0 ± 0.12[a]	5.5 ± 0.20[b]	2.8 ± 0.15[c]	2.4 ± 0.09[c]
Basal cover	7.6 ±0.13[a]	5.7 ± 0.17[b]	4.2 ± 0.12[c]	2.6 ± 0.08[d]
Litter cover	5.9 ± 0.13[a]	3.7 ± 0.17[b]	2.2 ±0.13[c]	0.4 ± 0.08[d]
Number of seedlings	2.7 ± 0.12[a]	2.6 ± 0.12[a]	0.7 ± 0.10[b]	0.4 ± 0.08[b]
Age distribution	2.7 ± 0.10[a]	2.5 ± 0.13[a]	1.7 ± 0.12[b]	1.4 ± 0.08[b]
Soil erosion	4.0 ± 0.08[a]	3.5 ± 0.14[b]	3.0 ± 0.08[c]	2.6 ± 0.08[d]
Total condition score	30.9 ± 0.29[a]	23.5 ± 0.34[b]	15.6 ± 0.25[c]	9.7 ± 0.27[d]
Total as % of benchmark		77%	50%	31%
Grassland condition class	Good	Fair	Poor	very poor
Medium altitude (2 300–2 600m)				
Species composition	6.9 ± 0.12[a]	5.4 ± 0.16[b]	3.5 ± 0.15[c]	1.5 ± 0.11[d]
Basal cover	7.7 ± 0.13[a]	6.3 ± 0.14[b]	5.0 ± 0.12[c]	3.4 ± 0.10[d]
Litter cover	6.1 ± 0.13[b]	3.3 ± 0.10[b]	2.4 ± 0.13[b]	0.7 ± 0.09[b]
Number of seedlings	2.6 ± 0.01[a]	1.7 ± 0.10[b]	1.3 ± 0.10[c]	0.4 ± 0.09[d]
Age distribution	3.7 ± 0.13[a]	2.7 ± 0.10[b]	2.4 ± 0.12[c]	1.5 ± 0.10[d]
Soil erosion	4.0 ± 0.08[a]	3.7 ± 0.11[b]	3.3 ± 0.08[c]	3.0 ± 0.09[d]
Total condition score	30.8 ± 0.29[a]	23.2 ± 0.27[b]	17.9 ± 0.25[c]	10.5 ± 0.31[d]
Total as % of benchmark		75%	58%	40%
Grassland condition class	Good	Fair	Poor	Poor
Highland (>2 600m)				
Species composition	7.1 ± 0.12[a]	6.6 ± 0.13[b]	3.3 ± 0.15[c]	2.7 ± 0.13[d]
Basal cover	8.1 ± 0.12[a]	6.7 ± 0.11[b]	5.3 ± 0.12[c]	3.6 ± 0.12[d]
Litter cover	6.7 ± 0.13[a]	4.0 ± 0.11[b]	2.7 ± 0.13[c]	1.1 ± 0.12[d]
Number of seedlings	3.1 ± 0.01[a]	2.4 ± 0.20[b]	1.7 ± 0.10[c]	0.7 ± 0.11[d]
Age distribution	3.6 ± 0.10[a]	3.3 ± 0.08[b]	2.7 ± 0.12[c]	2.0 ± 0.12[d]
Soil erosion	4.0 ± 0.08[a]	3.9 ± 0.08[a]	3.5 ± 0.08[a]	3.4 ± 0.11[a]
Total condition score	32.5 ± 0.29[a]	27.0 ±0.21[b]	19.1 ± 0.25[c]	13.5 ± 0.38[d]
Total as % of benchmark		83%	59%	42%
Grassland condition class	Good	Fair	Poor	Poor

[a, b, c, d] Means with different superscript within row differ at $P \leq 0.05$

Herbaceous biomass versus grassland condition

The total DM of the herbaceous species as well as its components showed the highest yield in the BM areas followed by the PGAs. The total dry matter and its component in the heavily grazed RGAs and CGAs showed lower yields in a decreasing order, respectively, in the present study (Table 4). The total dry matter and its components in the highlands showed the highest yield, intermediate yield in the medium altitude and bottomlands (Table 5). Within each grazing areas, the highlands showed the highest yield of 2 994 kg ha^{-1}, followed by the bottomlands with 2 713 kg ha^{-1}. However, the medium altitude had the lowest yield of 2 169 kg ha^{-1}compared to the highland and bottomlands in the study areas (Table 6). The contributions of decreaser grasses and the total grasses to the total dry matter yield were significant in all grazing areas with the highest in the BM areas and the lowest in the CGAs. Increasers had the highest yield in the PGAs compared to other grazing areas in all altitude ranges. However, the contribution of pioneer grasses was higher in the heavily grazed RGAs both in the bottomland and medium altitudes, whereas the communal grazing areas had a higher pioneer grasses in the highlands compared to other altitude ranges. The contribution of herbaceous legumes was higher in the BM areas in the bottomland and medium altitude ranges (Table 6).

Table 4: Least square means ± (SE) of biomass yield of natural pasture (kg ha^{-1}) from four grazing land types in the highland of Ethiopia

Categories	Grazing land types			
	Benchmarks	Private grazing	Riverside grazing	Communal grazing
Decreasers	3098.8 ± 98.7 ^{a}	843.9 ± 59.0^{b}	271.2 ± 24.1^{c}	77.3 ± 10.4^{d}
Inceasers	1076.8 ± 28.4^{a}	981.0 ± 66.3^{b}	753.5 ± 64.1^{c}	430.9 ± 56.6^{d}
Pioneers	293.6 ± 8.0^{b}	223.9 ± 15.2^{d}	362.7 ± 30.8^{a}	282.3 ± 35.8^{c}
Grass total	4470.2 ± 118.0^{a}	2048.8 ± 138.5^{b}	1387.4 ± 118.0^{c}	790.5 ± 100.3^{d}
Legumes	547.0 ± 40.9^{a}	121.5 ± 48.1^{b}	105.5 ± 40.9^{b}	111.2 ± 34.8^{b}
Forbs	181.1 ± 27.6^{a}	122.9 ± 32.4^{abc}	68.1 ± 27.6c	80.4 ± 23.5^{c}
Total DM yield	5198.3 ± 125.2^{a}	2293.2 ± 147.0^{b}	1561.0 ± 125.2^{c}	982.1 ± 106.4^{d}

a, b, c, d Means with different superscript within row differ (P<0.05)

Table 5: Least square means ± (SE) of biomass yield of natural pasture (kg ha^{-1}) from the three altitude ranges in the highland of Ethiopia

	Altitudinal gradients		
	Highland (>2600m)	Medium altitude (2300-2600m)	Bottomland (1900-2300m)
Decreasers	832.8 ± 33.6 ^{a}	640.0 ± 36.0^{c}	789.1 ± 41.5^{b}
Inceasers	1336.6 ± 50.8^{a}	845.9 ± 45.4^{b}	802.8 ± 43.8^{b}
Pioneers	448.5 ± 17.0^{a}	434.2 ± 23.1^{a}	392.1 ± 21.4^{a}
Grass total	2437.9 ± 99.6^{a}	1920.1 ± 102.2^{b}	1984.0 ± 108.4^{b}
Legumes	98.0 ± 34.59^{c}	350.2 ± 35.5^{a}	215.7 ± 37.6^{b}
Forbs	107.8 ± 23.4^{b}	55.1 ± 24.0^{b}	176.5 ± 25.4^{a}
Total DM yield	2643.7 ± 105.7^{a}	2325.4 ± 108.5^{b}	2377.2 ± 115.1^{b}

a, b, c, d Means with different superscript within row differ (P<0.05)

Table 6: The interaction effect of different grazing areas and altitudinal ranges on biomass yield of natural pasture (kg ha^{-1}; Mean ± SE) in the highland of Ethiopia

	Grazing land types			
	Bench marks	Private grazing	Riverside grazing	Communal grazing
Bottomland (1 900–2 300m)				
Decreasers	3254.7 ± 246.3^a	788.4 ± 99.9^c	1082.2 ± 169.1^b	106.8 ± 24.5^d
Inceasers	394.5 ± 36.9^b	1403.9 ± 174.6^a	299.8 ± 46.8^c	256.7 ± 56.6^{cd}
Pioneers	244.8 ± 18.3^c	394.2 ± 48.9^b	523.3 ± 82^a	187.1 ± 41.2^d
Grass total	3894.0 ± 298.7^a	2586.5 ± 310.8^b	1905.3 ± 49.0^c	550.6 ± 121.5^d
Legumes	471.1 ± 137.4^a	105.7 ± 24.2^d	256.7 ± 40.1^b	134.2 ± 26.2^c
Forbs	244.5 ± 70.5^a	239.9 ± 48.4^a	219.5 ± 49.6^a	243.1 ± 26.2^a
Total dry matter	4609.6 ± 302.4^a	2932.1 ± 321.3^b	2381.5 ±160.7^c	927.9 ± 144.3^d
Medium altitude (2 300–2 600m)				
Grass total	4056.2 ± 298.7^a	1883.8 ± 253.9^b	1859.3 ± 40.8^b	674.4 ± 140.3^c
Decreasers	2500.8 ± 185.4^a	990.8 ± 138.8^c	1134.4 ± 141.0^b	26.6 ± 7.2^d
Inceasers	1268.6 ± 93.4^a	767.7 ± 98.4^b	147.6 ± 18.7^d	399.4 ± 77.4^c
Pioneers	286.8 ± 21.1^b	125.3 ± 17.4^c	577.3 ± 72.1^a	248.4 ± 56.6^b
Legumes	1040.8 ± 13.7 ^{a}	166.5 ± 19.8^c	409.2 ± 50.8^b	99.1 ± 30.2^d
Forbs	123.6 ± 70.5^b	30.8 ± 39.6^c	145.0 ± 41.4^b	187.6 ± 30.2^a
Total dry matter	5220.6 ± 30.4^a	2081.1 ± 262.3^b	413.5 ± 134.0^d	961.1± 166.2^c
Highland (>2 600m)				
Decreasers	3474.9 ± 198.0^a	807.1 ± 77.1^c	1754.5 ± 169.1^b	67.8 ± 11.6^d
Increasers	1534.3 ± 86.5^a	1052.6 ± 99.3^b	314.0 ± 32.2^d	744.0 ± 105.8^c
Pioneers	349.4 ± 19.7 ^{a}	222.6 ± 21.5^b	112.2 ± 107.2^b	394.8 ± 56.1^a
Grass total	5358.6 ± 298.7^a	2082.3 ± 196.6^b	2180.7 ± 49.0^b	1206.6 ± 171.8^b
Legumes	129.0 ± 37.4^b	92.3 ± 15.3^{bc}	326.2 ± 31.4^a	100.4 ± 37.0^{bc}
Forbs/sedges	175.0 ± 70.5 ^{a}	98.1 ± 30.6^b	138.3 ± 49.6^a	78.3 ± 46.8^b
Total DM yield	5662.6 ±302.4^a	2272.7 ± 203.2^b	2654.2 ± 160.7^c	1385.3 ± 204.1^d

$^{a, b, c, d}$ Means with different superscript within row differ (P<0.05)

Discussion

Herbaceous species

The lightly grazed BM areas and PGAs had relatively a higher number of grass species compared to the heavily grazed RGAs and CGAs in the highlands of Ethiopia. The 32 identified herbaceous species in the present study were well known in different grazing areas in Ethiopia (Fromann and Persson 1974, Ayana and Baars 2000; Amsalu and Baars 2002; Abule et al. 2005; 2007; Tessema et al. 2010). 13 out of the 36 identified grasses were reported in the southern parts of Ethiopia (Ayana and Baars 2000). Amsalu and Baars (2002) reported 36 grass species out of the 87 species recorded in the rift valley of Ethiopia. Similarly, 14 grass species were identified in the heavily grazed sites of the middle Awash valley of Ethiopia (Abule et al. 2005). However, Tessema et al. (2010) has reported higher number of grass species (45 species out of the 69 total herbaceous species identified) in the Awash national park and Abernosa cattle breeding ranch in Ethiopia, and a total of 55 grass species in the highlands of north western Ethiopia (Tessema 2005).

The total number of herbaceous species identified in particular and the total grass species in general were very small in the present study. According to Amsalu and Baars (2002), a long term increase or relaxation of grazing pressure could change the plant community, and under heavy grazing pressure, palatable plants (decreasers) disappear and are replaced by less palatable plant species (increasers or invaders). Under low grazing pressure, the reverse might happen (Dykesterhuis 1949). Continuous heavy grazing alters the herbaceous vegetation composition through an increase in the abundance of annual species with a decline in perennials (Diaz et al. 2007; Hoshino et al. 2009). Smith (1979) reported that heavy grazing reduces the growth rate and reproductive potential of perennial grasses and influences the competitive relationships among the different species. Hence, the heavily grazed perennial grass species loss competitive power compared to the lightly grazed ones, and subsequently, unpalatable and grazing tolerant annual species remain dominant in heavily grazed patches (McNaughton 1979; Stuart-Hill and Tainton 1989).

The mechanism is described by previous studies as an interaction between grazing and competition within the plant community (Dyksterhuis 1949; Smith 1979; Tainton 1999). In this situation, grazing intolerant species disappear because they are highly nutritious and eaten before seed setting or other species that can tolerate heavy grazing and physical damage survive and subsequently replace highly grazed palatable species in the area (Abule et al. 2005; Tessema et al. 2010). Moreover, palatable perennial grass species may be dominated and replaced by annual species, weeds and woody plants) associated with increasing grazing pressure (Westoby et al. 1989; Milton and Hoffman 1994; Milton et al. 1994). The contribution of decreaser grass species in the present study were higher in the BM areas followed by the PGAs compared to the heavily grazed RGAs and CGAs in the present study. Our finding in the present was against the report of Amsalu and Baars (2002), but in agreement with Ayana and Baars (2000).

The scores for species composition of the BM areas and PGAs in all altitude ranges were higher and quite different to the heavily grazed RGAs and CGAs, indicating that BM areas were protected from heavy grazing pressure and as a result most grass species were palatable. All grassland condition factors were found good in the BM areas. The palatable grass species such as *Andropogon abyssinica* and *Andropogon pratensis* dominated the BM areas in all the three altitude ranges. However, the unpalatable grass species *Eleusine floccifolia, Pennisetum macrorum* and *Pennisetum schimperi* were dominant in the CGAs. Moreover, the tall but less palatable *Hyparrhenia* spp. and *Sprobolous africanus* dominated the RGAs, and these species are classified as an increaser’s species. According to Harrington and Pratchett (1974) and Amsalu and Baars (2002) under heavy grazing, *Hyparrhenia* spp. dominated grazing areas might change to another one dominated by shorter grasses like *Cynodon dactylon, Heteropogon contortus* and *Microchloa* species.

Grassland condition

The lightly grazed BM areas in all altitude ranges showed a good overall grassland condition, followed by the PGAs compared to the heavily grazed RGAs and CGAs. The grassland condition of a given area should therefore not be evaluated by considering the species composition alone (Anderson 1985; Tiedeman et al. 1991; Amsalu and Baars 2002; Gemodo et al. 2006). The percentage of bare ground were far lower for light grazing sites compared to heavy grazing sites, whereas the percentage basal cover of herbaceous species was far larger on lightly grazed sites (Tessema et al. 2010).Other parameters like soil condition, ground cover and age distribution should be included (Friedel 1991; Baars et al. 1997). We have assessed the grassland condition in the present study including species composition, basal and litter covers, number of seedlings and age distribution of grass species, and all these parameters were higher in the BM areas and PGAs than the CGAs and RGAs due to sustained heavy grazing pressure experienced in the past long years. Studies were conducted using similar criteria to evaluate the rangeland conditions in the lowland areas of Ethiopia (Ayana and Baars 2000; Amsalu and Baars 2002; Gemedo et al. 2006), and the range condition scores obtained from these studies corresponded with the major grazing areas of the highlands in the present study. We concluded that the grassland condition in the BM areas in the highland of Ethiopia and PGAs were almost similar in most lowland rangelands areas of the country. Moreover, these range condition assessment factors could be used not only in the lowland rangelands but also in the highland grazing areas with proper implementation of the procedures under field situation.

Biomass versus grassland condition

The total dry matter yield of the herbaceous species as well as its components showed the highest in the BM areas followed by the PGAs. However, the total dry matter yield and its component yield in the heavily grazed RGAs and CGAs were lower in the present study. Grazing areas with higher elevation under the light grazing pressure had a higher standing biomass of herbaceous species compared to the lowland grazing areas under heavy grazing pressure (Tessema 2005; Brinkmann et al. 2009; Tessema and Oustalet 2007; Tessema et al. 2011). Within each grazing areas, biomass yield was higher in the highlands followed by bottomlands in the present study. According to Snyman and Fouche (1993) there is a direct proportional relationship between biomass yield and grassland condition in such a way that forage production is low when the grassland condition is low. The relationship between biomass yield of the herbaceous layer and the grassland condition in our study supports the report of previous studies by Snyman and Fouche (1993). However, Amsalu and Baars (2002) reported a poor relationship between biomass yield of the herbaceous layer and the range condition in the rift valley of Ethiopia.

Conclusions

The species composition, biomass yield and grassland condition in the bench mark areas was found relatively in a good condition and the privately owned grazed areas were in fair conditions in the north-eastern highland of Ethiopia. However, the heavily grazed riverside grazing and communally owned grazing areas were found poor in terms of species composition, biomass yield and grassland condition, and resulted in severe land degradation, which is explained by the soil and herbaceous vegetation degradation indicators during our study. Unless this soil and vegetation degradation in major grazing land types are reversed, the north-eastern highlands of the country will be in high risk of food insecurity, loss of biological diversity and ecological instability in the future. The results of the present study confirmed that existing grassland condition assessment procedures developed for dryland areas of Africa could be used for the condition assessment of grazing lands (grasslands) in the highlands of Ethiopia. Finally, we recommend that community based pasture improvement interventions and proper land use planning should be in placed to optimize and sustain the huge livestock population as well as for better environmental and ecological utilization of the grazing areas in the north-eastern highlands of Ethiopia.

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References

Abebe Mekoya. 2008. Multipurpose fodder trees in Ethiopia: Farmers' perception, constraints to adoption and effects of long-term supplementation on sheep performance. PhD thesis, Wageningen University, Wageningen, the Netherlands.

Abule Ebro, Smit G.N and Snyman H.A. 2005. The influence of woody plants and livestock grazing on grass species composition, yield and soil nutrients in the Middle Awash Valley of Ethiopia. Journal of Arid Environments 60:343-358.

Abule Ebro, Smit G.N and Snyman H.A. 2007. Rangeland evaluation in the Middle Awash Valley of Ethiopia: Herbaceous vegetation layer. Journal of Arid Environments 70:253-271.

Adane Kitaba and Berhan Tamir. 2005 Effect of harvesting frequency and nutrient levels on natural pasture in the central high lands of Ethiopia. Tropical Science 45:77-82.

Alemayehu Mengistu 2004 Pasture and forage resource profiles of Ethiopia. FAO, Addis Ababa, Ethiopia.

Amsalu Sisay and Baars R.M.T. 2002. Grass composition and rangeland condition of the major grazing areas in the rift valley of Ethiopia. African Journal of Range and Forage Science 19: 161-166.

Anderson, E.W. 1985. Percent composition versus absolute units of measure - a view point. Rangelands 7: 247–248.

Anderson, P.M.L.,Hoffman, M.T. and O'Farrell, P.J. 2010. Aboveground perennial plant biomass across an altitudinal and land-use gradient in Namaqualand, South Africa. South African Journal of Botany 76: 471-48.

Ayana Angassa. 2016. Vegetation responses to site, elevation and land use in semi-arid rangeland of Southern Ethiopia. African Journal of Agricultural Research 11(5): 379-391.

Ayana Angassa and Baars, R.M.T. 2000. Ecological condition of encroached and non-encroached rangelands in Borana, Ethiopia. African Journal of Ecology 38: 321-328.

Angassa Angassa and Oba, G. 2010. Effects of grazing pressure, age of enclosures and seasonality on bush cover dynamics and vegetation composition in southern Ethiopia. Journal of Arid Environment 74: 111-120.

Ayele S, Assegid W, Jabbar, M.A., Ahmed M.M. and Belachew H. 2002 Livestock marketing in Ethiopia. A review of structure, performance and development initiatives. Socio-economic and policy research working paper 52. International Livestock Research Institute (ILRI), Nairobi, Kenya.

Baars, R.M.T., Chileshe E.C. and Kalokoni, D.M. 1997. Technical Note: Range condition in high cattle density areas in the Western province of Zambia. Tropical Grasslands 31: 569-573.

Bilotta, G.S., Brazier, R.E. and Haygarth, P.M. 2007. The impacts of grazing animals on the quality of soils, vegetation, and surface waters in intensively managed grasslands. Advances in Agronomy 94: 237-250.

Bureau of Agriculture and Rural Development (BOARD). 2005. Rural household socio-economic baseline survey. Amhara regional state, Bahir Dar. Ethiopia.

Chapin III F.S., Walker, H.H., Hobbs, R.J., Hooper, D.U., Lawton, J.H., Sala, O.E. 1997. Biotic cover over the functioning of ecosystems. Science 277:500-504.

Central Statistical Agency (CSA). 2008 Statistical abstracts. Statistical Survey Authority of Ethiopia, Addis Ababa, Ethiopia.

Cufodontis, G. 1953-1972. Enumeratio Plantaraum Athiopiae Spermatophyte, 2 vols. Jard. Bot. Etat., Bruxelles.

Dahlberg, A.C. 2000. Vegetation diversity and change in relation to land use, soil and rainfall-a case study from north-east District, Botswana. Journal of Arid Environments 44: 19-40.

Danckwerts, J.E. 1982. Veld condition assessment in the Eastern Cape region.Dohne-Agriculture 5: 9-15.

De Leeuw, P.N. and Tothill, J.C. 1990. The concept of rangeland carrying capacity in Sub-Saharan Africa-myth or reality. Pastoral development network paper 29b.Overseas development Institute, London.

Diaz, S., Lavorel, S., McIntyre, S., Falczuk, V., Casanoves, F., Milchunas, D.G., Skarpe, C., Rusch, G., Sternberg, M., Noy-Meir I., Landsberg, J., Zhang, W., Clark, H. and Campbell, B.D. 2007. Plant trait responses to grazing: a global synthesis. Global Change Biology 13: 313-341.

Dyksterhuis, E.J. 1949. Condition and management of rangeland based on quantitative ecology. Journal of Range management 2:104-112.

Edwards, S., Mesfin T and Hedberg, I. 1995. Flora of Ethiopia and Eritrea, vol. 2(2). Addis Ababa: The National Herbarium, Addis Ababa University; Uppsala: Department of Systematic Botany, Uppsala University.

Edwards S., Mesfin T., Sebsebe Demissew and Hedberg, I. 2000. Flora of Ethiopia and Eritrea, vol. 2(1). Addis Ababa: The National Herbarium, Addis Ababa University; Uppsala: Department of Systematic Botany, Uppsala University.

Edwards S, Sebsebe Demissew and Hedberg, I. 1997. Flora of Ethiopia and Eritrea, vol. 6. Addis Ababa: The National Herbarium, Addis Ababa University; Uppsala: Department of Systematic Botany, Uppsala University.

EEA (Ethiopian Economic Association). 2002. A research report on land tenure and agricultural development in Ethiopia, October 2002, Addis Ababa, Ethiopia.

FAO (Food and Agriculture Organization of the United Nations). 2001 Grassland resource assessment for pastoral systems, 2001. FAO Plant production and protection paper No. 162. 150p.

Friedel, M.H. 1991. Range condition assessment and the concept of thresholds: A viewpoint. Journal of Range Management 44: 422-426.

Froman B and Persson S 1974 An illustrated guide to the grasses of Ethiopia. Chilalo Agricultural Development Unit (CADU), Asella, Ethiopia.

Gemedo Dalle, Maass, B.L. and Issaelstein, J. 2006. Rangeland condition and trend analysis in the semi-arid Borana lowlands, southern Oromia, Ethiopia. Journal of Forage and Range Science 23: 49-58.

Getachew Eshete. 2002. An assessment of feed resources, their management and impact on livestock productivity in the Ginchi watershed area. MSc thesis submitted to the School of Graduate Studies, Alemaya University of Agriculture, Alemaya, Ethiopia.

Harrington, G.N. and Pratchett, D. 1974. Stocking rates in Ankole, Uganda. II. Botanical analysis and oesophageal fistula sampling of pastures grazed at different stocking rates. Journal of Agricultural Sciences 82:507-516.

Hedberg, I. and Edwards, S. 1989. Flora of Ethiopia, vol. 3. Addis Ababa: The National Herbarium, Addis Ababa University; Uppsala: University of Systematic Botany, Uppsala University.

Hedberg, I. and Edwards, S. 1995. Flora of Ethiopia, vol. 7. Addis Ababa: The National Herbarium, Addis Ababa University; Uppsala: University of Systematic Botany, Uppsala University.

Hedberg, I., Edwards, S. and Sileshi, N. 2003. Flora of Ethiopia and Eritrea, vol. 4. Addis Ababa: The National Herbarium, Addis Ababa University; Uppsala: University of Systematic Botany, Uppsala University.

Hoshino, A., Yoshihara, Y., Sasaki, T., Okayasu, T., Jamsran, U., Okuro, T. and Takeuchi, K. 2009. Comparison of vegetation changes along grazing gradients with different numbers of livestock. Journal of Arid Environments 73:687-690

ILCA (International Livestock Center for Africa). 1990. Livestock research manual.ILCA, Addis Ababa, Ethiopia. p.31-54.

Kucher, P. 1995. Range monitoring, evaluation and range survey methods. Southeast range project technical report. Addis Ababa, Ethiopia.

LMA (Livestock Marketing Authority). 1995. Annual report, Addis Ababa, Ethiopia

McNaughton, S.J. 1979. Grazing as an optimisation process: grass-undulate relationships in the Serengeti. American Naturalist 113:691-703.

Milton, S.T., Dean, W.R.J., du Plessis, M.A. and Siegfried, W.R. 1994. A conceptual model of arid rangeland degradation: The escalating cost of declining productivity. Bioscience 44: 70-76.

Milton, S.T. and Hoffman, M.T. 1994. The application of state-and-transition models to rangeland research and management in arid succulent and semi-arid grassy karoo, South Africa. African Journal of Range and Forage Science 11:18-26.

Nogues-Bravo, D., Araujo, M., Romdal, T. and Rahbek, C. 2008. Scale effects and human impact on the elevational species richness gradients. Nature 453:216 -219.

Pratt, D.J. and Gwynne, M.D. 1977 Rangeland management and ecology in east Africa. Hodder and Stoughton, London, UK.

Smith, E.L. 1979. Evaluation of the range condition concept. Rangelands 1:52-54.

Snyman, H.A. and Fouché, H.J. 1993. Estimating seasonal herbage production of a semi-arid grassland based on veld condition, rainfall, and evapo-transpiration. African Journal of Range and Forage Science 10:21-24.

Solomon, B. 2004. Assessment of livestock production systems feed resource base in Sinana Dinsho district of bale highlands, Southeast Oromia, MSc thesis submitted to the School of Graduate Studies, Alemaya University, Dire Dawa, Ethiopia.

Speed, J.D.M., Austrheim, G. and Mysterud, A. 2013. The response of plant diversity to grazing varies along an elevational gradient. Journal of Ecology 101:1225 -1236.

Stoddart, L.A., Smith, A.D. and Box, T.W. 1975. Range management. McGraw-Hill, New York.

Stuart-Hill, G.C. and Tainton, N.M. 1989. The competitive interaction between *Acacia* karoo and the herbaceous layer and how this is affected by defoliation. Journal of Applied Ecology 26:285-298.

Tainton, N.M. 1999. Veld management in South Africa. In: Tainton, N.M. (Eds). University of Natal Press, Pietermarizburg South Africa. 532p.

Tessema Zewdu, Aklilu Agdie and Amha Sebsbie. 2002. Assessment of the livestock production system, available feed resources and marketing situation in Belesa Woreda: A case study in drought prone areas of Amhara region. In: Proceedings of the 10th annual conference of the Ethiopian Society of Animal Production (ESAP). 22-24 August 2002. Addis Ababa, Ethiopia. Pp: 165-175.

Tessema Zewdu. 2005. Identification of indigenous pasture and the effect of time of harvesting and nitrogen fertilizer in the north western Ethiopian highlands. Tropical Science 45:73-77.

Tessema Zewdu and Oustalet, Y. 2007. Vegetation composition, biomass production, carrying capacity and grassland types in Odolla area of Shinile zone, eastern Ethiopia. East African Journal of Science 2:148-159.

Tessema Zewdu, Ashagre Abate and Solomon Mengitu. 2010. Botanical composition, yield and nutritional quality of grassland in response to stages of harvesting and fertilizer application in the highland of Ethiopia. African Journal of Range and Forage Science, 27: 117-124

Tessema Zewdu Kelkay, de Boer, W.F., Baars, R.M.T. and Prins, H.H.T. 2011. Changes in soil nutrients, vegetation structure and herbaceous biomass in response to grazing in a semi-arid savanna in Ethiopia. Journal of Arid Environments 75:662-670.

Tiedeman, J.A., Beck, R. and Vanhorn, E.R. 1991. Dependence of standing crop on range condition rating in New Mexico. Journal of Range Management 44:602-605.

Trollope, W.S.W., Trollope, L,A, and Bosch, O.J.H. 1990. Veld and pasture management terminologies in South Africa. Journal of the Grassland Society of South Africa 7:52-61.

Westoby, M., Walker, B. and Noy-Meir, I. 1989. Opportunistic management for rangelands not at equilibrium. Journal of Range Management 42:266–274.

Wilson, A.D. and Tupper, G.J. 1982. Concepts and factors applicable to the measurement of range condition. Journal of Range Management 35:684-689.

Yeshitila Admasu, Tessema Zewdu and AzageTegegne. 2008a. Availability of livestock feed resources in Alaba Woreda, Southern Ethiopia. 2008. In: Proceedings of the 16th annual conference of the Ethiopian Society of Animal Production (ESAP), October 8-9, 2008, Addis Ababa, Ethiopia. Pp. 21-32. 26.

Yeshitila Admasu, Tessema Zewdu and Azage Tegegne. 2008b. Utilization of feeds, livestock unit versus dry matter requirement in Alaba, Southern Ethiopia. In: Proceedings of the 16th Annual Conference of the Ethiopian Society of Animal Production (ESAP), October 8-9, 2008, Addis Ababa, Ethiopia. Pp. 33-38.