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Original Article

Biomass Production in the Rangelands of Gambella, Ethiopia

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Abstract

The study was conducted in the rangelands of Gambella, southwestern Ethiopia with the objectives of investigating biomass production of the grazing areas. For the vegetation survey the rangeland was stratified by districts namely: Itang and Jikawo and each district further divided into major grazing types (less, seasonal, communal grazed and river basins). Data were collected on grass species composition and estimation of the biomass was made on the dry matter basis. Biomass of standing grass and total biomass in the districts were significantly ($p<0.05$) affected by grazing. Accordingly, with the highest in less grazed areas (2,044 and 2,216 kg/ha) followed by moderately grazed areas (1,006 and 1,137 kg/ha) the least in river basins (467 and 563 kg/ha). In Jikawo district, total biomass of less grazed, moderately grazed and heavily grazed communal lands and river banks were 1678; 1032;652 and 457 kg/ha, respectively. The standing grasses biomass of these major grazing areas was with the order of 1513; 897; 573 and 369 kg/ha, respectively. The annual DMY of the herbaceous vegetation layer in the study districts under the grazing land use category may be estimated as 243,950.0 t DM/annum for Itang and 173,470.0 t DM/annum for that of Jikawo. According to the estimated biomass production of the grazing lands, the carrying capacity of the rangeland in Itang and Jikawo would be 0.16 and 0.13 TLU/ha, respectively. However, rangelands in Jikawo district support large number of livestock beyond their maximum capacity (0.85 TLU/ha) compared to the estimated CC. On the other hand, in Itang there was underutilization of the grassland due to lower livestock population depended on the available grassland feed resources (i.e., 0.05 TLU/ha). An attempt to employ appropriate management systems along with monitoring of the rangeland condition might be needed to promote the productivity of the study areas to the level of the carrying capacity to ensure its sustainable utilization.

Keywords: Annum, carrying capacity, dry matter yield, Gambella, grazing areas, tropical livestock unit

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Introduction

The range lands of Ethiopia are located around the peripheral or the outer edge of the country, almost surrounding the central highland mass (Alemayehu, 2004), constituting 62% of the country's land area (EARO, 2000; PFE, 2001; BLPDP, 2004). These areas are mainly found in the northern, northwestern and along the Baro River basin in the extreme western part of the country (Coppock, 1993). Most of these areas are below 1,500 m.a.s.l (EARO, 2000), characterized by arid and semi-arid agro-ecologies; experienced a relatively harsh environmental condition of unreliable, low and erratic rainfall with annual range of 200 to 700 mm, a regularly high temperature, between 15 and 50^0C, and low human population density (Beruk, 2003; Alemayehu, 2004; PFE, 2004), varied markedly in terms of the number of plant growing days per year, forage production, common plant associations, livestock and human carrying capacities and incidences of important livestock diseases (Coppock, 1993).

The pastoral areas of Ethiopia have a rich resource potential (PFE, 2001) despite the fact that, the country has not yet benefited from these resources. This could be attributed to various constraints (Coppock, 1994). Of the immense constraints, livestock feed scarcity resulting from rangeland degradation and productivity deterioration is known to be the prime and common features of the pastoral areas. Moreover, the current condition of rangelands, their future prospect and the pastoral production systems do not seem favorable (PADS, 2004). For efficient and sustainable utilization of the highest livestock potential from rangeland resources, ultimately, it is invaluable to understand the available resource base.

Like other pastoral areas of the Ethiopia, in Gambella Regional State (GRS), extensive pastoral production system is experienced, predominantly in areas where the Nuer Pastoral communities inhabit. According to GRS (2003), the Nuer pastoral communities subsist on the more arid area of the regional state, which is unsuited for crop production. The area consists of wide treeless grassy and seasonally flooded plains of the Itang, Jikawo and Akobo district. The communities are grouped on language and territorial grazing area and move back and froth with the seasonal flooding regime of the rivers.

Various range research and development works were conducted in the Southern and Eastern rangelands of Ethiopia (Coppock, 1993), in Borana by Ayana (1999), Oba (2001), Gemedo (2004), Middle Rift Valley by Russel (1984) and Amsalu (2000), part of the Somali region by Ahmed (2003), Belayenesh (2006) and Amaha (2006). However, in the Gambella Regional State in general and the Nuer pastoral areas in particular, research and development interventions have never been done. Moreover, there are no researches and documentations made regarding biomass production potential of the rangelands. It is, therefore, necessary to develop baseline scientific information on the herbaceous species biomass production of the major grazing areas. This would help to suggest ecologically sound and socio-economically feasible development and management interventions towards sufficient and sustainable use of the rangeland resources. To this effect the study aimed at investigating the biomass production of the rangeland herbaceous vegetation cover.

Materials and Methods

Description of the study area

The study was conducted in the Gambella Regional State which is located in the southwest part of Ethiopia, situated in the lowlands of the Baro-Akobo River Basin between latitudes $6^0$22' and $8^0$30' N, and longitudes $33^0$10' and $35^0$50' E, and covers a total area of about 34,063 square kilometers (GRS, 2003). The regional state is characterized as mid, lowland and semi-desert agro-ecological zones. Itang and Jikawo districts are located in the semi- desert agro-ecological zone. Forests and woodlands are in existent except for some scattered bushes and shrubs, thus it is logical to defining the grassland as open grassland (GRS, 2003) with an extensive plain topographic feature (PADS, 2004). The annual rainfall and mean annual

temperature in the Regional State are 1,247 mm and 34.37 ^{0}C, respectively (IAR, 1990). The rainfall regime is unimodal, referred to as the "*Sudan Type"*, occurs in the lowlands along the border with Sudan (Coppock, 1994). Poorly drained *vertisol* is the characteristic soil type of the grassland (GRS, 2003). The highest livestock population in Tropical Livestock Unit (TLU) is found in Jikawo district 156,168.5 (53%), followed by Akobo, 114,390.8 (39.3%). The lowest TLU in Gog, which is, 1,341.6 (0.5%) (PADS, 2004). The major breed is the Nuer (zebu) which is a very good performer in dairying and beef production provided proper management levels (GRS, 2003) and considered to have high tolerance to tse-tse challenges (Alemayehu, 2004).

Site selection and sampling procedure

A vegetation survey was conducted in the two districts (Itang and Jikawo), which are predominantly inhabited by the Nuer pastoral community. The sampling method used was 'Systematically Stratified Random Sampling Technique' (ILCA, 1990). Accordingly, each district was stratified into four range sites namely: communal grazing, seasonal grazing, river basins and less grazed areas, which represent the major grazing areas of the pastoral community. As a benchmark, the relatively less grazed areas were used for comparison with other grazing areas in their representative districts. A total of 11 range sites (3 from each of less grazed, communally grazed and river basins and 2 from seasonal grazing areas) were selected from Itang district. For each grazing types, from Jikawo district (3 range sites with a total of 12) were selected. Each range site was further divided into three randomly selected sample sites. Four samples from each sample site were grouped using 0.5 m x 0.5 m quadrat. Using GPS channel 12; the altitude, longitude and latitude readings of each range site were determined and recorded. From a randomly established reference points, samples were taken by radiating 30m to four directions. The random selection reference point was made using line coordination, for communal grazing lands, less grazed lands and seasonally grazed areas. Samples from river basin were taken on the flat side of the river within the range of 100 - 400 m from the river bank on non-water logged area. The assessment was carried out late in the long rainy season 2006, when most of the grasses were flowered.

Biomass Production of the Herbaceous Vegetation

Dry matter biomass determination

The herbaceous vegetation within 0.5 m x 0.5 m sample quadrat was harvested at ground level using hand shears. Vegetation samples from each site were classified into grasses, legumes and forbs thereafter into different species. The fresh and dry weights of each individual species were determined by using an electronic digital balance. DM of each species was determined on dry weight basis dried in an oven at 60 ^{0}C for 72 hours. Total herbaceous dry weight, dry weight of grasses, increasers, decreasers, invaders and forbs of the experimental unit were derived from the dry weight of each species in each sample.

Carrying capacity estimation

The theoretical carrying capacity (CC) of the land use type under grazing category of the study districts was calculated as:

$$CC = (B*K)/PD \times 6.25$$ (Stoddart, 1976) in which,

CC= carrying capacity;
B= the biomass edible in kg DM/ha;
K= the animal use ratio which varies between 0.1 and 0.9 but usually 0.3 is considered as the grazing land has limit to for proper pasture regeneration;
PD= the period duration in days, and
6.25= kg of DM consumed by one TLU/day.

The hectare under the land use type category (grassland) was multiplied by the annual forage DM biomass ha- study area. The annual herbaceous DMY was derived from the total biomass production the study districts. Data on the area under grazing category and the livestock population were obtained from the Bureau of Agricultural Development of the Regional State. Livestock population in number was converted into Tropical Livestock Units (TLU) (ILCA, 1990). Standard livestock-unit conversion factors used were 0.7 for cattle and 0.1 for sheep and goats.

Statistical analysis

From each range site composite samples of the four quadrates of 0.5 m x 0.5 m (0.25 m^2) was considered as an experimental unit. The composite samples were sorted out by districts and major grazing types. Accordingly, 33 samples fell in the Itang district and 36 in Jikawo (a total of 69 samples) were used for the analysis. The data obtained from the vegetation variables were subjected to ANOVA using the GLM procedure of Statistical Analytical System (SAS) (1999) computer software. Duncan's Multiple Range Test was used for mean comparison. To determine the relationship of biomass with grazing types and districts linear regression procedure was used.

Results and Discussion

Biomass at Different District Levels

Itang

Biomass of standing grass and total biomass in Itang district were significantly ($p<0.05$) affected by grazing (Table 1). Total grass biomass (2,044 kg/ha) and total biomass (2,216 kg/ha) in less grazed areas were significantly ($p<0.05$) the highest of all followed by moderately grazed areas with 1,006 and 1,137 kg/ha, respectively. River basins were significantly ($p<0.05$) the least of all grazing areas in their total standing grass biomass (467 kg/ha) and total dry matter yield (563 kg/ha) (Table 1). This indicates that biomass production follows a similar trend with range condition.

Table 1: LSM ± SE DMY in kg/ha of different categories of grass species and other herbaceous species of major grazing areas in Itang district

	Grazing areas					
Parameters	LG	SG	CG	RB	CV	CR
Dec	983.59±12.28^a	337.02±15.04^b	61.87±12.28^c	37.09±12.28^c	20.67	75.36
Inc	808.43±14.70^a	489.84±18.00^b	492.74±14.70^b	280.53±14.70^c	16.95	90.19
Inv	251.73±8.99^a	179.10±11.01^b	173.80±8.99^b	149.74±8.99^b	28.47	55.17
Tgs	2043.75±23.59^a	1005.95±28.90^b	728.42±23.59^c	467.36±23.59^d	13.28	144.80
Frb	172.69±4.29^a	130.68±5.26^b	88.09±4.29^c	95.81±4.29^c	21.30	26.36
Total	2216.44±23.47^a	1136.62±28.74^b	816.51±23.47^c	563.17±23.47^d	11.86	144.00

Dec = Decreasers; Inc = Increasers; Inv = Invaders; Tgs = Total grasses; Frb = Forbs; LG = Less grazed; SG = Seasonally grazed; CG = Communally grazed; RB = River basins; CV= Coefficient of variation; CR= Critical range; Means with different letters in a row are significantly different ($p<0.05$).

In agreement with the reports of Amsalu (2000), Abule (2003) and Gemedo (2004), by which total biomass of (2,216 kg/ha) from less grazed areas orderly decreased to 563 kg/ha in heavily grazed river banks as range condition declines from 'Good' to 'Poor' class. The lower biomass of highly palatable grass species (<62 kg/ha) were significantly similar between heavily grazed communal lands and river basins. Between seasonally and communally grazed areas biomass of increaser were similar but significantly ($p<0.05$) lower and higher than less grazed areas and river basins, respectively. Biomass of undesirable grass species differed non-significantly among seasonally and communally grazed areas as well as river banks (Table 1).

Jikawo

In Jikawo district, biomass of grasses and total herbaceous biomass were significantly ($p<0.05$) different among the major grazing areas (Table 2). Total biomass of less grazed, moderately grazed and heavily grazed communal lands and river banks were 1,678; 1,032; 652 and 457 kg/ha, respectively. The standing grass biomass of these major grazing areas were with the order of 1,513; 897; 573 and 369 kg/ha, respectively for less, moderately and heavily grazed areas (Table 2). The dry matter yield of highly palatable grasses (490 kg/ha) in less grazed areas followed by seasonally grazed areas (199 kg/ha), was significantly ($p<0.05$) the highest of all grazing areas. The heavily grazed communal lands and river basins were significantly similar in the biomass of decreasers. Between less grazed and seasonal grazing areas, there was no significant difference in the biomass of undesirable species (Table 2) and river basins followed with significantly ($p<0.05$) higher invaders biomass than communal grazing areas. In general, biomass and range condition have similar trend by which higher forage production can be obtained from rangelands of good condition and the vise versa holds true for rangelands in poor condition. This report agrees with the assumptions of Dyksterhuis (1949) and findings of Amsalu (2000), Abule (2003) and Gemedo (2004).

Table 1: LSM ± SE DMY in kg/ha of different categories of grass species and other herbaceous species of major grazing areas in Jikawo district

Parameters	Grazing areas				CV	CR
	LG	SG	CG	RB		
Dec	489.60±20.35^{a}	198.82±20.35^{b}	59.46±20.35^{c}	32.81±20.35^{c}	62.56	117.24
Inc	777.21±14.79^{a}	437.21±14.79^{b}	356.73±14.79^{b}	139.36±14.79^{c}	20.63	85.23
Inv	246.47±7.33^{a}	261.10±7.33^{a}	146.12±7.33^{c}	197.08±7.33^{b}	20.67	42.21
Tgs	1513.28±28.14^{a}	897.11±28.14^{b}	573.32±28.14^{c}	369.25±28.14^{d}	20.14	162.13
Frb	164.58±5.11^{a}	134.79±5.11^{b}	78.46±5.11^{c}	87.32±5.11^{c}	26.37	29.44
Total	1677.85±26.73^{a}	1031.90±26.73^{b}	651.78±26.73^{c}	456.57±26.73^{d}	16.80	154.01

Dec = Decreasers; Inc = Increasers; Inv = Invaders; Tgs = Total grasses; Frb = Forbs; LG = Less grazed; SG = Seasonally grazed; CG = Communally grazed; RB = River basins; CV= Coefficient of variation; CR= Critical range; Means with different letters in a row are significantly different ($p<0.05$).

Effect of Grazing on Biomass Production

Biomass of total standing grasses and total biomass were significantly ($p<0.05$) affected by grazing pressure (Table 3). The highest biomass was in the less grazed areas followed by seasonally grazed and the least in the river basins. Total grass biomass of less grazed, seasonally grazed, communally grazed areas and river basins were: 1,779; 941; 651 and 418 kg/ha, respectively. Total biomass of 1,947; 1,074; 734 and 560 kg/ha were produced in their order of grazing pressure from less grazed areas to the heavily grazed river banks. Under variable grazing pressure, biomass of highly desirable grasses were significantly ($p<0.05$) highest (737 kg/ha) in less grazed areas followed by moderately grazed areas (254 kg/ha). On the other hand, the heavily grazed communal lands and river basins were significantly similar and at ($p<0.05$) the least with 61 and 35 kg/ha of their biomass production of the highly palatable grasses category.

Table 3: LSM ± SE DMY in kg/ha of different categories of grass species and other herbaceous species by major grazing areas

Parameters	Grazing areas				CV	CR
	LG	SG	CG	RB		
Dec	736.59±39.26^{a}	254.10±43.02^{b}	60.67±39.26^{c}	34.95±39.26^{c}	61.13	113.60
Inc	792.82±23.62^{a}	458.26±25.88^{b}	430.25±23.62^{b}	209.94±23.62^{c}	21.16	68.33
Inv	249.10±12.55^{a}	228.29±13.75^{a}	173.41±12.55^{b}	159.96±12.55^{b}	26.40	36.31
Tgs	1778.51±50.29^{a}	940.65±55.09^{b}	650.87±50.29^{ac}	418.30±50.29^{d}	22.50	145.40
Frb	168.63±6.57^{a}	133.14±7.20^{b}	91.57±6.57^{c}	83.28±6.57^{c}	23.50	19.00
Total	1947.14±49.96^{a}	1073.79±54.73^{b}	734.15±49.96^{c}	509.87±49.96^{d}	19.87	144.50

Dec = Decreasers; Inc = Increasers; Inv = Invaders; Tgs = Total grasses; Frb = Forbs; LG = Less grazed; SG = Seasonally grazed; CG = Communally grazed; RB = River basins; CV= Coefficient of variation; CR= Critical range; Means with different letters in a row are significantly different ($p<0.05$).

Biomass of undesirable grass species were significantly similar between less and moderately grazed areas and between those of the heavily grazed communal lands and river banks (Table 3). The changes in the undesirable species composition, loss of high yielding forage species and the overall reduced productivity are among the profound effects of heavy grazing pressure. Between total biomass (Y) and grazing types (X), a significant ($p<0.05$) and positive linear relationship ($Y= 0.653+0.00171X$) with higher correlation coefficient of (0.803) was found in determining their relation using regression analysis. In general, the above result holds true with the conventional theory of stocking rate (Pluhar *et al*., 1987) and reports of Walter *et al*., (1990) and Amsalu (2000).

Effect of District on Biomass Production

The palatable grasses biomass (357 kg/ha) in Itang was significantly ($p<0.05$) higher than that of Jikawo (195 kg/ha) (Table 4). Biomass of total standing grasses and total biomass were not significantly affected by district. Furthermore, the two districts were non-significantly differing in their biomass production of less desirable, undesirable grass species and other herbaceous species.

Table 4: LSM ± SE DMY in kg/ha of different categories of grass species and other herbaceous species by district

Parameters	District		CV	CR
	Itang	Jikawo		
Decreasers	356.52±56.55[a]	195.17±54.10[b]	89.18	156.10
Increasers	520.44±40.58[a]	430.38±38.82[a]	49.20	112.10
Invaders	189.45±11.09[a]	212.69±10.61[a]	31.59	30.63
Total grasses	1066.40±97.79[a]	838.20±93.56[a]	59.26	270.00
Forbs	121.01±7.79[a]	116.29±7.45[a]	37.71	21.51
Total	1187.40±103.20[a]	954.50±98.72[a]	55.57	284.90

CV= Coefficient of variation; CR= Critical range; Means with different letters in a row are significantly different ($p<0.05$).

Carrying Capacity Estimation

The annual biomass production of the herbaceous vegetation layer in the rangelands of the Nuer pastoral area under the grazing land use category may be estimated as: 243,950.0 t DM/annum for Itang district and 173,470.0 t DM/annum for that of Jikawo. The estimated livestock population of (cattle, sheep and goats) for Itang and Jikawo districts was 11,163 and 155,820 TLU, respectively. According to the estimated biomass production of the grazing lands in the study districts, the carrying capacity of the rangeland would be 0.16 TLU/ha, for Itang and 0.13 TLU/ha, to that of Jikawo. However, rangelands in Jikawo district support large number of livestock beyond their maximum capacity 0.85 TLU/ha compared to the estimated CC of 0.13 TLU/ha. This implies that the presence of overgrazing on the grasslands of Jikawo district associated with overstocking. On the other hand, in Itang there was underutilization of the grassland due to lower livestock population depended on the available grassland feed resources (0.05 TLU/ha) as compared to the estimated CC of the grassland (0.16 TLU/ha).

Conclusion

The vegetation analysis in this study was based on a single season data where the parameters studied could be influenced by both spatial and temporal variations. Therefore, further studies need to be carried out in different seasons, years as well as locations so as to finally produce unbiased information on the range resources and potentials. Furthermore, range condition and trend analysis should be conducted to determine the actual carrying capacity of the grassland.

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