FORAGE COMPOSITION, BIOMASS AND CARRYING CAPACITY DYNAMICS IN YABELLO RANGELAND, SOUTHERN ETHIOPIA USING DIFFERENT GRAZING SITES

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Abstract. Forage species composition, biomass production and carrying capacity potential are primary indicators of rangeland conditions. The article aimed to assess the changes occurring in forage species composition, biomass production and carrying capacity of different grazing sites with relation to seasonal variation by using the benchmark and biomass methods in Yabello rangeland, Southern, Ethiopia. Results indicated that the species abundance and height showed significant variation across the sampling site in relation to seasonal difference. *Chloris roxburghiana*, *Cenchrus ciliaris* and *Chrysopogon aucheri* grass species were shown to be dominant and registered the highest average single species coverage and biomass yield for all grazing sites. The grazing vegetation index value of conserved grazing site were shown higher value 62.8% and 64.4% during rainy season and 48% and 54.7% during dry season from open communal and woody plant infested grazing site respectively. 76.7% and 90.9% higher biomass production was observed from ranch grazing site as compared to open-communal and woody covered grazing area, respectively. The carrying capacity variation within ranch grazing site was 77%, 76% and 76.7% greater from open-communal grazing site and 92.7%, 86.4% and 90.9% greater from woody plant infested grazing site compared during rainy season, dry season and yearly average value respectively.
Keywords: *abundance, stoking rate, production, palatability value, height*

Introduction

Forage species play an important role in livestock feeding in arid and semi-arid regions (Arzani et al., 2006), and also improve ecosystem services for the welfare of pastoral societies. Biomass of forage in rangelands is mainly determined by the amount of, distribution and duration of rainfall, effects of invasive alien species, livestock grazing intensity and other anthropogenic factors (Kassahun, 2008; Lemus, 2010). Recently, most pastoral areas of Ethiopia, including the Yabello rangelands, have been exhibiting a shift from herbaceous species to woody plants, a feature that is accompanied with some degree of degradation resulting from overgrazing, expansion of cultivation, also frequent drought and settlement resulted in decline in forage biomass and carrying capacity (Gemedo-Dalle et al., 2006; Oba et al., 2008; Angassa and Oba, 2010; Angassa, 2014). The Yabello pastoralists have been practicing transhumance to counter seasonal fluctuations in forage and water availability (Angassa and Oba, 2010; Habtamu, 2013; Takele et al., 2014). The factors that have been reported to affect the forage production and carrying capacity of

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rangelands are caused due to seasonal variability (Snyman, 1998), species variation (Arzani et al., 2008), soil nutrient status of production location (Tessema et al., 2011), grazing pressure (Adisu, 2009) and mismanagement aspects (Van der et al., 2005). In the semi-arid Yabello rangeland, this translates into seasonal shortages of forage and low carrying capacity of rangelands (Alemayehu, 2006), further hindering sustainable livestock production and affecting the socio- economic of the pastoralist livelihood (Herlocker, 1999; Gemedo-Dalle et al., 2005; Bikila et al., 2014).

Assessment of rangeland based on forage biomass productivity was used to sustainable rangeland management through balancing the livestock population with an amount of forage production, that used to reduce further degradation (Ganskopp and Bohnert, 2001; Arzani et al., 2006; Keno and Suryabhagavan, 2018). The Yabello pastoralists have been known to exist since before the thirteenth century (Oba and Kotile, 2001) and have adapted the local knowledge to manage their range land from different threating factors like drought, invasive plant species, overgrazing and other anthropogenic factors (Oba and Kotile, 2001; Teshome et al., 2012). Assessing forage productivity and carrying capacity are key factors of rangeland inventory and monitoring programs which are highly required for the sustainability of natural resources (Galt et al., 2000; Tsegaye et al., 2010; Lemus, 2010; Abdella, 2010; Bikila et al., 2014; Hailu, 2017; Cheng et al., 2017; Meshesha et al., 2019). Land use evaluation is an important tool in making decisions in planning type of animals to be used and land suitable to them accordingly based on their specified requirements, preference and predictors of specific activates (Mligo, 2009; Lin et al., 2010; Tamrat and Stein, 2015; Bikila et al., 2016; Siraj and Abdella, 2018). The productivity and carrying capacity of Yabello rangeland is degrading and decreasing ultimately (Habtamu, 2013). Since, Yabello rangeland is a depleted range area, the assessment of present potential of the range resource is important in order to plan its sustainable development. However, there is not enough information available on the effect of invasive plant infestation on native grass species, forage biomass production and therefore carrying capacity of the study area. Therefore, in this study we examined the change of herbaceous species ground cover, forage production and carrying capacity in the Yabello rangelands of southern Ethiopia.

Materials and methods

Study area

The study was conducted at Yabello district in the Borana zone of Southern Ethiopia using both ranch, communal and woody grazing site (*Fig. 1*). The site was selected because it is one of the most arid parts of Borana zone and, therefore, the pastoral communities of this district are the most vulnerable to the rangeland degradation due to overgrazing because of the large number of livestock population and bush encroachment. Yabello is located at 566 km south of Addis Ababa along Addis – Moyale road. The total area of district is 15,430 km^2 of which 68% (10,492 km^2) is rangeland and it is located between 4°30′55.81″ and 5°24′36.39″ north latitudes and between 7°44′14.70″ and 38°36′05.35″ east longitudes (Gemedo-Dalle et al., 2015). The altitude is about 1000-1500 m, with a maximum altitude of 2000 m. The rainfall of the area is characterized as bi-modal. Most (73%) of the rainfall occurs in March to May, which is called the long (gaana) rainy season, and the remainder (27%) occurs in September to November, which is called the short rainy (hagaya) season (Gemedo-Dalle et al., 2015).

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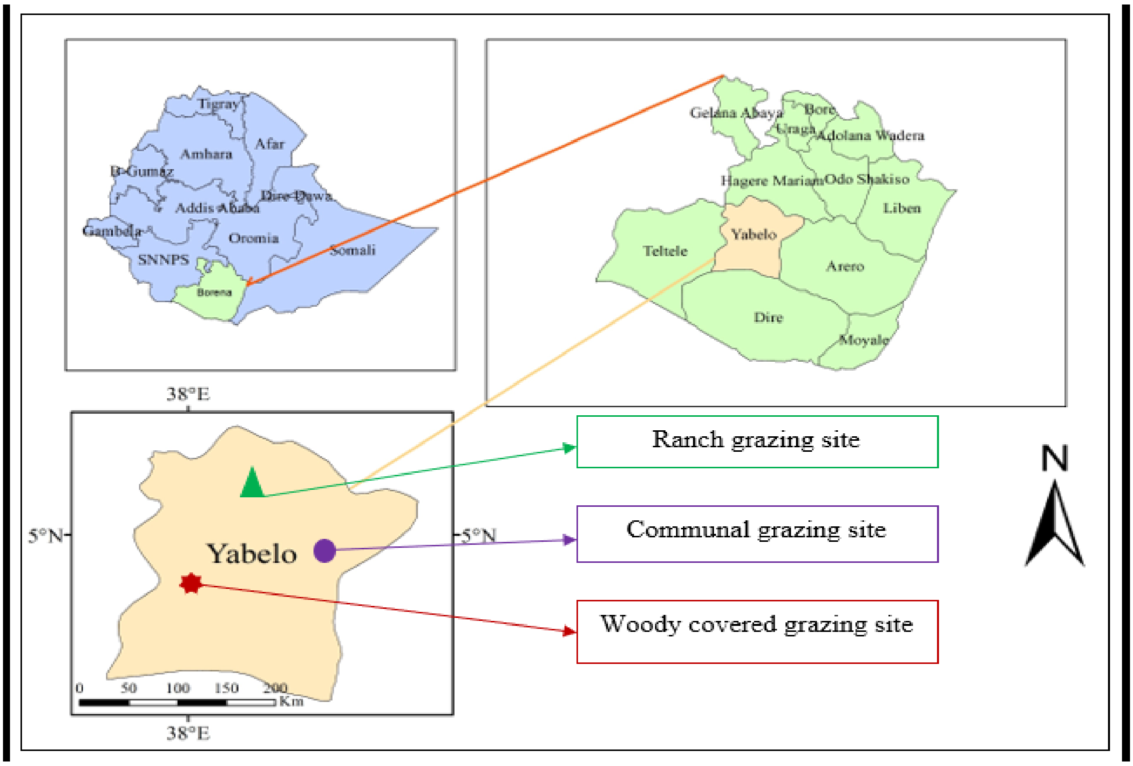

Figure 1. *Location of the study area*

The mean annual rainfall is recorded between 450-700 mm (Angassa, 2014) while the mean annual temperature varies from 19-24°C with little seasonal variation (*Fig. 2*). The potential evapotranspiration is 700-3000 mm (Billi et al., 2015). The soil in the study area includes, 53% red sandy loam soil, 30% black clay, and volcanic light-colored silt clay and 17% silt and the vegetation is mainly dominated by encroaching woody species, and those that frequently thinned out including *Senegalia mellifera*, *Vachellia reficiens* and *Vachellia oerfota* (Coppock, 1994). According to the latest census conducted in 2015, the national census reported that the total population for this district was 70,501, of whom 36,246 were men and 34,255 were women; 4,874 or 6.91% of this population includes urban dwellers. Cattle, goats, sheep, camel, mule, donkey and horse are the main reared livestock species.

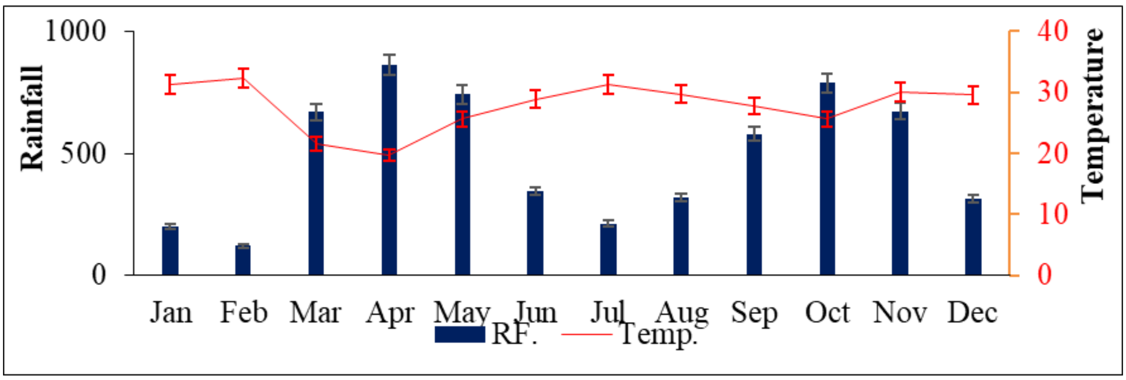

Figure 2. *Average monthly rainfall and temperature (±SE) for year 2019 in the Yabello rangeland site. RF = rainfall, Temp = temperature. (source: - EMA, 2019)*

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Data collection methods

Sampling species composition and forage biomass production

In order to quantify the forage composition and biomass dynamics in different grazing land types, above ground herbaceous was collected and biomass measurement was conducted. Within each rangeland grazing type, one linear 5 km transect was assigned and six 25 * 25 m^2 sampling plots were systematically placed at 500 m interval at each grazing site in total 3*3= 9 plots. And within each plot three were (3) 5 * 5 m^2 sub plots randomly assigned in total 3*3*3= 27 subplots. Finally, five (5) 1 * 1 m^2 quadrants in total 3*3*3*5= 135 quadrants were assigned by throwing randomly to the back side in order to minimize any biases resulting from selective placement within each sub plot for herbaceous and grass species sample collection. All the above ground forage samples were harvested by using cutter and collected in paper bags. The fresh weight of forage sample was measured in the field with a scale.

Samples were taken to Yaballo Pastoral and Dryland Agriculture Research Center soil laboratory and oven dried for 24 h at 105°C to determine the biomass. Then the dry matter was measured after 24 h of drying and converted into kilogram per hectare (kg/ ha), and the proper use factor (PUF) have been taken as 30% to calculate available forage (Sintayehu, 2006; Meshesha et al., 2019). Thereafter, dry matter (DM) biomass and livestock carrying capacity were determined by the following procedures described by Niguse, 2008 and grazing vegetation index percentage (GVI) methods. Identification of the grass species were done in the field with the help of field identification keys and plates, using Flora of Ethiopia books, and Addis Ababa University national herbarium (Elmore et al., 2000; Gemedo-Dalle et al., 2005). Data collection on grass species sampling was commenced twice per year, in the dry season (January-February 2019) and in the rainy season (March-May 2019) at the time when grass species were identified easily and peak biomass were recorded. Field data was collected with three replications for each season.

Grazing site vegetation index, height and palatability of grass species

The grazing site vegetation index (GVI) valuing each study site (*Fig. 3*) was analyzed using both percentage coverage (PC) of each species within each sampling plot and in combination of ecological index values (EIV) (Vorster, 1982; Solomon et al., 2006). The EIV and palatability value (PV) of grass species was recorded by direct observation of the grazing livestock, semi-structured focus group discussion and field on site explanation of the local pastoralists with a total of 110 participants (71 males and 39 females) and identification was carried out with the help of elder pastoralist and district experts. The participants were selected based on their experience, direct linkage of livestock rearing, age, year spent on the study site and based on recommendation of experts in addition with their voluntarism. For this study the EIV was grouped into four (4) classes with its value, namely: decreasers = 10; increaser I=7; increaser II = 4; Increaser III = 1 (Solomon et al., 2006). PC value of each species was calculated.

The PV was also grouped in to four (4) classes and values were assigned, like: highly palatable = 8; Moderately palatable = 6; less palatable = 4 and unpalatable = 2. The percentage composition of grass species in each class was summed up, after which the sum for each class was multiplied by EIV and PC value. These amounts were then totaled to give the vegetation index. For our case we also calculated the grand total score of our benchmark grazing site and the most probable maximum assuming that all species were grouped under decreases. The average height of each individual grass species at each grazing site were measured both

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during February and May for dry and rainy season respectively when the two seasonal features clearly and at the time where grass species were identified easily and peak biomass were recorded. And the field data collected with three replications for each season.

Figure 3. *Picture representation of sampling site*

Carrying capacity determination used ranch grazing site as the benchmark

To determine grazing capacity with the benchmark method, the GVI percentage, obtained from either the ecological index or grazing value index, was used. It also incorporated the average annual rainfall for the grazing site. The equation used for this method was described below at *Eq. 1* (Niguse, 2008; Habtamu, 2013).

$$CC\ (AU/ha) = \{[-0.03 + 0.00289 \times GVI\%] + [(RF - 419.7) \times (0.000633)]\} \quad (Eq.1)$$

where, CC = Carrying capacity in animal unit per hectare (AU)/ha, GVI = grazing vegetation index in % of the benchmark rangeland, RF = Average annual rainfall for the grazing site.

Carrying capacity determination using the biomass method

This method described by (Moore and Jung, 2001), uses the grass biomass per hectare to determine the grazing capacity for animal units (AU) for one year. It assumes that one AU consumes 11.25 kg grass per day (2.5% of its body mass of 450 kg). The method also includes a utilization factor 0.30 (30%) depending on the recommendation for savanna rangelands including Borana and calculated using *Eq. 2* given below (Habtamu, 2013).

$$CC = \frac{d \div [DM \times Uf]}{r} \quad (Eq.2)$$

where, **CC** = Carrying capacity in AU/ha, **d** = number of days in the year (or period to be grazed), **DM** = dry matter (biomass) in kg/ha, **Uf** = utilization factor (0.3), **r** = daily dry matter required by one grazing animal (2.5% of bodyweight), which is 11.25 kg for an AU (450 kg grazing animal (cattle).

Statistical analysis

The rangeland productivity, livestock, carrying capacity, palatability value, percentage cover, height data were analyzed by means of Microsoft Excel program and descriptive statistics in the Statistical Package for Social Sciences (SPSS) to generate descriptive statistics. Significant differences evaluation at P < 0.05 were done by using analysis of

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variance (ANOVA) used to analyse difference with regards to different grazing site and seasonal variation and Principal Component Analysis (PCA) was performed on the complete dataset to reduce its complexity and get a better understanding of the underlying vegetation structure.

Results and Discussion

Grass species composition of rangeland

A total of 23 grass species were identified and recorded using both their scientific and local name. The species and their average coverage for the different grazing site are presented in *Table 1*. *Chloris roxburghiana*, *Cenchrus ciliaris* and *Chrysopogon aucheri* grass species showed dominance and registered the highest average single species coverage in both season across all grazing sites and highly abundance at communal and woody grazing site. This is because of high resistance capacity of species during overgrazing and competent features with woody plant species, as a result this species are highly recommended for rehabilitation of degraded rangeland. Results showed that there was a significant difference (P<0.05) in most grass species coverage across different grazing sites both during rainy and dry season. And among the total 23 grass species that were found in the study area, in ranch grazing site, coverage of 20 and 19 species was above 1%, abundance of 2 and 1 species was below 1% and the remaining 1 and 3 species did not exist in the grazing site during rainy and dry season respectively (*Table 1*).

Table 1. *Grass species cover (%) across different grazing land site and season (Values showed the average percentages based on 1 m^2 quadrats in which a given species was recorded)*

No.	List of Species		Grazing site					
			Ranch		Communal		Woody	
	Scientific name	Local name	Rs	Ds	Rs	Ds	Rs	Ds
1.	*Chrysopogon aucheri*	Alaloo	45**	34**	19**	14**	56**	43**
2.	*Dactyloctenium aegyptium*	Ardaa	8*	6*	7*	3*	+*	-*
3.	*Xerophyta humilis*	Areedoo	5	4	14*	12*	1*	+*
4.	*Aristida kenyensis*	Biilaa	39**	21**	+*	-*	5*	2*
5.	*Eragrostis capitulifera*	Biilaa	3	2	+	+	2	+
6.	*Harpachne schimperi*	Biilaa	8*	6*	18*	21*	24*	29*
7.	*Leptothrium senegalense*	Biilaa diidaa	28**	13**	-	-	-	-
8.	*Melinis repens*	Buuyyoo xirooftuu	15**	9**	11	10	4*	3*
9.	*Themeda triandra*	Gaaguroo	19*	17*	4	4	+	+
10.	*Digitaria milanjiana*	Hiddoo	7*	2*	24**	20**	10**	+**
11.	*Chloris roxburghiana*	Hiddoo luucolee	54**	33**	49**	40**	34**	27**
12.	*Digitaria naghellensis*	Ilmogorii	45**	33**	+*	-*	-	-
13.	*Panicum maximum*	Loloqaa	18*	12*	-	-	+*	-*
14.	*Bothriochloa insculpta*	Luucolee	1**	-**	7	5	2*	+*
15.	*Cenchrus ciliaris*	Mata guddeessa	51**	37**	26*	21*	23**	15**
16.	*Pennisetum mezianum*	Ogoondhichoo	41**	32**	+**	-**	-	-
17.	*Eragrostis papposa*	Saamphillee	-	-	-**	+**	+*	1*
18.	*Sporobolus discosporus*	kootichaa	21**	8**	2*	+*	1**	-**
19.	*Grewia tenax*	Saarkama	1*	+*	17**	5**	9*	2*
20.	*Cynodon dactylon*	Sardoo	+*	-*	3	2	1**	-**
21.	*Cyperus sp.*	Saattuu	41**	27**	+*	-*	-	-
22.	*Cyperus bulbosus*	Saattuu arbaa	17*	10*	8*	14*	3	4
23.	*Sporobolus pellucidus*	Salaqoo	+**	8**	9*	11*	5*	8*

Note: * = significant, ** = highly significant, + = indicates grass species present with cover <1%, - = indicates grass species absent, Rs = rainy season, Ds = dry season

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At the communal grazing site, abundance of 15 and 14 species was above 1%, 5 and 3 species were below 1% and the reaming 3 and 6 species did not exist in the grazing site both rainy and dry season, respectively. On woody covered grazing site, 15 and 10 species were found with a coverage above 1%, 4 and 5 species were below 1% and the reaming 4 and 8 species did not exist in the grazing site both at rainy and dry seasons, respectively. As we have seen from *Table 1*, even if the species was found in all grazing site, its abundance showed declined pattern from conserved ranch grazing site to open communal and woody covered rangeland site.

And also, seasonal variation had a great impact on the grass species occurrence and abundance based on our result and past reported data (Han et al., 2013). Almost all, grass species showed increasing trend during rainy season and decreasing trend during dry season, with the exception of *Cyperus bulbosus, Sporobolus pellucidus, Harpachne schimperi* and *Eragrostis papposagrass* species that showed increasing trend of their abundance during dry season as compared to rainy season. From this we can understand that this grass species had the capacity to resist rainfall security and will be recommended for rangeland rehabilitation in the aera where more frequent drought occurred, and this result is in agreement with the data reported by Han et al., 2013.

In general, from this study we can observe that grass species existence and abundance had a direct influence and it is linked with grazing land type. That is grass coverage was higher in well managed ranch rangeland site and showed great decreasing rate both in abundance and total absence in the non-managed open communal and woody plant infested grazing site. This told us random grazing trend and bush infestation of rangeland had a great impact on both the composition and mass of herbage species and this had a direct influence on the livelihood of livestock pastoralists as well as the economy of both the local people and the whole country. This finding on the pattern of species composition showed an opposite trend that data reported by (Lanta et al., 2009), whose studies indicated that excluding herbage from livestock grazing decreases species richness and increases it under conditions of grazing pressure. The spatial distribution and composition of grass species in relation to seasonal variation as assessed by the component analysis of PCA is provided (*Fig. 4*). The first two PCA component axes cumulatively explained 97.7% of the total variance in species, which shows that the two components have accounted for most of the species types composition in the rotated space.

Grazing site vegetation index of rangeland

Concerning the grazing system, we used a well-managed and conserved government ranch site as our benchmark in order to analyze the ecological status of grass species. We used two variations, one relies on the ecological index value classification (decreasers and increasers) of grasses and the other percentage occurrence value of each species are calculated above (*Table 1*). The recorded multiplicative value is in the ‘Score’ columns. In most studies a grand total was assumed as 900-1000 for the benchmark site (excellent rangeland condition) (Marake et al., 2019), but in our case the grand total value was obtained by collecting and analyzing all the grass species existed on the site that was a highly conserved and well managed government ranch site. The percentage difference between these two sites (i.e. the well managed ranch and non-managed open communal and woody covered grazing site) represents the ecological index value (EIV).

In *Table 2* above the EIV indicated the assigned values rather than classified groups. That is, 10= for decreasers; 7= for increaser I; 4= for increaser II and 1= for increaser III. In this case, grouping of grass species under decreasers and increasers was conducted based on their

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basal area coverage percentage conducted in *Table 1* above in combination with direct field observation of their occurrence and abundance in each grazing site and past trends of the species based on elder pastoralist information obtained during focus group discussion and field assistance and grouped as follows: abundance greater than 20% under decreasers, 15-20% under increaser I, 10-14% under increaser II and with abundance less than 10% under increaser III (the same technique used by Baars (2002)).

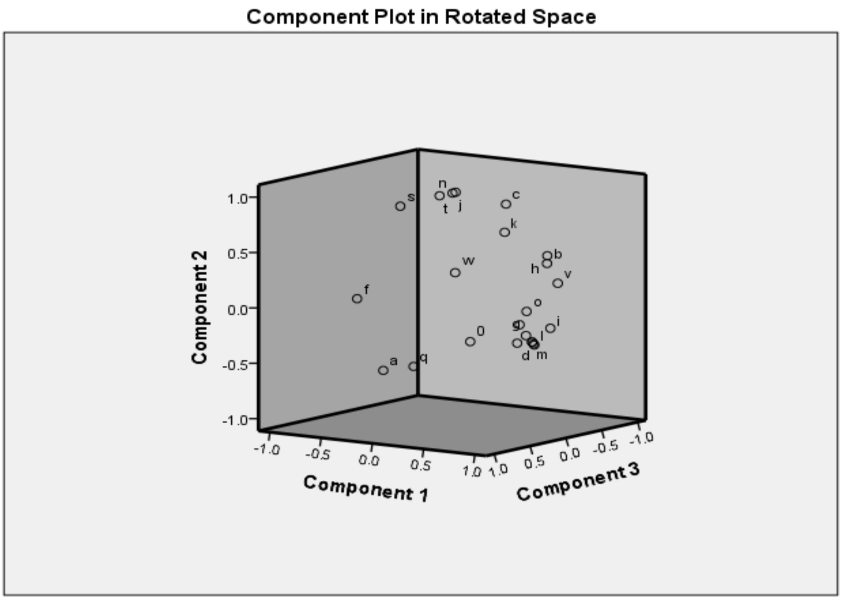

Figure 4. *PCA component analysis of grass species based on occurrence frequency with in each grazing site in relation to seasonal variation. (a=Chrysopogon aucheri, b=Dactyloctenium aegyptium, c=Xerophyta humilis, d=Aristida kenyensis, e=Eragrostis capitulifera, f=Harpachne schimperi, g=Leptothrium senegalense, h=Melinis repens, i=Themeda triandra, j=Digitaria milanjiana, k=Chloris roxburghiana, l=Digitaria naghellensis, m=Panicum maximum, n=Bothriochloa insculpta o=Cenchrus ciliaris, p=Pennisetum mezianum, q=Eragrostis papposa, r=Sporobolus discosporus, s=Grewia tenax, t=Grewia tenax, u=Cyperus sporobouls, v=Cyperus bulbosus, w=Sporobolus pellucidus)*

In the ranch grazing site, 39.1% and 30.4% of grass species were grouped under decreasers, 17.4% and 4.3% of grass species under increaser I, 0% and 13% of grass species under increaser II and 43.5% and 39.1% of grass species under increaser III during rainy and dry grazing season, respectively. In the open-communal grazing site, 13% and 17.4% of grass species were grouped under decreasers, 13% and 0% of grass species under increaser I, 8.7% and 21.7% of grass under increaser II and 52.2% and 34.8% of grass species under increaser III during rainy and dry grazing season, respectively. At woody plant infested grazing site, 17.4% and 13% of grass species were grouped under decreasers, 0% and 4.3% of grass species under increaser I, 4.3% and 0% under increaser II and 60.9% and 47.8% of grass species under increaser III during rainy and dry grazing season, respectively. And the average ratio of each grass species category was: in ranch grazing site, 34.8%, 13%, 8.7% and 43.8% of grass species were grouped under decreasers, increaser I, increaser II and increaser III, respectively.

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Table 2. *Ecological status of species analyzed by the benchmark method, using ecological index groups and percentage coverage (%) of grass species for each grazing sites*

No.	List of Species		Grazing site																	
	Scientific name	**Local name**	**Ranch**						**Communal**						**Woody**					
			Rs			**DS**			**Rs**			**Ds**			**Rs**			**Ds**		
			PC	EIV	**SC**	PC	EIV	**SC**	PC	EIV	**SC**	PC	EIV	**SC**	PC	EIV	**SC**	PC	EIV	**SC**
1.	*Chrysopogon aucheri*	Alaloo	45	10	**450****	34	10	**340****	19	7	**133****	14	4	**56****	56	10	**560****	43	10	**430****
2.	*Dactyloctenium aegyptium*	Ardaa	8	1	**8**	6	1	**6**	7	1	**7**	3	1	**3**	+	1	**1***	-	-	**-***
3.	*Xerophyta humilis*	Areedoo	5	1	**5**	4	1	**4**	14	4	**56***	12	4	**48***	1	1	**1**	+	1	**1**
4.	*Aristida kenyensis*	Biilaa	39	10	**390****	21	10	**210****	+	1	**1***	-	-	**-***	5	1	**5**	2	1	**2**
5.	*Eragrostis capitulifera*	Biilaa	3	1	**3**	2	1	**2**	+	1	**1**	+	1	**1**	2	1	**2**	+	1	**1**
6.	*Harpachne schimperi*	Biilaa	8	1	**8**	6	1	**6**	18	7	**126****	21	10	**210****	24	10	**240****	29	10	**290****
7.	*Leptothrium senegalense*	Biilaa diidaa	28	10	**280****	13	4	**52****	-	-	-	-	-	-	-	-	-	-	-	-
8.	*Melinis repens*	Buuyyo	15	7	**105****	9	1	**9****	11	4	**44**	10	4	**40**	4	1	**4**	3	1	**3**
9.	*Themeda triandra*	Gaaguroo	19	7	**133***	17	7	**119***	4	1	**4**	4	1	**4**	+	1	**1**	+	1	**1**
10.	*Digitaria milanjiana*	Hiddoo	7	1	**7***	2	1	**2***	24	10	**240****	20	10	**200****	10	4	**40****	+	1	**1****
11.	*Chloris roxburghiana*	Hiddoo luucolee	44	10	**440****	33	10	**330****	49	10	**490****	40	10	**400****	34	10	**340****	27	10	**270****
12.	*Digitaria naghellensis*	Ilmogorii	45	10	**450****	33	10	**330****	+	1	**1***	-	-	**-***	-	-	-	-	-	-
13.	*Panicum maximum*	Loloqaa	18	7	**126****	12	4	**48****	-	-	-	-	-	-	+	1	**1***	-	-	**-***
14.	*Bothriochloa insculpta*	Luucolee	1	1	**1***	-	-	**-***	7	1	**7**	5	1	**5**	2	1	**2**	+	1	**1**
15.	*Cenchrus ciliaris*	Mata guddeessa	51	10	**510****	37	10	**370****	26	10	**260****	21	10	**210****	23	10	**230****	15	7	**105****
16.	*Pennisetum mezianum*	Ogoondhichoo	41	10	**410****	32	10	**320****	+	1	**1***	-	-	**-***	-	-	-	-	-	-
17.	*Eragrostis papposa*	Saamphillee	-	-	-	-	-	-	-	-	**-***	+	1	**1***	+	1	**1**	1	1	**1**
18.	*Sporobolus discosporus*	*kootichaa*	21	10	**210****	8	1	**8****	2	1	**2**	+	1	**1**	1	1	**1***	-	-	**-***
19.	*Grewia tenax*	Saarkama	1	1	**1**	+	1	**1**	17	7	**119****	5	1	**5****	9	1	**9***	2	1	**2***

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No.	List of Species		Grazing site																	
	Scientific name	Local name	Ranch						Communal						Woody					
			Rs			DS			Rs			Ds			Rs			Ds		
			PC	EIV	SC	PC	EIV	SC	PC	EIV	SC	PC	EIV	SC	PC	EIV	SC	PC	EIV	SC
20.	Cynodon dactylon	Sardoo	+	1	**1***	-	-	**-***	3	1	**3**	2	1	**2**	1	1	**1***	-	-	**-***
21.	*Cyperus sporobolus*	Saattuu	41	10	**410****	27	10	**270****	+	1	**1***	-	-	**-***	-	-	**-**	-	-	**-**
22.	*Cyperus bulbosus*	Saattuu arbaa	17	7	**119****	10	4	**40****	8	1	**8****	14	4	**56****	3	1	**3**	4	1	**4**
23.	*Sporobolus pellucidus*	Salaqoo	+	1	**1***	8	1	**8***	9	1	**9****	11	4	**44****	5	1	**5**	8	1	**8**
Grand total score means of each site			**176.9**^{a}			**107.6**^{b}			**65.8**^{b}			**55.9**^{c}			**62.9**^{b}			**48.7**^{c}		
Seasonal percentage difference (grazing site vegetation index with related to ranch site) calculated as: GVI%= (GTR-GT each site)/GTR X 100									**62.8**^{a}			**48.0**^{b}			**64.4**^{a}			**54.7**^{b}		
Yearly average grazing site Vegetation index, YGVI %= (YGTR-YGT each site) * 100/ YGTR, (YGT= GTRs+ GTDs /2)									**57.2**						**60.8**					

Note: * = significant, ** = highly significant, GVI= grazing site vegetation index, GTR= grand total of ranch site, GT= grand total, YGVI = yearly grand vegetation index, YGT= yearly grand total, Rs= rainy season, Ds= dry season, GTRs= grand total of rainy season, GTDs= grand total of dry season, YGTR= yearly grand total of ranch site, -= grass species absent, Pc=percentage coverage, EIV= ecological index value, Sc= Score (PC* EIV). GT and GVI value with different letter at the same row indicate there is a significant difference related to benchmark site across each season

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In open-communal grazing site, 17.4%, 8.7%, 17.4% and 43.8% of grass species were grouped under decreasers, increaser I, increaser II and increaser III, respectively. At wood plant infested grazing site, 17.4%, 4.3%, 4.3% and 56.5% of grass species were grouped under decreasers, increaser I, increaser II and increaser III, respectively. From this ratio, we can understand that decreasers grasses were highly abundant in rangelands in a good condition for grazing (ranch), but decreased in number when the rangeland was over-grazed or infested by woody plant species. With regard to GVI value, the conserved grazing site (ranch) showed higher value such as 62.8% and 64.4% during rainy season and 48% and 54.7% during dry season compared with unmanaged open-communal grazing site and woody plant infested grazing site respectively (*Table 2*). And also, ranch grazing site showed 57.2% and 60.8% higher grass species composition from communal and woody grazing site during assessing the yearly GVI value.

Palatability classification of rangeland grass species

Classification of grass species based on palatability value (PV) at different grazing site was recorded by directly observing the grazing livestock in the field for two different seasons. These field observations were further confirmed from knowledge gathered from pastoralist and local experts. In order to calculate the degree of palatability, we simply focus on grazing site variation. There were no visible differences based on the morphological grass parts preferred by livestock. This is may be because of all grass species in our study area have showed almost similar morphological and phenological palatability features. And this observational result is in agreement with the data reported by Marake et al. (2019). Results regarding palatability value of existing grass species in our study rangelands revealed great variation in Palatability rate (*Table 3*).

In ranch grazing site, among the total 22 identified grass species (*Table 1*), 3 (14%) species grouped under highly palatable (Hp), 5 (23%) under moderately palatable (Mp), 8 (36%) under less palatable (Lp) and 6 (27%) under unpalatable (Up). At ranch grazing site most species grouped under less palatable grass species, this is due to the well managed grazing area that the grazers have the chance to access different forage source grass species, as a result their preference of grazing become diverse and not focused on a certain grass species. In the open-communal grazing site, among the total 21 identified grass species (*Table 1*), 7 (33%) species were grouped under highly palatable (Hp), 9 (43) under moderately palatable (Mp), 5 (24%) under less palatable (Lp) and no species were grouped under unpalatable (Up) grouped. In the woody infested grazing site, from the 19 grass species identified (*Table 1*), 6 (31%) species were grouped under highly palatable (Hp), 10 (53%) under moderately palatable (Mp), 3 (16%) under less palatable (Lp) and no grass species remain as unpalatable. From this we can understand that, in the degraded grazing site all species that can be preferable for grazing, because there is scarcity of forage source and no species remain unpalatable if the rangeland faced degradation.

In general, the palatability rating score (highly palatable and moderately palatable) were found to be the highest in the woody area (84%), followed by the open- communal grazing site (76%) and lastly on the ranch (37%) and the rating scores of the other two species categories (less palatable and unpalatable) were found the highest in the ranch area (63%), followed by open-communal grazing site (24%) and lastly woody infested grazing site (16%). This is because of accessibility of variety of species and no scarcity on the properly utilized and managed grazing site (ranch) and the current study is directly in line with the data reported by Solomon et al., 2006.

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***Table 3.** Palatability classification of grass species based on palatability value (PV)*

No.	List of *Species*		Grazing site												
	Scientific name	Local name	Ranch				Communal				Woody			
			Hp	**Mp**	**Lp**	**Up**	**Hp**	**Mp**	**Lp**	**Up**	**Hp**	**Mp**	**Lp**	**Up**
1.	*Chrysopogon aucheri*	Alaloo	8	-	-	-	8	-	-	-	8	-	-	-
2.	*Dactyloctenium a.*	Ardaa	-	-	4	-	-	6	-	-	-	6	-	-
3.	*Xerophyta humilis*	Areedoo	-	6	-	-	8	-	-	-	-	-	4	-
4.	*Aristida kenyensis*	Biilaa	-	-	-	2	-	-	4	-	-	6	-	-
5.	*Eragrostis capitulifera*	Biilaa	-	6	-	-	-	-	4	-	-	6	-	-
6.	*Harpachne schimperi*	Biilaa	-	6	-	-	8	-	-	-	8	-	-	-
7.	*Leptothrium senegalense*	Biilaa diidaa	-	-	-	2	-	-	-	-	-	-	-	-
8.	*Melinis repens*	Buuyyoo	-	6	-	-	-	6	-	-	-	6	-	-
9.	*Themeda triandra*	Gaaguroo	-	6	-	-	-	6	-	-	-	6	-	-
10.	*Digitaria milanjiana*	Hiddoo	-	-	4	-	-	6	-	-	-	-	4	-
11	*Chloris roxburghiana*	Hiddoo	8	-	-	-	8	-	-	-	8	-	-	-
12.	*Digitaria naghellensis*	Ilmogorii	-	-	-	2	-	-	4	-	-	-	4	-
13.	*Panicum maximum*	Loloqaa	-	-	4	-	-	-	-	-	-	6	-	-
14.	*Bothriochloa insculpta*	Luucolee	-	-	-	2	-	6	-	-	-	6	-	-
15.	*Cenchrus ciliaris*	Mata	8	-	-	-	8	-	-	-	8	-	-	-
16.	*Pennisetum mezianum*	Ogoondhichoo	-	-	4	-	-	6	-	-	-	-	-	-
17.	*Eragrostis papposa*	Saamphillee	-	-	-	-	-	-	4	-	-	6	-	-
18.	*Sporobolus discosporus*	kootichaa	-	-	4	-	-	6	-	-	-	6	-	-
19.	*Grewia tenax*	Saarkama	-	-	-	2	-	-	4	-				
20.	*Cynodon dactylon*	*Sardoo*	-	-	4	-	-	6	-	-	-	6	-	-
21.	*Cyperus sp.*	Saattuu	-	-	4	-	8	-	-	-	-	-	-	-
22.	*Cyperus bulbosus*	Saattuu arbaa	-	-	4	-	8	-	-	-	8	-	-	-
23.	*Sporobolus pellucidus*	Salaqoo	-	-	-	2	-	6	-	-	8	-	-	-

Note: Hp= highly palatable, Mp= moderately palatable, Lp= less palatable, Up = unpalatable, -= no vale under that PV, 8 = indicates Hp, 6 = indicate Mp, 4 = indicate = Lp, 2 = indicate Up

Grass species height of rangeland

The height of grass species recorded from the study sites also showed a significant variation across the grazing site and presented below in *Table 4*.

The grass species collected from the sampling site showed height variation across the grazing site difference with relation to seasonal influence. Grass species height in woody covered grazing site was found the shortest as compared to ranch and communal grazing site and in the ranch grazing site all grass species showed a better height among other sites. This difference in height could possibly be due to less vigour associated with herbage under woody vegetation cover as a result of light competition effect. This may cause species to easily break in case of environmental disturbances like grazing and wind, hence not able to grow tall to the heights comparable to those with no light shade effect in open grass land area.

In general, the impact of unmanaged livestock grazing and infestation of woody plant species showed significant ($P<0.05$) variation with regards to livestock forge species growth on the grazing site, so that species heights in a well-managed ranch site significantly showed a better growth performance than those in over-grazed and woody infested range site. However, as we have seen from *Table 4*, the height of herbage species

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Chrysopogon aucheri, *Chloris roxburghiana* and *Cenchrus ciliaris* showed great resistance across all sampling sites and served as a main source for forage for livestock throughout the year. According to the data obtained directly from our field investigation and also from both direct interview and focal group discussion of the local communities those grass species had high resistance capacity and recommended for further degraded range land rehabilitation method either through reseeding or direct planting of it. Our data were directly supported by the study conducted by Yeneayehu et al. (2020), on effects of vegetation cover, grazing and season on herbage species composition and biomass in the case of Yabello rangeland, Southern Ethiopia.

Table 4. *Grass species height (m) per different grazing site and season (Values from 1 m^2 quadrats in which a given species was recorded)*

No.	List of *Species*		Grazing site					
	Scientific name	Local name	Ranch		Communal		Woody	
			Rs	Ds	Rs	Ds	Rs	Ds
1.	*Chrysopogon aucheri*	Alaloo	0.74^{**}	0.39^{**}	0.61^{**}	0.35^{**}	0.52^{**}	0.18^{**}
2.	*Dactyloctenium a.*	Ardaa	0.35^{**}	0.13^{**}	0.28^{*}	0.21^{*}	0.11^{**}	$-^{**}$
3.	*Xerophyta humilis*	Areedoo	0.48^{**}	0.20^{**}	0.28^{*}	0.31^{*}	0.21^{**}	$-^{**}$
4.	*Aristida kenyensis*	Biilaa	0.57^{**}	0.36^{**}	0.06	-	0.19^{*}	0.10^{*}
5.	*Eragrostis capitulifera*	Biilaa	0.39^{**}	0.17^{**}	0.24^{*}	0.10^{*}	0.17^{*}	0.10^{*}
6.	*Harpachne schimperi*	Biilaa	0.39^{**}	0.09^{**}	0.47^{**}	0.27^{**}	0.27^{*}	0.17^{*}
7.	*Leptothrium senegalense*	Biilaa diidaa	0.59^{**}	0.29^{**}	-	-	-	-
8.	*Melinis repens*	Buuyyoo	0.55^{**}	0.07^{**}	0.38^{*}	0.31^{*}	0.06	0.02
9.	*Themeda triandra*	Gaaguroo	0.17^{**}	0.01^{**}	0.19^{*}	0.21^{*}	0.19^{*}	0.12^{*}
10.	*Digitaria milanjiana*	Hiddoo	0.49^{**}	0.14^{**}	0.48^{**}	0.16^{**}	0.33^{**}	0.03^{**}
11	*Chloris roxburghiana*	Hiddoo	0.68^{**}	0.33^{**}	0.49^{*}	0.32^{*}	0.37^{**}	0.23^{**}
12.	*Digitaria naghellensis*	Ilmogorii	0.21^{*}	0.10^{*}	0.32^{**}	$-^{**}$	-	-
13.	*Panicum maximum*	Loloqaa	0.03	0.07	-	-	0.2	-
14.	*Bothriochloa insculpta*	Luucolee	0.02	-	0.31^{*}	0.22^{*}	0.29^{**}	0.11^{**}
15.	*Cenchrus ciliaris*	Mata	0.88^{**}	0.43^{**}	0.59^{**}	0.31^{**}	0.45^{**}	0.22^{**}
16.	*Pennisetum mezianum*	Ogoondhichoo	0.19^{*}	0.10^{*}	0.36^{**}	$-^{**}$	-	-
17.	*Eragrostis papposa*	Saamphillee	-	-	-	0.02	0.21^{*}	0.15^{*}
18.	*Sporobolus discosporus*	kootichaa	0.49^{**}	0.27^{**}	0.25^{**}	0.03^{**}	0.25^{**}	$-^{**}$
19.	*Grewia tenax*	Saarkama	0.36^{**}	0.11^{**}	0.35^{*}	0.23^{*}	0.25^{*}	0.17*
20.	*Cynodon dactylon*	*Sardoo*	0.09^{*}	$-^{*}$	0.18^{**}	0.04^{**}	0.41^{**}	$-^{**}$
21.	*Cyperus sp.*	Saattuu	0.24^{*}	0.14^{*}	0.22^{**}	$-^{**}$	-	-
22.	*Cyperus bulbosus*	Saattuu arbaa	0.32^{**}	0.07^{**}	0.39^{*}	0.30^{*}	0.31^{*}	0.24^{*}
23.	*Sporobolus pellucidus*	Salaqoo	0.22	0.21	0.15^{**}	0.01^{**}	0.07	0.03

Note. * = significant, ** = highly significant, - =indicates species absent, Rs= rainy season, Ds= dry season

Grass species biomass production of rangeland

In the current study, only grass species that are identified and available to animals for grazing are classified as forage. Data were collected in rainy (May) and dry season (February). Comparison of means for forage biomass production (kg/ha) and grazing status of the three (3) grazing sites (ranch, open-communal and woody covered) during the study period was given in *Fig. 5* below. According to the results, total biomass production from ranch grazing site were 4,584 and 1,890 kg/ha, from open-communal

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grazing site were 1,053 and 453 kg/ha and from woody covered grazing site were 336 and 256.2 kg/ha were recorded during rainy and dry season, respectively. Seasonal variation showed significant impact on the biomass production of rangeland across all grazing sites. 58.8%, 57% and 23.8% higher biomass production was observed during rainy season at ranch, open-communal and woody covered grazing site, respectively. This is due to rainfall is the primary determinant factor for forage production both in the conserved and degraded rangeland area.

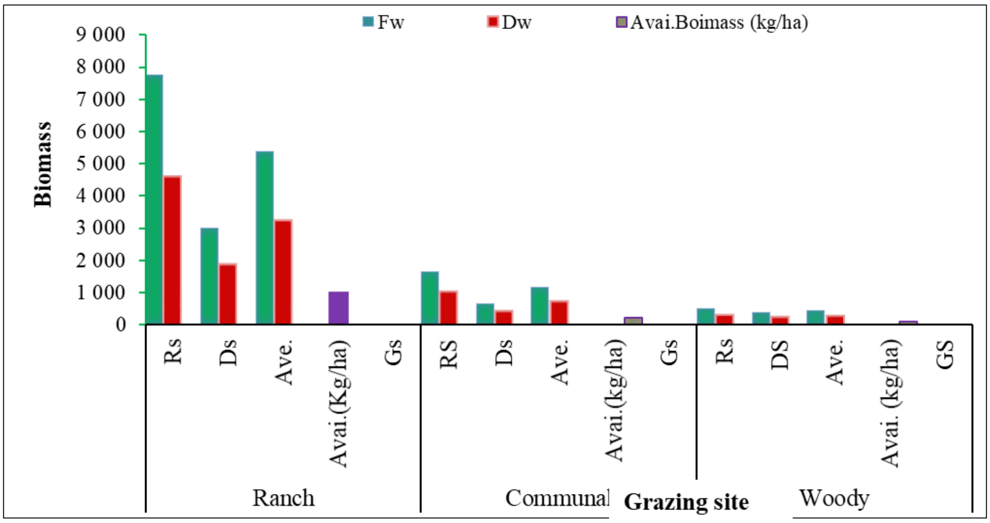

Figure 5. *Seasonal forage biomass production (kg/ha) and grazing status of range sites of the Yabello rangeland. (Note: Fw= fresh weight(kg), Dw= dry weight (kg) Rs = rainy season, Ds= dry season, Ave= average biomass (kg/ha),Avai= availbale biomass (averge dry mass* Uasble factor (0.3)) , Gs = grazing status of the grazing site, 10= repersentes slightly grazing, 4 = represents overgrazing)*

The biomass production rate during dry season also showed the same reduction trend across all grazing site. Overall forage productivity was also high during rainy season across the three grazing sites. Average biomass was higher at well managed grazing site (ranch) as compared to others, that is 3,237 kg/ha, 753 kg/ha and 296.1 kg/ha at ranch, open-communal and woody covered grazing site, respectively. That means, 76.7% and 90.9% higher biomass production was observed from open- communal and woody covered grazing area, respectively. The available forage biomass with a useable factor of 30% recorded from each grazing site was 971.1 kg/ha, 225.9kg/ha and 88.8 kg/ha from ranch, open-communal and woody covered rangeland grazing site, respectively.

Based on the total available biomass production and field observational results the grazing status (Gs) of ranch grazing site was well managed and livestock grazing was done through planned and programed way and the status was under very good condition. It used as a demonstration sample site for different rangeland management practice and awareness creation was conducted at the district and classified as slight grazing category. Whereas, the rest were grouped under overgrazing category (*Fig. 4*) above. Since, rainfall is the major determinant factor for rangeland biomass production, the productivity measured and reported here in our result should be interpreted with caution and it is expected to be valid in an average annual rainfall amount of around 605 mm (which is the case of the data obtained from the Ethiopian metrological authority, for the year 2019

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in our study area) and our conclusions agree with the data reported by Alemayehu (2006), Sisay (2006) and Elias (2007).

Carrying capacity of the rangeland

In this study, carrying capacity was calculated by two methods: (I) using GVI value calculated for each season and yearly for each grazing site (*Table 2*) and the average rainfall for the year 2019 used ranch grazing site as our benchmark and (II) by using biomass method.

Carrying capacity of rangeland using ranch grazing site as benchmark

According to our results showed at *Table 5* and *Fig. 6* below the seasonal and overall carrying capacity of degraded rangelands such as open-communal and woody covered grazing site was low as compared to the ranch grazing site. The carrying capacity during rainy season was 11.22 ha/AU/Y and 11.2 ha/AU/Y, in dry season was 11.27 ha/AU/Y and 11.24 ha/AU/Y with an average overall carrying capacity was 11.24 ha/Au/Y and 11.23 ha/AU/Y for open-communal and woody covered grazing site, respectively.

Table 5. *Carrying capacity of Yabello rangeland at different grazing sites (as benchmark method)*

Grazing site	season	GVI value (%)	Average RF (mm)	CC (ha/AU/y)	CC (AU/ha/Y
Communal	Rs	62.8	605	(-)11.22	0.08919
	Ds	48	605	(-)11.27	0.08872
	Ave.	55.4	605	(-)11.24	0.08894
Woody	Rs	64.4	605	(-)11.2	0.08921
	Ds	54.7	605	(-)11.24	0.08892
	Ave.	59.6	605	(-)11.23	0.08907

Note. Rs= rainy season, Ds= dry season, Ave.= average, GCI= grazing condition index, ha/AU/Y= hectare per animal unit per year, AU/ha/Y= animal unit per hectare per year (Note. To convert AU/ha to ha/AU, divide 1 by AU/ha value (Abdullah et al., 2017)

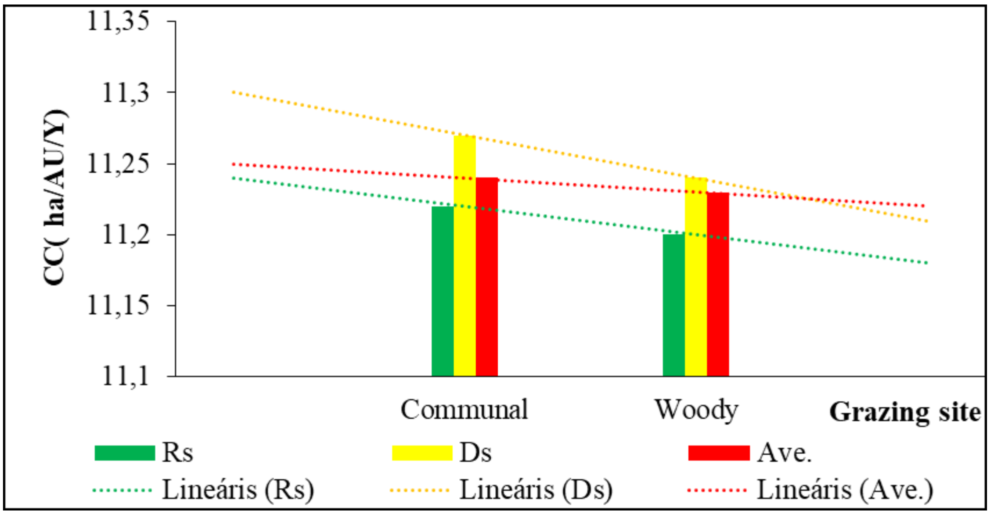

Figure 6. *Carrying capacity comparison of grazing sites (communal and woody) during different seasons*

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The negative (-) sign at *Table 5* indicated the carrying capacity difference as compared with the ranch site. That means, the carrying capacity of the degraded grazing sites were less by 11 ha/AU/Y when compared with the conserved ranch grazing site. In other words, in order to support equal number of livestock overgrazing rate would have been zero or no overgrazing would have been observed in ranch grazing site, while in the case of open-communal and woody grazing site the overgrazing rate would have been 11 ha/AU/Y. That means the degraded grazing area was exposed to overgrazing 11 times higher than the normal or recommended capacity that can support. From this we can understand that in order to support equal number and type of livestock it would be needed additional 11 times grazing site area in case of degraded (open-communal and woody infested) grazing site.

In general, from this result does not mean that the carrying capacity of grazing site both at rainy and dry season were equal. Instead, the dry biomass production at rainy season was higher and it is clear that during rainy season the carrying capacity of Yabello rangeland was better across all grazing sites. Therefore, biomass productivity ultimately decreased due to overgrazing and infestation of woody invasive plant species leading to poor carrying capacity. Our result is in agreement with the data reported by Solomon et al. (2007) for the same study site using different method.

Carrying capacity by biomass method

This technique clearly provided visible and clear information about the impact of seasonal variation and overgrazing on biomass productivity potential and carrying capacity across the grazing site.

Carrying capacity value ranged between the interval 2.99 to 53.40 ha/AU/Y or 0.33 to 0.019 AU/ha/Y with the average yearly value of 4.23 to 46.24 ha/AU/Y or 0.24 to 0.022AU/ha/Y (*Table 6*). When we have seen seasonal carrying capacity difference across the grazing site 58.7%, 57% and 23.7% better carrying capacity potential was observed from ranch, open-communal and woody covered grazing site, respectively during rainy season as compared with dry season. Based on this we can concluded that, it is crucial to analyze the vulnerability of pastoral livelihoods to combined threats within a risk-prone environment and developed adaptation strategies to reduce the impact of drought on their livestock and our result is highly constituent with the data reported by Habtamu (2013), Angassa and Oba (2010) and Bat et al. (2016).

Table 6. *Carrying capacity of Yabello rangeland at different grazing site (Biomass method)*

Grazing site	Season	Biomass Kg/ha	Available biomass Kg/ha	CC ha/AU/Y	CC AU/ha/Y	Grazing status value
	Rs	4,584	1,375.2	2.99**	0.33	
Ranch	Ds	1,890	567.0	7.24**	0.14	10
	Ave.	3,237	971.1	4.23**	0.24	
	Rs	1,053	315.9	13.00**	0.077	
Communal	Ds	453	135.9	30.22**	0.033	4
	Ave.	753	225.9	18.18**	0.055	
	Rs	336	100.8	40.73**	0.025	
Woody	Ds	256.2	76.9	53.40**	0.019	4
	Ave.	296.1	88.8	46.24**	0.022	

Note. ** = highly significant, CC= carrying capacity, Rs= rainy season, Ds= dry season, Ave.= average, GCI= grazing condition index, ha/AU/Y= hectare per animal unit per year, AU/ha/Y= animal unit per hectare per year. And under grazing status value column,10 = is value of slightly grazing, 4= is value of over grazing

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The maximum carrying capacity was observed at well managed (ranch) grazing site throughout the year (both in rainy and dry season). That was 2.99 ha/AU/Y, 7.24 ha/AU/Y and 4.23 ha/AU/Y at rainy season, dry season and in yearly, respectively. The carrying capacity potential of ranch grazing site showed higher values of 77%, 76% and 76.7% compared to open-communal grazing site, and 92.7%, 86.4% and 90.9% compared to woody-plant infested grazing site during at rainy season, dry season and yearly respectively. The reason for the low carrying capacity potential of non-conserved grazing site (communal and woody) is that degradation resulted from overgrazing and infestation of woody plant species in combination with both climatic and anthropogenic factors. And the current status of open-communal and woody grazing site is under degradation because of overgrazing (*Table 6*). Overall, the rangeland of Yabello showed overgrazing and changed to non-usable stage because of serious degradation, which challenges the survival rate of livestock, livelihood of the pastoral community and the economy of the country.

Conclusion

Based on our overall results, we clearly understood that the seasonal variation and grazing site management difference had a great influence on the available grass basal area coverage, height, biomass production and carrying capacity potential of rangeland. It helps to put a baseline data for decision how it is valuable to conserve and manage grazing site based on the data recorded from our benchmark site, since plant cover, dry mass and carrying capacity are the primary indicators for how a certain range land site would be used sustainably without further deterioration. In Yabello rangeland the pastoralists community are more challenged because of the factors like overgrazing, invasive plant species infestation, frequent drought and other climatic and human factors caused for rapid decline of biomass production and carrying capacity rate. The main target to quantify the change of optimal grazing site with relation to grass basal cover, biomass production, growth height performance and carrying capacity was to create awareness with in the community and the scholars with regards to how to conserve further degradation by incorporating scientific techniques and applying practical immediate managerial decision. The forage biomass production in Yabello area is primarily determined by the inconsistence variability of rainfall and rapid infestation rate of woody plant. The overall biomass production in the rangeland was not adequate to meet the requirements of the tropical livestock unit in the area. There is a big difference between the conserved and non- conserved grazing site due to the ultimate influence of overgrazing and woody plants. However, this study was preliminary, based on the result we highly recommend that subsequent ecological studies should be conducted on spatial and temporal variations of forage production. The productive potential of rangelands is not the same across the study site and carrying capacities are needed to be periodically reviewed to accommodate any changes in land resources, or environment. There is a severe problem of overgrazing that leads to year-round stress on grazed species. Therefore, the adjustment of stocking rate is compulsory and planned grazing should be introduced and implemented to release the stress over grazed species.

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Competing interests. The authors declare that they have no conflict of interests.

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