J. Resour. Ecol. 2020 11(2): 159-170
DOI: 10.5814/j.issn.1674-764x.2020.02.004
www.jorae.cn

Effects of Vegetation Cover, Grazing and Season on Herbage Species Composition and Biomass: A Case Study of Yabello Rangeland, Southern Ethiopia

Yeneayehu FENETAHUN[1], XU Xinwen[2], YOU Yuan[2], WANG Yongdong[2,*]

1. University of Chinese Academy of Science, Beijing 100049, China;
2. State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institution of Ecology and Geography, Chinese Academy of Science, Urumqi 830011, China

Abstract: The Yabello rangeland is a semi-arid area in Borana, Ethiopia that is facing great degradation challenges. Increasing infestation of vegetation cover, over grazing and high seasonal variation have significantly affected the herbage composition and biomass in the Yabello rangeland. This study focused on assessing the effect of vegetation cover, grazing and season on both herbage composition and biomass in the Yabello rangeland. An experiment was conducted using randomized plots of 1 m × 1 m. Sites were selected based on vegetation cover type and grazing variation, and seasonal impacts were also assessed. Data on herbage composition, height and mass with respect to those parameters were analyzed using SAS statistical software version 9.1 (SAS Institute, 2001) and Microsoft Excel. A total of 26 grass species were recorded and *Chloris roxburghiana Chrysopogon aucheri* and *Chrysopogon aucheri* grass species showed the highest average single species cover height and biomass production, for all the sites among all parameters. As a result, those grass species are highly recommended for the rehabilitation of degraded rangeland in the study area. This study also showed that vegetation cover type grazing and seasonal variation were the key factors in determining herbage species composition, height and biomass production. Finally, we recommended that sustainable management which controls bush vegetation cover and balances grazing levels is essential for sustainable herbage production and biodiversity conservation in the area.

Key words: Yabello rangeland; species composition; biomass; bush land; grazing; herbage height; rainy season; dry season

1 Introduction

Maintaining species composition and biomass production of rangelands requires extensive knowledge of how the vegetation responds to the dominant environmental factors such as grazing, seasonal variability and vegetation cover. Improper grazing, nonnative species and the occurrence of drought as a result of seasonal variation are concerns for rangeland management in the Borana-Yabello rangelands of Ethiopia, and they are become the primary stresses that have led to deterioration of the Yabello rangelands and a subsequent die-off of livestock populations after severe droughts (Angassa and Oba, 2010; Angassa, 2014; Takele et al., 2014). The recurring drought, and the consequent critical shortages of fodder and moisture are severely impacting the productivity of both livestock and agriculture, and hence the overall socio-economic development of the society (Gemedo et al., 2005). The pastoralists that live in the rangeland area have used their own traditional practices to endure the harsh

Received: 2019-05-14 **Accepted:** 2020-01-06
Foundation: The Funding Source Science and Technology Partnership Program, Ministry of Science and Technology of China (KY201702010); The China-Africa Joint Research Center Project of the Chines Academy of Science (SAJC201610).
First author: Yeneayehu FENETAHUN, E-mail: yeneayehu07@gmail.com
***Corresponding author:** WANG Yongdong, E-mail: wangyd@ms.xjb.ac.cn

Citation: Yeneayehu FENETAHUN, XU Xinwen, YOU Yuan, et al. 2020. Effects of Vegetation Cover, Grazing and Season on Herbage Species Composition and Biomass: In Case of Yabello Rangeland, Southern Ethiopia. *Journal of Resources and Ecology*, 11(2): 159–170.

conditions, such as the scarcity of both water and forage, that have great impacts on their livelihood (Habtamu et al., 2013). The energy expended by the livestock was inversely related to herbage mass production; meaning that if the herbage production is high then the livestock lose little energy in search its forage, but if herbage mass is low the energy expended by the livestock will be high (Tamrat and Stein, 2015). This shows the inverse relationship between grazers and biomass yield (Kramberger et al., 2014). In general, the herbage biomass production of a certain rangeland site indicates the status and condition of that rangeland site and appropriate measures can be taken based on that observed information (Herlocker, 1999). In addition, herbage biomass can be used to measure and estimate the carrying capacity of a rangeland site (Bikila et al., 2014). The assessment of rangeland based on herbage biomass is used for sustainable rangeland management by balancing the livestock population with forage production, and it is used to further reduce degradation of the rangeland (Chave et al, 2014). Rangeland herbage production depends on various factors, but rangeland vegetation cover types, grazing and seasons are among the primary parameters that determine the herbage species composition and biomass production of a rangeland (Teshome et al., 2012). Therefore, a better understanding of the interactive effects of vegetation cover types, grazing and season on herbage mass productivity is pre-requisite for appropriate rangeland management (Siraj and Abdella, 2018). In different landscape areas, vegetation cover and species composition are two of the major causes of variability in herbage mass production due to differences in physiological responses among species (Bartolome et al., 2007). For example, in a rangeland area where shrub/tree coverage was high, the production of available herbage was reduced as compared to non-covered rangeland area (Sánchez-Jardón et al., 2010). The impacts of seasonal variation, availability and location water sources, elevation of the grazing sites and the amount of herbage vary with time and place, and this variation makes it difficult to understand their direct relationships and to constantly follow the level of impact in a certain area (Bikila et al., 2016). Depending on accessibility, some rangeland sites may be frequently preferred by livestock, leading to overgrazing which can result in the reduction of rangeland nutrient availability and consequently affect herbage quantity and species composition; and these developments together with several other factors may ultimately determine how grazing intensity and distribution influence herbage productivity (Mligo, 2009; Lin et al., 2010). In rainy seasons, rangelands typically have enough water and herbage supply for animals, but the conditions deteriorate during dry seasons. Such deterioration is evidenced by declines in both herbage mass and quality in a rangeland. These patterns of change are usually the main cause of seasonal movements of grazers between the dry and wet seasons (Ayana and Gufu, 2007). Information on herbage production and composition is needed for establishing grazing stocking rates and carrying capacities for different rangeland sites. Several rangeland sites in Yabello, Ethiopia, have been reported to be overgrazed and degraded due to overstocking and overgrazing. Hence, there is general need for rangeland site-specific information to support the decision-making processes for improving biodiversity conservation and sustainable livestock production systems. The key information required for this are inventories of herbage quantity and quality with respect to prevailing environmental factors, which can serve as the basis for establishing productivity levels. Equally important is the identification of specific factors and the extent to which they influence the herbage quantity and species composition. Therefore, the aim of this study was to answer the question: How do vegetation cover type, grazing and season affect herbage species composition and herbage biomass in the Yabello area of southern Ethiopia?

2 Materials and methods

2.1 Description of the study area

This study was conducted from December 2018 to May 2019 at Dida Tuyura, Danbal-Waccu and Arero kebele of Yabello district, Borana zone, southern Ethiopia (Fig. 1). It is located 566 km south of Addis Ababa along the Addis – Moyale road. The area of Yabello town is 5426 km^2, and it is located between 4°30′56″ and 5°24′36″ north latitude and between 7°44′15″ and 38°36′05″ east longitude. The altitude mostly spans about 1000–1500 m, with a maximum altitude of 2000 m. The climate type is arid and semi-arid, and the annual average temperature is 19–26 ℃, with only small seasonal changes. 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 (Dalle et al., 2015). The potential evapotranspiration is 700–3000 mm (Billi et al., 2015). The study area is dominated by savannah vegetation containing mixtures of perennial herbaceous species. It is also confronted with the problem of bush expansion in the native savannah grasslands, in addition to the area characterized by savanna grassland.

2.2 Research procedure and design

A completely randomized plot arrangement design was used to determine the effects of vegetation cover types, grazing

and season on herbage species composition and herbage production. Two vegetation cover types based on vegetation cover (Bush land (BL) and Open grassland (OG)) and two grazing factor categories (grazed and non-grazed) were randomly assigned as whole plots and sub-plots, respectively, and the experiment was conducted during two different seasons (the dry season from Dec. to Feb. and the rain season from Mar. to May) in order to determine the impacts of season on both herbage species composition and mass (Fig. 2). Each treatment was replicated three times.

Fig. 1 Location of the study area

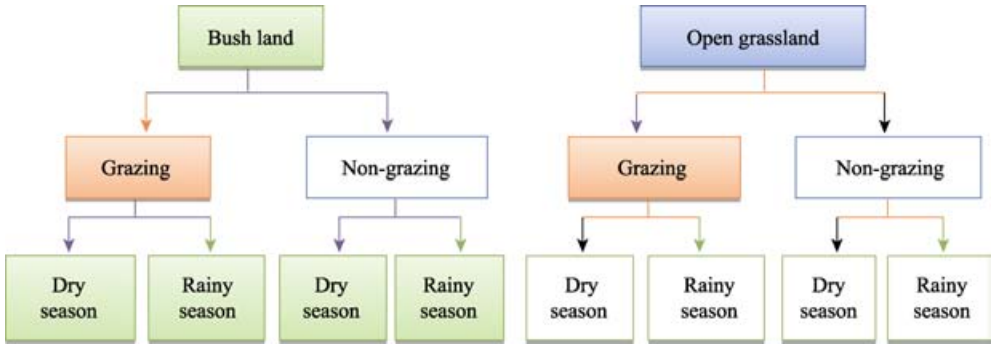

Fig. 2 The plot experimental arrangement for the study

2.3 Species composition and herbage mass sample collection

Two quadrats of 1 m × 1 m were randomly placed in each of the treatment plots for above-ground herbage mass harvesting and quantification in January (for the dry season) and in May (for the rainy season) in 2019, and the above ground herbage mass was harvested by cutting to the ground level using a sickle. Then, the harvested herbage was hand sorted to remove litter and other non-herbaceous plant materials. The fresh herbage samples were weighed, and then transported to the lab for drying at 105 ℃ until they achieved a constant weight. The ratio of the dry weight of the sub-sample to the full sample weight was used to calculate the dry matter (DM) yield for each quadrat in g DM m^{-2} (Angassa, 2014).

2.4 Data analysis

SAS statistical software version 9.1 (SAS Institute, 2001) and Microsoft Excel were used for statistical analysis for the data.

3 Results

3.1 Herbage species composition

A total of 26 grass species were recorded and identified by both their scientific and local names. The species and their average covers for the different treatments are presented in Table 1. *Chloris roxburghiana*, *Cenchrus ciliaris* and *Chrysopogon aucheri* grass species showed the highest average single species cover of 10% or more for all the sites and in both seasons, and high abundance in non-grazing rangeland especially during the rainy season. The results showed significant differences in cover among different herbage species and the differences in height for the species recorded from the study sites were also significant. The data for species average height are presented in Table 2.

3.2 Effects of vegetation cover types, grazing and season on species composition

Table 1 Herbage species cover (%) per vegetation cover type, grazing and season treatments. Values shown are the average percentages based on 1 m^2 quadrats in which a given species was recorded

List of Species		Vegetation type				Grazing treatment			
Scientific name	Local name	Bush land		Open grass land		Grazing		Non- grazing	
		Ds	Rs	Ds	Rs	Ds	Rs	Ds	Rs
*Chrysopogon aucheri**	Alaloo	11	18	14	24	10	17	18	35
Dactyloctenium aegyptium	Ardaa	+	4	1	7	+	5	5	12
Xerophyta humilis	Areedoo	2	9	6	11	–	3	11	15
Aristida kenyensis	Biilaa	+	10	5	22	–	1	15	29
Eragrostis capitulifera	Biilaa	+	1	11	23	+	13	13	23
Harpachne schimperi	Biilaa	–	+	1	5	+	7	2	16
Leptothrium senegalense	Biilaa diidaa	4	13	5	22	3	21	16	19
Melinis repens	Buuyyoo xirooftuu	–	+	1	3	+	4	8	15
Themeda triandra	Gaaguroo	3	11	6	12	2	9	7	9
Digitaria milanjiana	Hiddoo	5	14	8	17	3	21	7	27
*Chloris roxburghiana**	Hiddoo luucolee	12	21	16	28	13	33	22	54
Digitaria naghellensis	Ilmogorii	+	2	+	7	–	1	3	5
Panicum maximum	Loloqaa	–	+	1	3	–	2	+	8
Bothriochloa insculpta	Luucolee	–	3	1	9	–	11	+	11
*Cenchrus ciliaris**	Mata guddeessa	10	19	14	31	15	29	31	51
Pennisetum mezianum	Ogoondhichoo	+	1	3	6	–	1	1	7
Eragrostis papposa	Saamphillee	–	+	+	2	–	2	1	5
Sporobolus discosporus	Saamphillee kootichaa	+	7	5	8	+	9	8	11
Grewia tenax	Saarkama	+	1	1	3	+	1	+	5
Grewia tenax	Saarkama	+	9	11	9	–	3	5	15
Cyperus sp.	Saattuu	1	4	2	17	+	7	6	11
Cyperus bulbosus	Saattuu arbaa	1	2	3	10	1	2	3	7
Sporobolus pellucidus	Salaqoo	7	9	5	13	2	3	4	4
Cynodon dactylon	Sardoo	3	7	10	16	1	20	18	21
Heteropogon contortus	Seericha	+	1	2	11	1	14	11	12
Loudetia flavida	Seericha gaaraa	+	3	3	13	+	5	7	21

Note: + indicates grass species present with cover <1%; – indicates grass species absent; Ds = Dry season; Rs = Rainy season; * means that grass species were highly abundance (% in 1 m^2 sample site)

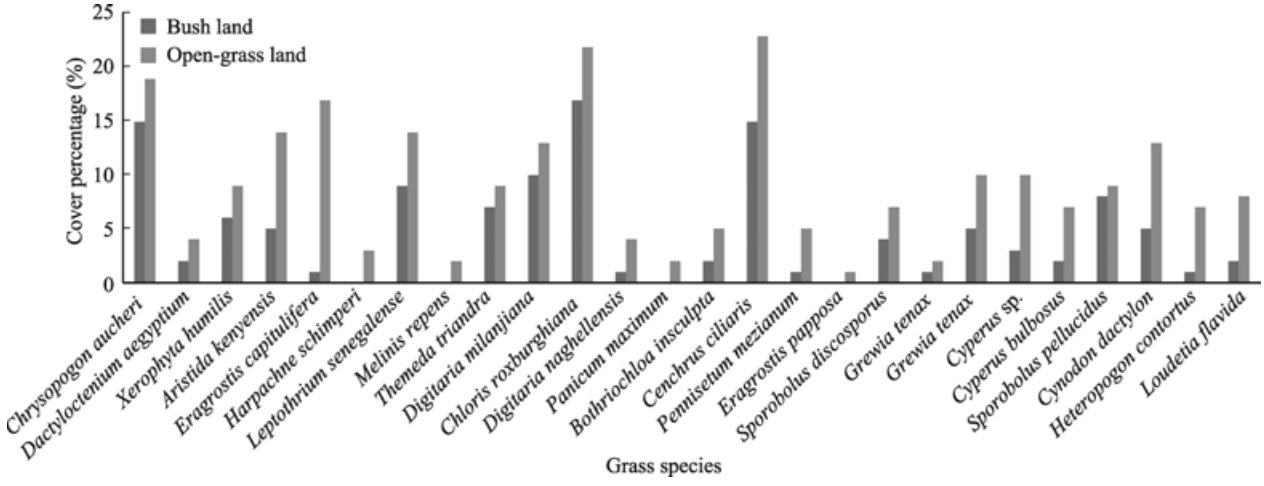

Fig. 3 Effect of vegetation cover type on herbage percentage cover

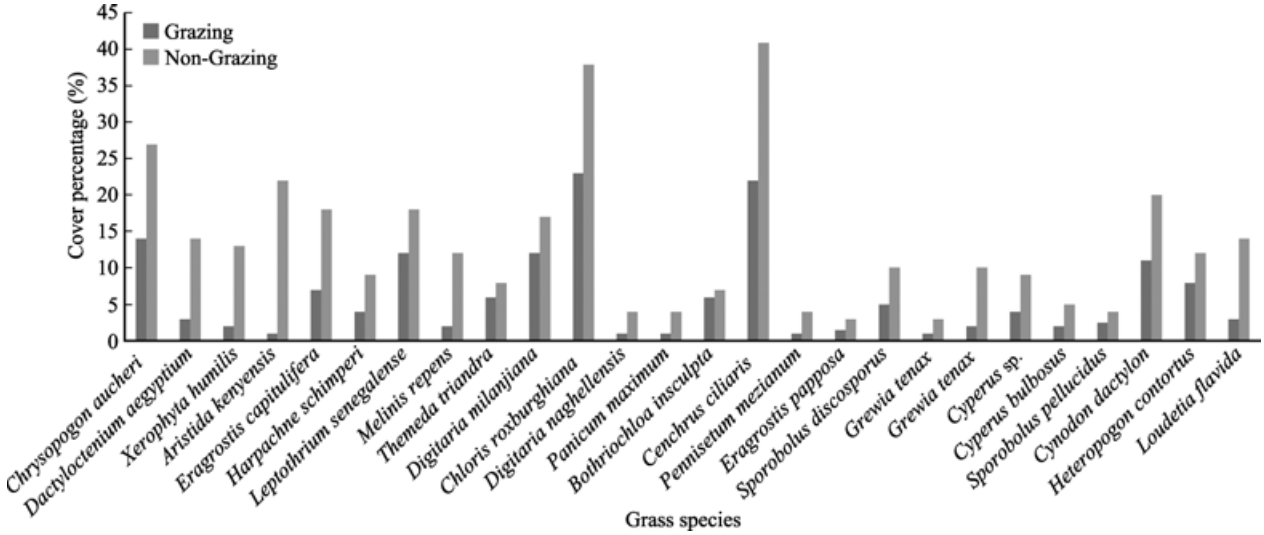

Fig. 4 Effect of grazing on herbage percentage cover

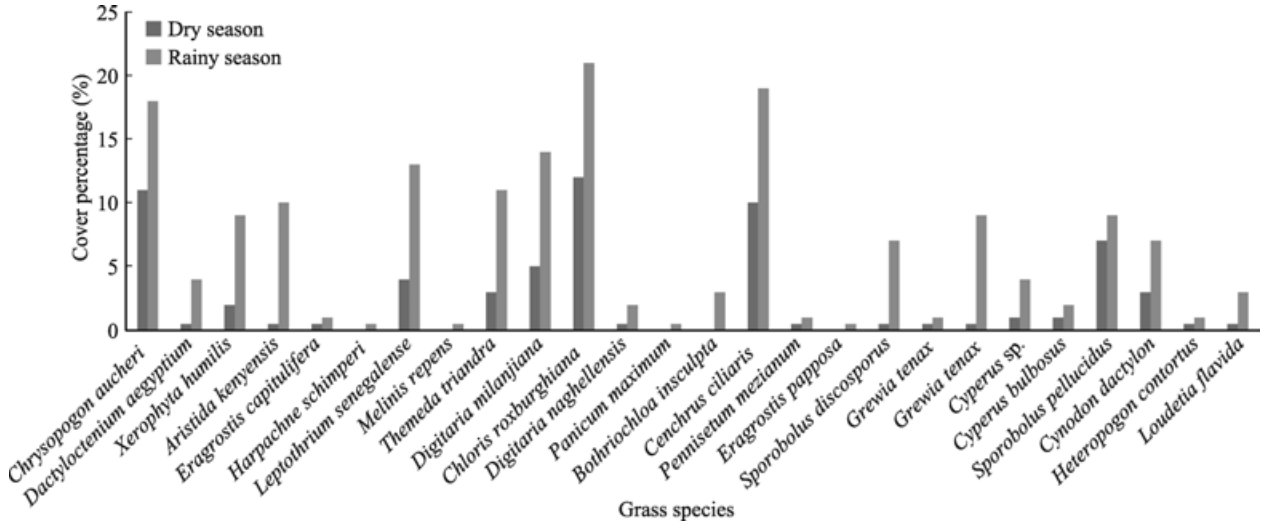

Fig. 5 Effect of season on herbage percentage cover in bush cover rangeland area

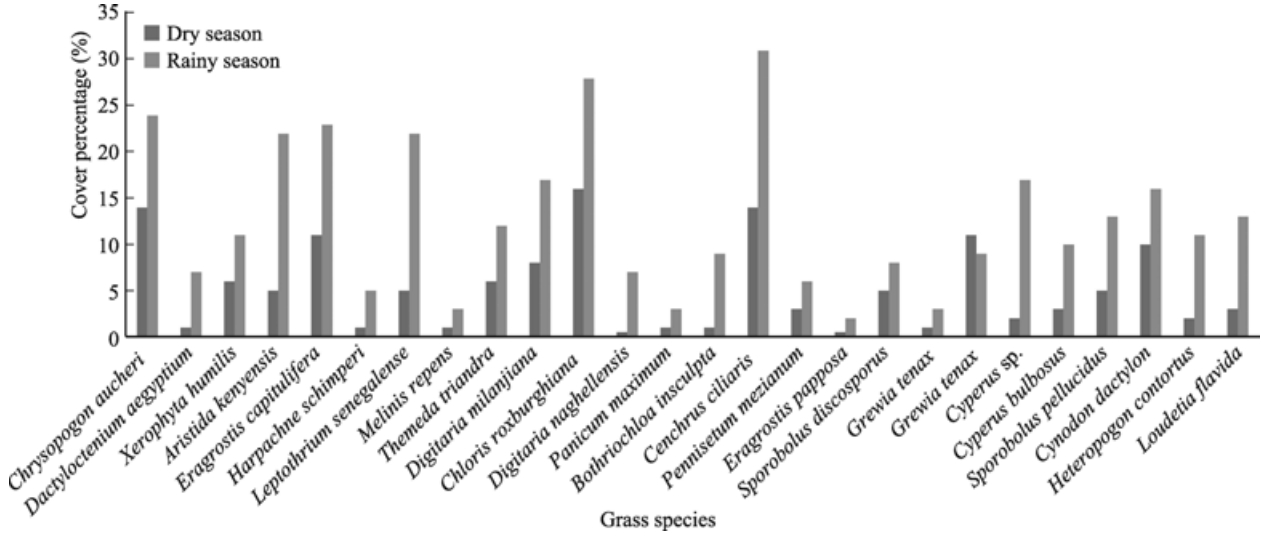

Fig. 6 Effect of season on herbage percentage cover in open grassland area

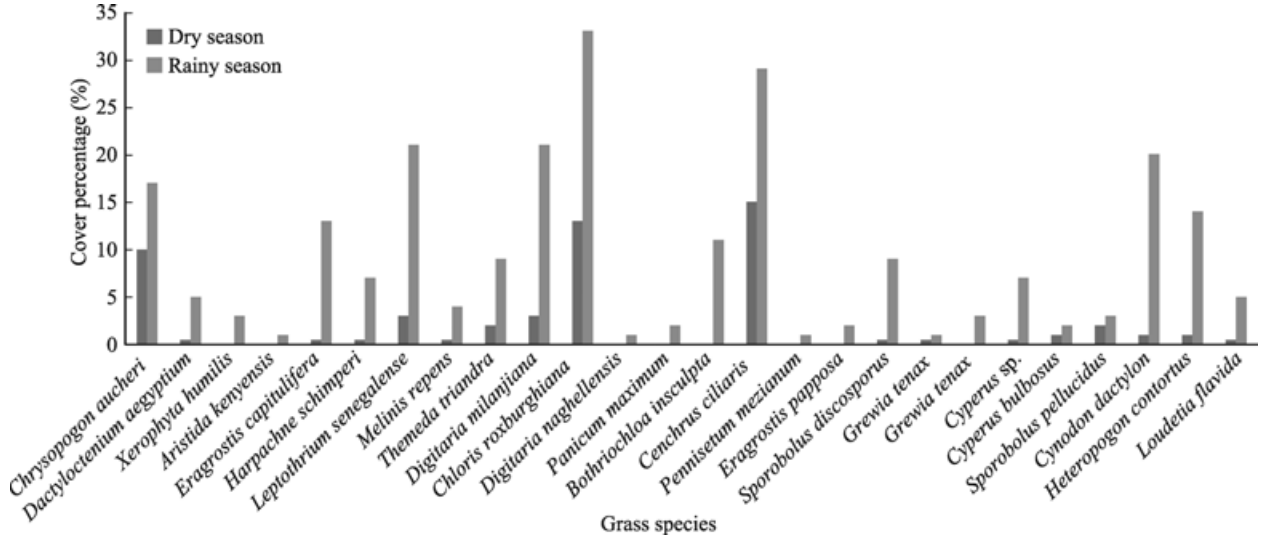

Fig. 7 Effect of season on herbage percentage cover in grazing rangeland area

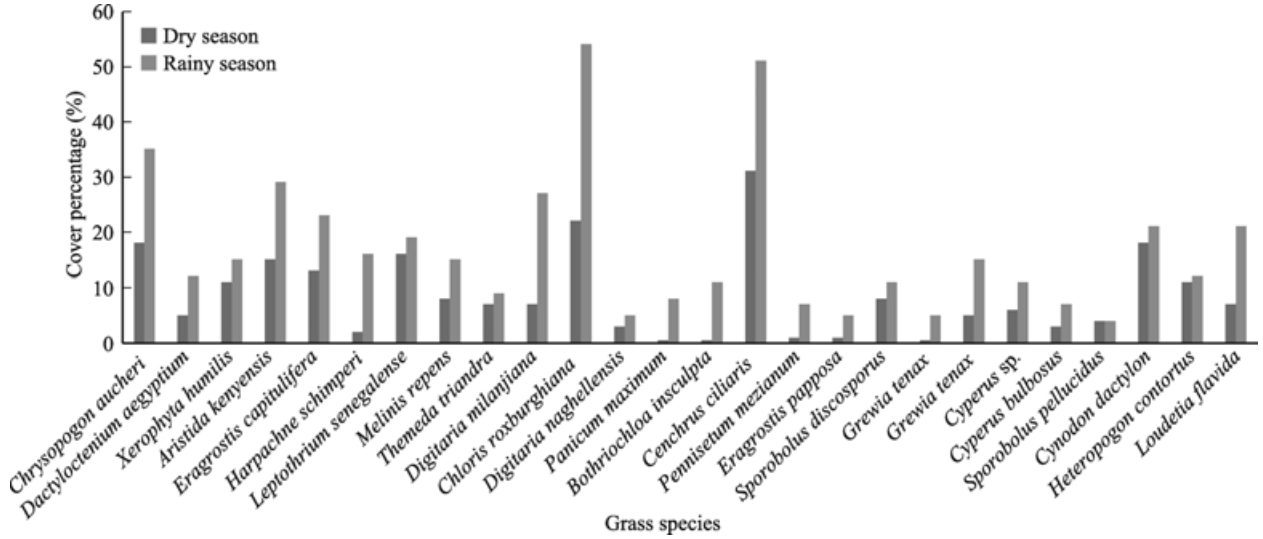

Fig. 8 Effect of season on herbage percentage cover in non-grazing rangeland area

3.3 Effect of vegetation cover types, grazing and season on herbage species heights

The differences in height for the species recorded from the study sites for each parameter also showed significant variation and are presented below in Table 2.

3.4 Effects of vegetation cover type, grazing and season on herbage mass production

The data in Table 1 show that herbage species cover was significantly higher in open grassland than in bush land. In addition, among the 26 grass species found in the study area only 11 during the dry season and 22 during the rainy season showed coverage above 1%; 10 in the dry season and four in the rainy season showed abundance below 1% coverage; and the remaining five grass species were not found in the rangeland area infested by bush coverage during the dry season. These findings indicate that seasonal variation had a great impact on species composition, and in the bush coverage rangeland area the abundance of existing species and number of grass species were higher in the rainy season as compared to the dry season in all study sites. The effect of grazing on species composition among all 26 grass species shows that: 1) only 10 grass species during the dry season and 26 grass species in the rainy season showed abundances of more than 1%; 2) eight grass species occurred in a very small abundance, almost below 1% coverage during dry season; and 3) the remaining eight grass species did not exist in the range land area during dry season grazing time. In addition, the impacts of season in both grazing and non-grazing sites were very critical and influential. In both sites, that is in bush land area, open grassland area, grazing and non-grazing areas, the abundances of the above three grass species show the highest percentages of cover

Table 2 Herbage height (m) for each vegetation type, grazing and season treatment. Values from 1 m^2 quadrats in which a given species was recorded

List of *Species*		Vegetation type				Grazing treatment			
Scientific name	Local name	Bush land		Open grass land		Grazing		Non-grazing	
		Ds	Rs	Ds	Rs	Ds	Rs	Ds	Rs
*Chrysopogon aucheri**	Alaloo	0.15	0.30	0.4	0.70	0.12	0.41	0.62	0.74
Dactyloctenium aegyptium	Ardaa	+	0.13	0.18	0.21	0.11	0.24	0.33	0.52
Xerophyta humilis	Areedoo	0.02	0.50	0.28	0.31	–	0.41	0.37	0.51
Aristida kenyensis	Biilaa	+	0.26	0.06	0.29	–	0.13	0.5	0.58
Eragrostis capitulifera	Biilaa	+	0.01	0.11	0.23	+	0.17	0.33	0.38
Harpachne schimperi	Biilaa	–	0.02	0.15	0.33	0.03	0.47	0.41	0.51
Leptothrium senegalense	Biilaa diidaa	0.09	0.29	0.21	0.29	0.35	0.41	0.49	0.70
Melinis repens	Buuyyoo xirooftuu	–	0.07	0.18	0.31	0.06	0.62	0.67	0.69
Themeda triandra	Gaaguroo	0.03	0.11	0.54	0.61	0.20	0.59	0.41	0.69
Digitaria milanjiana	Hiddoo	0.29	0.34	0.08	0.66	0.03	0.57	0.70	0.88
*Chloris roxburghiana**	Hiddoo luucolee	0.20	0.55	0.46	0.67	0.22	0.67	0.79	0.87
Digitaria naghellensis	Ilmogorii	0.11	0.20	0.32	0.48	–	0.29	0.30	0.51
Panicum maximum	Loloqaa	–	0.17	0.19	0.37	–	0.27	0.39	0.58
Bothriochloa insculpta	Luucolee	–	0.35	0.31	0.22	–	0.11	0.27	0.51
*Cenchrus ciliaris**	Mata guddeessa	0.18	0.33	0.49	0.61	0.25	0.82	0.81	0.90
Pennisetum mezianum	Ogoondhichoo	0.13	0.32	0.24	0.36	–	0.8	0.11	0.37
Eragrostis papposa	Saamphillee	–	0.08	0.09	0.22	–	0.23	0.28	0.30
Sporobolus discosporus	Saamphillee kootichaa	0.09	0.27	0.25	0.48	0.05	0.49	0.58	0.61
Grewia tenax	Saarkama	0.06	0.31	0.33	0.43	0.05	0.47	0.42	0.44
Grewia tenax	Saarkama	0.09	0.31	0.11	0.29	–	0.33	0.45	0.55
Cyperus sp.	Saattuu	0.04	0.14	0.22	0.27	0.03	0.37	0.46	0.48
Cyperus bulbosus	Saattuu arbaa	0.09	0.27	0.29	0.40	0.05	0.41	0.39	0.45
Sporobolus pellucidus	Salaqoo	0.02	0.21	0.15	0.31	0.07	0.33	0.42	0.49
Cynodon dactylon	Sardoo	0.03	0.17	0.10	0.21	0.09	0.20	0.26	0.38
Heteropogon contortus	Seericha	0.09	0.12	0.29	0.34	0.08	0.32	0.37	0.39
Loudetia flavida	Seericha gaaraa	0.08	0.22	0.19	0.27	0.07	0.20	0.32	0.41

Note: + indicates the grass species that have a height of very low almost is difficult to express in number; – indicates species absent; Ds = Dry season; Rs = Rainy season; * grass species were highly abundance.

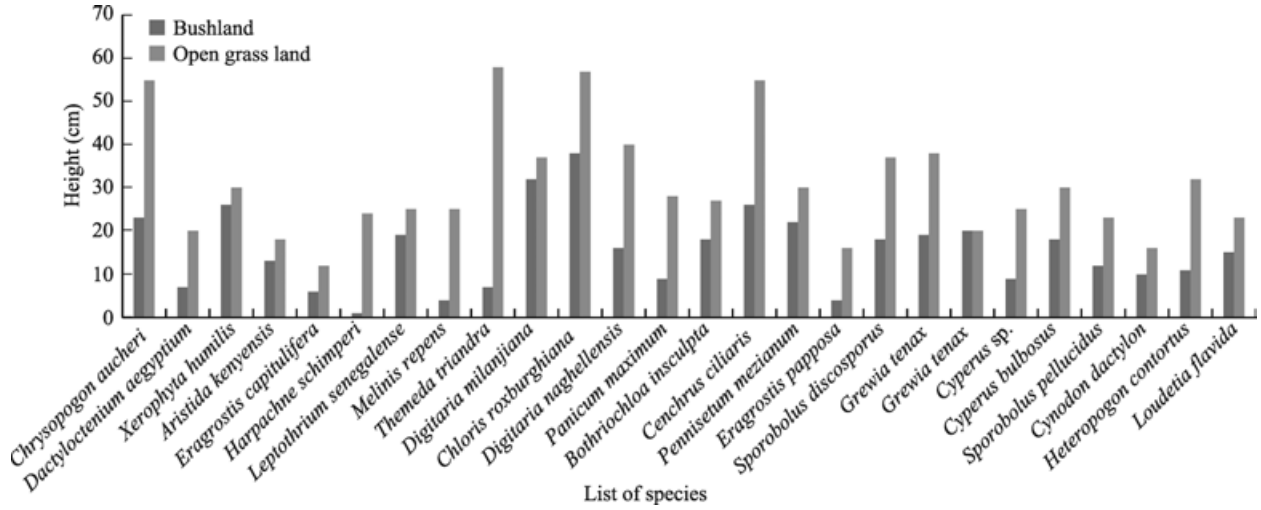

Fig. 9 Effect of vegetation cover type on herbage species height

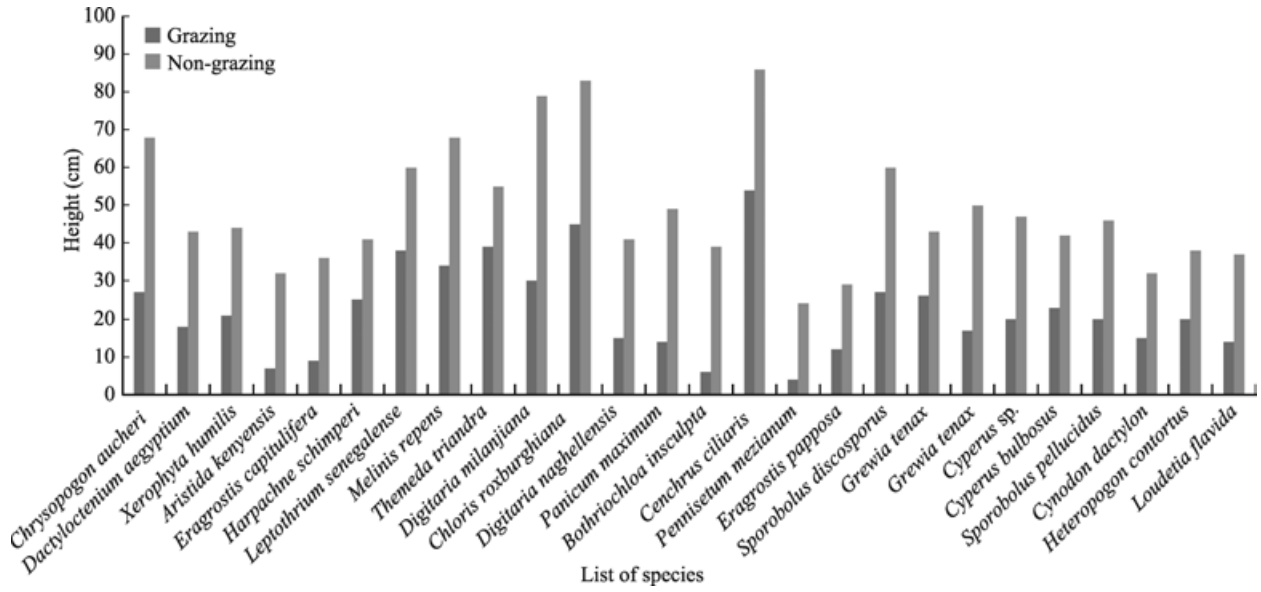

Fig. 10 Effect of grazing on herbage species height

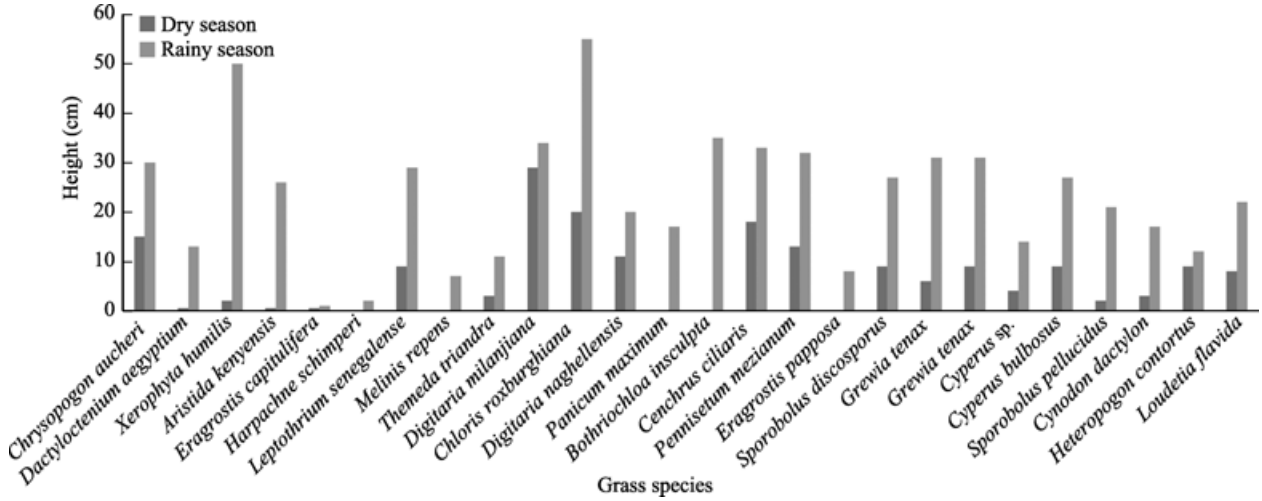

Fig. 11 Effect of season on herbage species height in bush land area

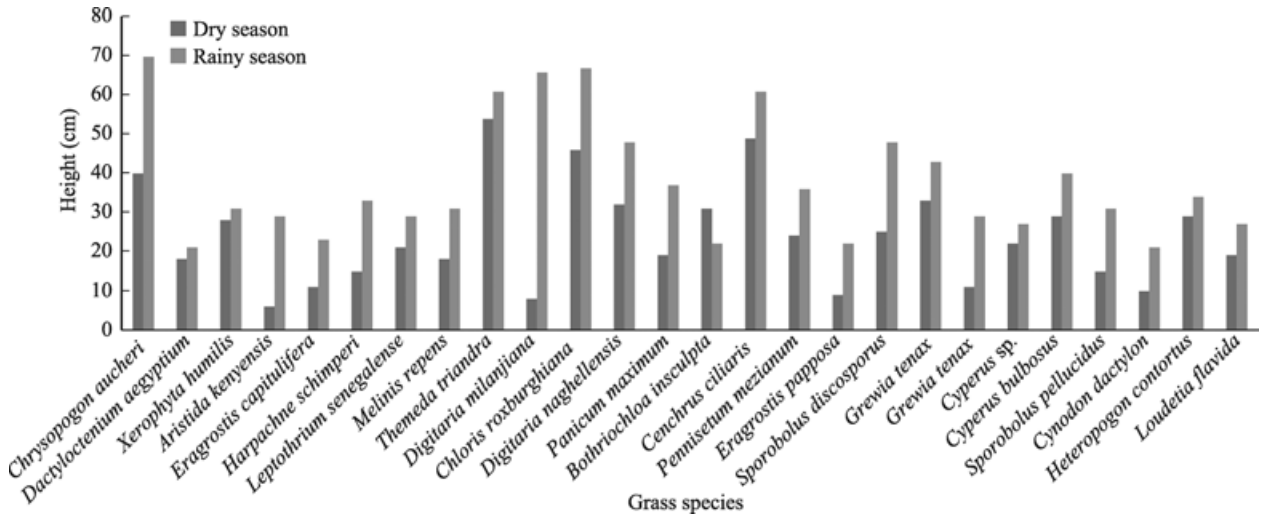

Fig. 12 Effect of season on herbage species height in open grassland area

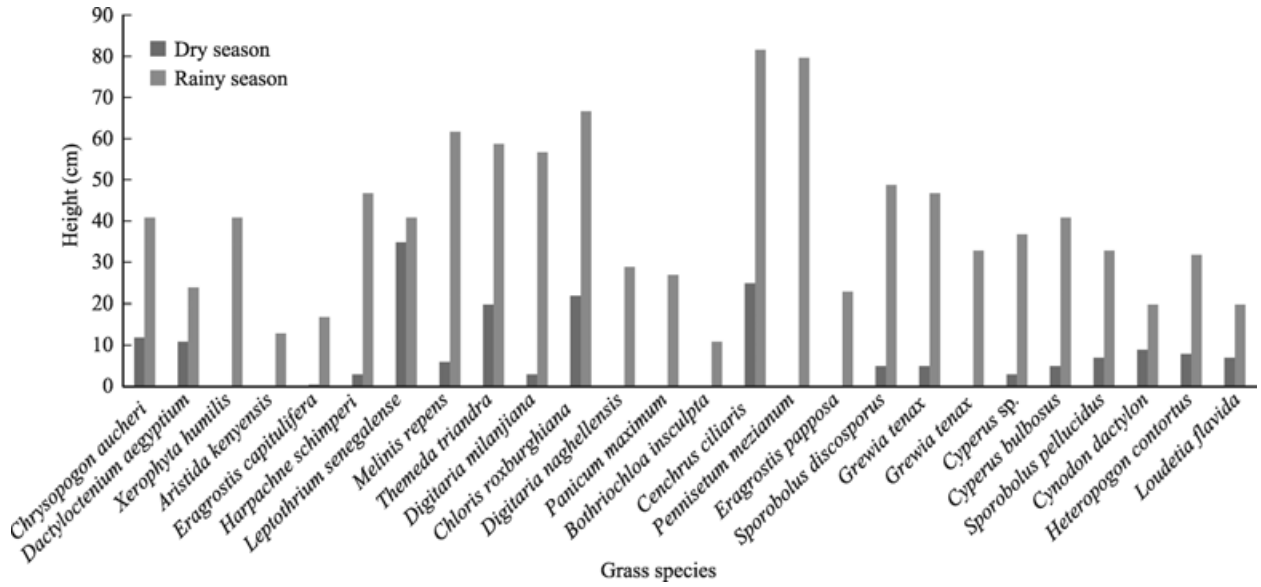

Fig. 13 Effect of season on herbage species height in grazing grassland area

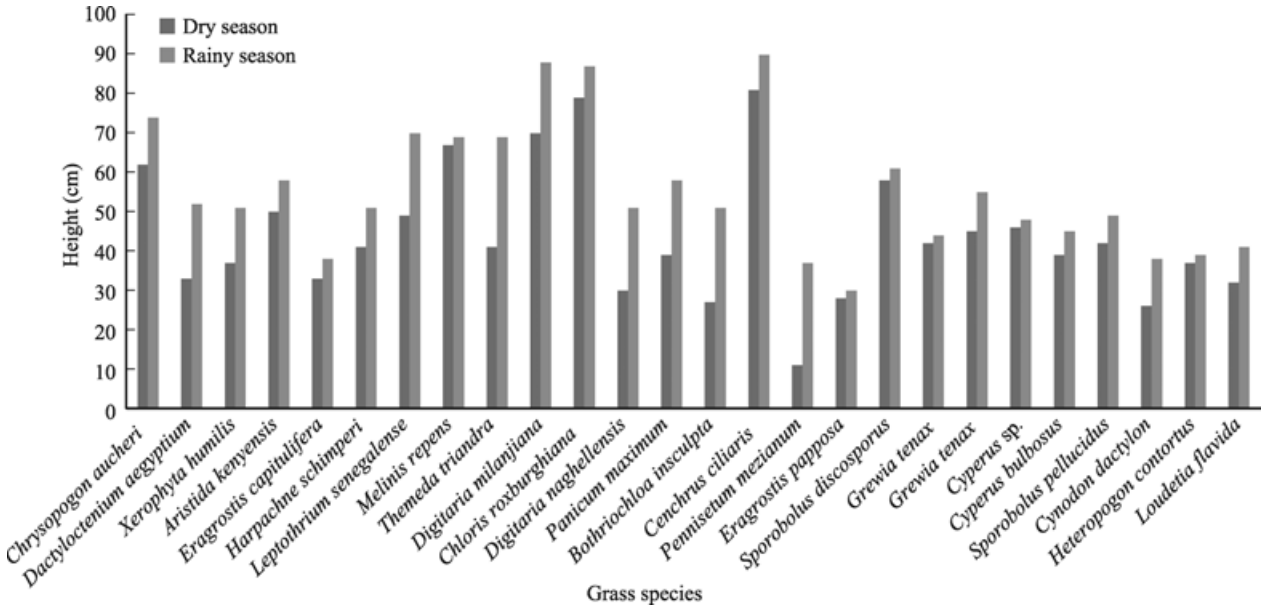

Fig. 14 Effect of season on herbage species height in non-grazing grassland area

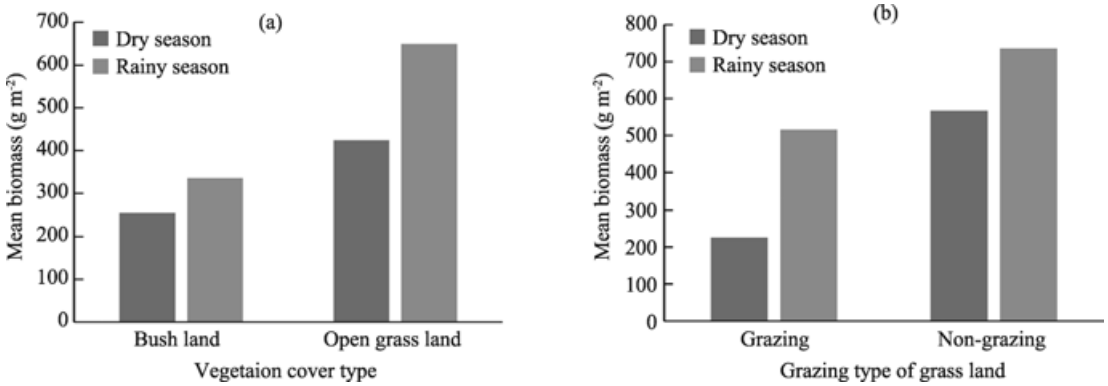

Fig. 15 Effects of vegetation cover type linked to season on herbage mass production (a) and effects of grazing linked to season on herbage mass production (b)

compared to the other grass species. Based on this data and other related studies, we can conclude that those grass species were very essential and suitable for rangeland rehabilitation, either through reseeding or direct planting methods. Data on the effects of vegetation cover, grazing and season at each site on herbage cover and herbage height are presented below.

In general, from this study we can observe that presence and percentage coverage for a grass species were directly influenced by and linked with vegetation cover type (Fig. 3). That is grass coverage was higher in open grassland and while some of the grass species were totally absent from bush covered rangeland, those grass species were present in open grassland area. For example, *Harpachne schimperi*, *Melinis repens*, *Panicum maximum*, *Bothriochloa insculpta* and *Eragrostis papposa* grass species were totally absent in the dry season, and in the rainy season they only had very small coverage in the bush covered rangeland area (Fig. 5); but all of those grass species were present in both dry and rainy seasons in the open grassland area (Fig. 6). This shows that bush infestation of rangeland had a strong impact on both the composition and mass of herbage species, and this directly influences the livelihood of livestock owners and the local community, as well as the economy of both the local people and the country in general. Open grassland was found to have a generally higher species coverage than bush land area (Fig. 3). This is due to the shade effect from trees and shrubs that leads to competition for light, which tends to exclude some species and leave a few of the most competitive ones as was reported previously (Hasenn et al., 2013).

As for the effect of grazing on herbage species composition, non-grazed sites had more herbage species than grazed sites (Fig. 4), an indication that in non-grazing rangeland areas there were no more disturbances and this resulted in maintaining the species richness. This pattern in species composition is the opposite of the trends reported by Lanta et al. (2009), whose studies indicated that excluding herbage from livestock grazing areas decreases species richness but increases it under conditions of grazing pressure. We found the dominance of three herbage species in both sites, the grass species *Chrysopogon aucheri*, *Chloris roxburghiana* and *Cenchrus ciliaris*. This result indicates that those grass species are the most preferable species for rangeland rehabilitation in the studied rangeland area, since they tend to resist both grazing influences and bush infestation as compared to the other species. Further, we also understand that overgrazing of the rangeland results in no selective grazing on herbage grass species as a result of shortage of forage for the livestock, and as a result, the livestock graze on all the herbage species at the same rate.

Seasonal patterns of herbage composition cover showed that the rainy season was associated with higher species numbers than the dry season, which can be attributed to relatively higher rainfall resulting in the growth and presence of most of the herbage grass species in all study sites (Figs. 5–8). However, the dry season had the lowest number of species, most likely due to drought stress, especially in grazing and bush infested rangeland areas. High grazing pressure on herbage species was observed during the dry seasons in overgrazing areas due to a shortage of food for the livestock (Fig. 7). Under these conditions, there is no alternative source of food and the animals prefer to graze in bush land areas during the dry season, due to the availability some herbage species. Also, the shade from bush trees leads to further reduction of herbage species composition in the dry season in those two sites.

Regarding the impact of vegetation cover, grazing and seasonal variation as related to herbage species height (Figs. 9–14), the following patterns were observed. Herbage species height in bush land was significantly less than in open grassland area (Fig. 9). This difference in height could possibly be due to reduced vigour associated with herbage under bush vegetation cover as a result of the light competition effect. This may cause plants to easily break due to environmental disturbances like grazing and wind, and render them unable to grow to heights comparable to those with no light shade effect in open grass land area. In general, the impacts of all the above parameters as related to herbage height showed significant variations. That means all vegetation covers, grazing and seasonal differences are directly linked to the herbage grass species growth performance. Therefore, species heights in grazing sites were significantly less than those in non-grazing rangeland sites (Fig. 10), and also species heights in the dry season in all study sites showed significant variations as compared to the rainy season in all those study sites (Figs. 11–14). However, as we have seen from the data in Figs. 9–14, the heights of herbage species *Chrysopogon aucheri*, *Chloris roxburghiana* and *Cenchrus ciliaris* showed great resistance of all those influencing parameters and serve as the main source of forage for livestock in all harsh conditions. According to the additional data obtained directly from our field investigation and also from both direct interviews and focal group discussions in the local communities, those grass species have high resistance capacities and are recommended for further degraded range land rehabilitation methods, either through reseeding or direct planting. This is also directly supported by the study conducted by Samuel (2017) on "estimating Grass Productivity under Different Clipping Frequencies and Rainfall Amount: Implications for Rangeland Responses to Climate Change in Borana rangeland, Ethiopia".

According to the results obtained in our study, the overall mean herbage mass recorded from the study sites showed variations as a result of the indicated parameters. The herbage mass production obtained from our experiment, from both bush land and open grassland, were minimum masses during dry season of 107.3 g m^{-2} (from *Eragrostis papposa* grass species) and 239.9 g m^{-2} (from *Grewia tenax* grass

species), respectively; and maximum production in the rainy season of 498.7 g m^{-2} and 761.2 g m^{-2}, respectively. Consequently, herbage mass yields in the different vegetation types were significantly different. Our data on the grass mass production difference in both bush land and open grassland showed 55% higher mass in open grass grassland for the minimum production; and 35% higher mass in open grassland for the maximum mass production when comparing the two sites. The mean herbage masses (g m^{-2}) calculated from bush land and open grassland areas were 254.5 g m^{-2} and 423.8 g m^{-2} in the dry season, and 335.7 g m^{-2} and 649.3 g m^{-2} in the rainy season, respectively (Fig. 15a). Among the herbage masses of individual grass species, *Chrysopogon aucheri*, *Chloris roxburghiana* and *Cenchrus ciliaris* accounted for almost 75% of the mean mass recorded in both sites. The maximum herbage mass production obtained in both sites among the species, both in the maximum and minimum, *Cenchrus ciliaris* yielded 498.7 g m^{-2} and 761.2 g m^{-2} in bush land and open grass land area, respectively.

Grazing had a significant effect on herbage mass production. Non-grazed sites had significantly higher herbage mass yield than the grazed ones. Means of herbage mass production for grazed sites were 225.6 g m^{-2} and 515.7 g m^{-2} in the dry and rainy seasons, respectively, and for un-grazed sites they were 567.1 g m^{-2} and 735.5 g m^{-2} in the dry and rainy seasons, respectively (Fig. 15b). The minimum herbage mass production recorded in both sites were 97.9 g m^{-2} (from *Pennisetum mezianum* grass species) and 327.3 g m^{-2} (from *Grewia tenax* grass species) in grazing and non-grazing sites, respectively, and these data in both sites were recorded in the dry season. These data show that the herbage mass difference was 70% higher for the non-grazing range land area. The maximum herbage mass production recorded from those study sites was 461.4 g m^{-2} from the grazing site and 792.6 g m^{-2} from the non-grazing site, and these data were recorded in the rainy season in both sites. This data shows a 42% herbage mass production difference between the two study sites, and the herbage species *Chrysopogon aucheri*, *Chloris roxburghiana* and *Cenchrus ciliaris* accounted for almost 73% of the mean mass recorded from both sites. From this we can conclude that those grass species were dominant in both study sites and have the capacity to resist both harsh conditions which occurred in the grassland area, and they are therefore recommended for further rehabilitation.

In general, the findings of our study show that herbage mass production is higher on open grassland rangeland sites than on bush land rangeland sites. This is in agreement with the findings by Samuel (2017), in a study conducted on the Borana rangeland site. As was expected, grazing significantly reduced the amount of herbage mass harvested at a given site compared to non-grazed sites. The results also show significant seasonal differences in herbage mass production, with the rainy season having the highest herbage mass production in all sampling sites.

4 Conclusions

This study show that vegetation cover type, grazing and season are very important factors to consider when assessing herbage composition and production potentials of rangelands. Therefore, bush land infestation and grazing management should always consider seasonal variation, and it should be given great emphasis in the rangeland development strategies and policies. There is, therefore, a need to establish the appropriate bush land infestation rates and grazing levels which allow sustainable rangeland herbage production potentials and biodiversity levels to be maintained, since bush land infestation, overgrazing and under grazing are liable to compromise the rangeland health conditions, especially in the long-term.

Acknowledgements

We would like to acknowledge the University of China Academy of Science that gave us facilities and financial support. Our great thanks also go to the Yabello Pastoral and Dry Land Agricultural Research Center which provided all laboratory facilities, and also to all the laboratory technicians for their continued follow-up and support throughout the completion of the study. Our great thanks go to the local community of the Yabello district for the basic information they provided, and also for indicating the factors that are still the major challenges for our next research step.

References

Angassa A. 2014. Effects of grazing intensity and bush encroachment on herbaceous species and rangeland condition in southern Ethiopia. *Land Degradation and Development*, 25(5): 438–451.

Angassa A, 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 Environments*, 74(1): 111–120.

Ayana A, Gufu O. 2007. Relating long-term rainfall variability to cattle population dynamics in communal rangelands and a government ranch in southern Ethiopia. *Agricultural Systems*, 94(3): 715–725.

Baars, R M T. 2002. Rangeland utilisation assessment and modelling for grazing and fire management. *Journal of Environmental Management*, 64(4): 377–386.

Bartolome J W, Jackson R D, Betts A D K, et al. 2007. Effects of residual dry matter on net primary production and plant functional groups in Californian annual grasslands. *Grass and Forage Science*, 62(4): 445–452.

Bikila N, Bedasa E, Samuel T, et al. 2014. Control of bush encroachment in Borana zone of southern Ethiopia: Effects of different control techniques on rangeland vegetation and tick populations. *Pastoralism*, 4(1): 18.

Bikila N G, Tessam Z K, Abule E G. 2016. Carbon sequestration potentials of semi-arid rangelands under traditional management practices in Borana, Southern Ethiopia. *Agriculture, Ecosystem and Environment*, 223: 108–114.

Billi P, Alemu Y T, Ciampalini R. 2015. Increased frequency of flash floods in Dire Dawa, Ethiopia: Change in rainfall intensity or human impact? *Natural Hazards*, 76(2): 1373–1394.

Chave J, Réjou-Méchain M, Búrquez A, et al. 2014. Improved allometric models to estimate the aboveground biomass of tropical trees. *Global*

Change Biology, 20(10): 3177–3190.
Cowling R M. 2000. Challenges to the “new” rangeland science. *Trends in Ecology & Evolution*, 15(8): 303–304.
Dalle G, Maass B L, Isselstein J. 2015. Rangeland condition and trend in the semi-arid Borana lowlands, southern Oromia, Ethiopia. *African Journal of Range & Forage Science*, 23(1): 49–58.
Gemedo D, Brigittie L M, Johannes I. 2005. Plant biodiversity and Ethnobotany of Borena pastoralists in southern Oromia, Ethiopia. *Economic Botany*, 59(1): 43–65.
Habtamu T K, Madakadze I C, Angassa A, et al. 2013. Nutritive value of grasses in semi-arid rangelands of Ethiopia: Local experience based herbage preference evaluation versus laboratory analysis. *Asian-Australasian Journal of Animal Sciences*, 26(3): 366–377.
Hasenn G, Hao X, Zhao M, et al. 2013. Effect of grazing intensity on carbon and nitrogen in soil and vegetation in a meadow steppe in Inner Mongolia. *Agriculture*, *Ecosystems & Environment*, 125: 21–32.
Herlocker D J. 1999. Rangeland ecology and resource development in eastern Africa. Nairobi: German Agency for Technical Co-operation.
Kramberger B, Gselman A, Podvršnik M, et al. 2014. Effects of low precipitation periods on the herbage yield of mesic semi-natural grasslands under different cutting regimes. *Zemdirbyste-Agriculture*, 101: 11–18.
Lanta V, Dole J, Lantová P, et al. 2009. Effects of pasture management and fertilizer regimes on botanical changes in species-rich mountain calcareous grassland in Central Europe. *Grass and Forage Science*, 64(4): 443–453.
Lin Y, Hong M, Han G, et al. 2010. Grazing intensity affected spatial patterns of vegetation and soil fertility in a desert steppe. *Agriculture*, *Ecosystems & Environment*, 138(3–4): 282–292.
Mligo C. 2009. Determination of the soil organic carbon, nitrogen, available phosphorus and the combined aboveground plant materials in the semi-arid Mbulu District, Tanzania. *African Journal of Ecology*, 47(3): 352–359.
Samuel Tuffa. 2017. Estimating grass productivity under different clipping frequencies and rainfall amount: Implications for rangeland responses to climate change. PhD Diss, University of Hohenheim.
Sánchez-Jardón L, Acosta B, del Pozo A, et al. 2010. Grassland productivity and diversity on a tree cover gradient in Nothofagus pumilio in NW Patagonia. *Agriculture*, *Ecosystems & Environment*, 137(1–2): 213–218.
Siraj K, Abdella G. 2018. Effects of bush encroachment on plant composition, diversity and carbon stock in Borana rangelands, Southern Ethiopia. *International Journal of Biodiversity and Conservation*, 10(5): 230–245.
Takele D, Amanu T, Eba B. 2014. Feed resources, feeding system and feed marketing for dairy production in the lowland and mid-highland agro-ecologies of Borana Zone, Ethiopia. *International Journal of Innovation and Applied Studies*, 7(3): 1025–1033
Tamrat A B, Stein R M. 2015. Assessing the effects of woody plant traits on understory herbaceous cover in a semiarid rangeland. *Environmental Management*, 56(1): 165–175.
Teshome A, Abule E, Lisanework N. 2012. Evaluation of woody vegetation in the rangeland of Southeast Ethiopia. *International Research Journal of Agriculture Science and Soil Science*, 2(3): 113–126.

植被覆盖、放牧和季节对牧草种类组成和生物量的影响：以埃塞俄比亚南部 Yabello 牧场为例

Yeneayehu FENETAHUN[1]，徐新文[2]，尤　源[2]，王永东[2]

1. 中国科学院大学，北京 100049；
2. 中国科学院新疆生态与地理研究所，沙漠与绿洲生态国家重点实验室，乌鲁木齐 830011

摘　要：Yabello 牧场是埃塞俄比亚博拉纳的一个半干旱地区的牧场，目前面临着草场退化的严重挑战。植被覆盖的变化、过度放牧和季节性变化极大地影响了 Yabello 牧场的牧草组成和生物量。本文评估了植被覆盖、放牧和季节对 Yabello 牧场的牧草组成和生物量的影响。首先采用 1 m × 1 m 的随机样方进行实验，根据植被覆盖类型和放牧变化选择样点，并对季节影响进行评估。使用 SAS 统计软件和 Microsoft Excel 分析牧草组成、牧草高度和质量数据。本研究总共记录了 26 种草种，其中 *Chloris roxburghiana*, *Chrysopogon aucheri* 和 *Chrysopogon aucheri* 草种均表现出最高的平均单种覆盖高度和生物量产量。因此，建议将这些草种用于研究区域退化草地的恢复。研究结果还表明，植被覆盖类型、放牧和季节变化是决定牧草种类组成、牧草高度和生物量产量的关键因素。最后，研究结论还认为控制灌木丛植被并平衡放牧水平的可持续管理对于该地区的可持续牧草生产和生物多样性保护至关重要。

关键词：Yabello 牧场；物种组成；生物量；放牧；牧草高度；雨季；旱季