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Vegetation structure changes in arid and semi-arid rangelands in Iran

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Abstract

In Iran, rangeland ecosystems constitute the main part of renewable natural resources which have an important role in providing livestock ration. Rangeland management under different ecological conditions is not yet fully understood. Studying and understanding the interrelationships of the components of rangeland ecosystems are of the most important tools to adopt appropriate administrative measures in rangelands. This study has been conducted in two semi-steppe and steppe regions. Steppe sites and semi-steppe ones are located in Markazi and Isfahan provinces, respectively. Canopy cover, production, plant composition, range condition and trend were recorded for both range groups. Results showed that among the studied regions and various species, there is a meaningful difference. Studying the plant composition of steppe and semi-steppe rangelands with regard to the palatability of existing species demonstrated that in semi-steppe rangelands and steppe rangelands, the species of class I and III constituted the composition, respectively. Comparing the data given by the canopy cover measurements indicated that total canopy cover of annuals and perennials in the range sites having better weather or management was higher as compared with other sites. Results show that there is a meaningful difference between the production rates of steppe and semi-steppe sites as production of semi-steppe sites (235 kg ha^{-1}) is higher than steppe ones (129 kg ha-*1*). Range condition and range trend in semi steppe rangelands was better than steppe rangelands. At the end weather and management were two important indicator in range condition.

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Introduction

In Iran, rangeland ecosystems constitute the main part of renewable natural resources which play an important role in providing livestock ration. Yet, rangeland management under different ecological conditions is not fully understood. Studying and understanding the interrelationships of the components of rangeland ecosystems (especially livestock and plant species) are of the most important tools to adopt appropriate administrative measures in rangelands (Zarekia *et al*, 2013). Vegetation growth has been found as the direct outcome of rainfall. Its growth pattern fluctuates with the increase or decrease of rainfall (Spano *et al*, 1999).

Rainy seasons play an important role in regulating the growth pattern and the harvest time of vegetation (Omotosho, 1992). Several studies have demonstrated the relationship between the weather and climatic fluctuations and forage yield (Hien, 2006; Bets *et al*, 2006 and Ehsani *et al*, 2007). Weather variables, especially precipitation in the arid and semiarid ecosystems are considered as the principal environmental factors influencing the plant growth (George *et al*, 1989). Composition, function and productivity of rangeland ecosystems are largely driven by the yearly fluctuations in the abiotic drivers, primarily precipitation. However, some other factors such as high grazing have impacts on the ecosystem (Fynn and O'Connor, 2000, Sullivan and Rohed, 2002).

Weather variations most frequently dictate the stocking rate adjustments. Drought, floods, late spring or early fall frost, hail and very cold or very hot temperatures may decrease the forage production or delay the plant growth. Raid forage growth and high yields are often encouraged by abundant soil moisture timely rains, warm springs and moderate summer temperatures. Over grazing or adverse weather conditions may reduce desirable plant vigor. Indicators of good plant vigor are new abundant tillers or rhizomes, rapid re-growth and an appropriate amount of plant material remaining unused at the end of the season.

When vigor is low, the reduced stocking rate can encourage the renewal of plant health. The dominant influence of climatic changes on rangeland growth is expected to be the changes in the amount of rainfall (Crimp *et al.,* 2002). Furthermore, changes in the distribution of rainfall may reduce the effectiveness of rainfall through the increased within seasons (as fewer project variations, more intense rainfall events) from year to year (more frequent droughts). In warmer climates, the increased heat stress and the increased evaporative demand would likely have negative effects on pastures.

Willey *et al.* (1992) found a linear model to estimate forage production from the annual rainfall in Nigeria. Fall and winter precipitation, winter temperature and winter dry period patterns have strong impacts on peck standing crop (George et.al., 1989). In particular, both the size and timing of rain events are strong drivers of ecological processes (Zeppel *et al.*, 2008). As a result, responses to the changes in the distribution of precipitation over time are likely to differ from those to individual drought events (Luo *et al.*, 2011). While the effects of individual droughts have been extensively studied (Breshears *et al.*, 2009), the effects of altered timing of precipitation on plants remain largely unknown (Volder *et al.*, 2013). In addition to direct effects on plant growth and mortality rates, the altered timing of precipitation may have significant effects on local climatic conditions (Zeppel *et al.*, 2014). In steppe and semi-steppe rangelands, the evidences of changes in plant species composition are observed during different times in two semi-steppe and steppe regions to investigate the effects of two important indicators in range condition.

Materials and methods

Sites description

Steppe rangelands

Studied areas are located in 60 km of northeastern Saveh in Markazi province, Iran, between 50° 36′ to 50° 45′ eastern longitude and 35°24′ and 35° 32′ northern latitude.

According to the long-term statistics of synoptic station in Saveh, the mean annual precipitation and mean annual temperature are 200 mm and 19 °C, respectively. The climate of the area based on Domarten classification is cold dry desert. The mean height is 1325 m above sea level and the soil texture is sandy clay loam. Study sites include:

Steppe rangelands

Kachalu Rangeland: The site is located in 65km in the east of the city. The mean height of the area is1125 m above sea level and the mean annual precipitation is about152 mm. Vegetation type in the area is *Stipa barbata-Artemisia sieberi* and it can be accounted as a winter rangeland.

Nemati Rangeland: The site is a part of winter rangeland and for six months per year, it is grazed as rest-rotational with moderate grazing intensity. *Artemisia sieberi–Salsola laricina* is the main plant species in this rangeland. Mid May is the time of livestock entering and the time of exiting is early November.

Khoshkrud Rangelands: The site is located in 56 km of northeastern Saveh. The mean height of area is 1405 m above sea level and the mean annual precipitation is about 190 mm. Based on Domarten classification, the climate is dry desert. Vegetation type in this area is *Noaea mucronata-Hulthemia persica* and it can be accounted as a winter rangeland.

Semi-steppe rangelands

Vardasht Rangeland: This site is located in Semirom Sefli around Isfahan province, Iran, between 51° 39´ longitude and 31° 36´ latitude. The mean height of the area is 2503 m above sea level. The mean precipitation is 491 mm. The dominant vegetation type is *Scariola orientalis-Bromus tomentellus*. Soil texture is sandy clay and it has a granular structure.

Pashmakan Rangeland: This site is located in SemiromOlia in Isfahan province, Iran with 51° 30´ in eastern latitude and 31° 23´ northern longitude. The mean height of the area is 2900 m above sea level and the mean precipitation is 681 mm. The dominant vegetation type is *Astragalus susianus-Bromus tomentellus*. The soil texture is sandy clay loam. The amount of lime in the underground part is high but it is not a limiting factor.

Akhcheh Rangeland: This site is located in Feridounshahr 50° 1´ eastern longitude and 33° 2´ northern latitude. The mean height is 2800 m above sea level and the mean precipitation is 624 mm. The dominant vegetation type is *Scariola orientalis-Cousinia cylindracea* and it is among the low-grade rangeland.

Methodology

To study various vegetation factors in each range Management plan, a reference area was selected. In the next step, sampling was carried out by a randomized systematic method in the reference areas. In the steppe rangelands, 60 plots (2 m×2 m) were established along four transects with the length of 400 m and 100 m intervals. But in semi- steppe rangelands a total of 40 plots (1 m×2 m) were established along four transects of 200 m length with 20 m intervals. Canopy cover, density, production, plant composition, height of the species, range condition, range trend were measured. Data on vegetation/canopy cover was obtained using the quadrat estimation methods (Hanley, 1978). The plant density was measured by counting the number of individuals of a species in a plot (Coulloudon *et al.*, 1999). The plant production was measured by the clipping and weighting method for 25% of randomly selected plots. The production was also estimated for the other plots by a regression equation between canopy cover and production (kg ha^{-1}) (Arzani and King, 1992). It was estimated only for used plant by livestock.

Statistical analyses of the experimental data were performed using the SAS 9.1 software. All reported results are the means of five replicates and deviations were calculated as the standard error of the mean (SEM).

The statistical processing was mainly conducted by analysis of variance (after testing for homogeneity of variance and confirming a normal distribution). Duncan test post hoc analysis was performed to define which specific mean pairs were significantly different. A probability of 0.05 or lower was considered as significant.

Results

Changes of vegetation canopy cover in steppe and semi-steppe rangelands

The vegetation cover measured in the plots for the semi-steppe rangelands (Vardasht, Pashmakan and Akhcheh) is presented in Table 1.

Table 1. Changes of vegetation canopy cover in semi-steppe site.

Palatability Category	Species	Canopy Cover (%)			
		Vardasht	Pashmakan	Akhche	P
I	*Bromus tomentellus*	4.05±0.6a	0.47ab 3.45±	1.67±0.19b	**
II	*Stipa barbata*	0.1a 0.76±	0.1a 0.73±	0.05a 0.1±	NS
I	*Festuca ovina*	0.21a0.8±	0±0b	0±0b	**
I	*Agropyron elongatum*	0±0b	0.1a 0.5±	0±0b	**
I	*Agropyron trichophorum*	0±0b	0.24a 1.63±	0/850.11ab ±	**
II	*Poa bulbosa*	0/850.28a ±	0±0b	0±0b	**
II	*Noaea mucronata*	1/360.14a ±	0.13b 0.16±	0.23±0.06b	**
II	*Scariola orientalis*	3/930.81a ±	0.25b 0.9±	1.38±0.22b	**
III	*Astragalus fragilis*	0.86a 3.9±	0.04b 0.03±	0.71±0.31b	**
III	*Astragalus susianus*	0/630.29ab ±	0.91a 1.55±	0±0b	**
III	*Astragalus adsendens*	0c0 ±	1.25a 7.63±	1.31±0.7b	**
III	*Astragalus verus*	0±0b	0.11±0.1b	6.28±1.02a	**
II	*Astragalus podolobus*	0±0a	0.24a 0.41 ±	0±0a	NS
III	*Andrachne rotundifolia*	0±0b	0±0b	0.73±0.32a	**
III	*Acantholimon* sp.	0±0a	0±0a	0.25±0.11a	NS
II	*Stachys inflata*	0.1a 0.31±	0±0a	0±0a	NS
III	*Cousinia*	0/360.16b ±	0.37ab 0.95±	1.21±0.19a	*
III	*Euphorbia* sp.	0±0a	0.05a 021±	0.19±0.13a	NS
III	*Erynjium* sp.	0±0b	0.1a 0.6±	0±0b	**
II	*Phlomis persica*	0±0a	0.25a 0.55±	0±0a	NS
	Annuals	4/040.75a ±	1.17a 4.2±	5.24±0.98a	NS
	Litter	3/360.82a ±	1.29a 5.5±	3.63±0.23a	NS
	Stone and pebbles	12/032.04b ±	1.19bc 7.58	36.26a	**
	Bare soil	59.04	50.7	30.56	**

Significant: **P<0.01,*P<0.05 and NS: No Significant.

The plants with less than 0.1% canopy cover were removed from the Table. The results showed significant differences among the studied areas (P< 0.05). It was mainly observed for dominant plant species of the studied areas., Canopy cover of the some plant species like *A. podolobus, Acantholimon* sp., *S. inflata, S. barbata* and *P. persica* showed no significant differences among the studied sites (P>0.05). But *B. tomentellus* in Vardasht site (4.05 %) had a higher canopy cover than the other areas (P<0.001) and *A. trichophorum* in Pashmakan site (1.63 %) had higher canopy cover than the other sites.

Based on the data related to the canopy cover of annuals in Akhcheh had the highest percent (5.24%); no significant difference was observed between the desired sites whereas the highest litter estimated as 5.5% was attributed to Pashmakan site.

The highest and lowest stone and pebbles given as 36.26 and 7.58% might be related to Akhcheh and Pashmakan sites, respectively (Table 1).

Results pertaining to the changes of canopy cover with respect to the species in steppe rangelands (Nemati, Khoshkerood and Kachaloo) have been presented in Table 2.

Results showed that among the studied sites and various plant species, there was significant difference.

According to Table 2, such species as *S. laricina*, *A. sieberi*, *S. hohenackeriana* and *P. sinaica* were of the highest canopy cover in Nemati site and *S. laricina* had the highest canopy cover calculated as 5.8% as compared to the above-mentioned species.

Table 2. Changes of vegetation canopy cover in steppe site.

Palatability Category	Species	Canopy Cover (%)			
		Nemati	Khoshkrud	Kachalu	P
II	*Salsola laricina*	5.8±0.58a	0±0b	0.005b	**
II	*Artemisia sieberi*	6.22±1.1a	0.59±0.1c	2.9±0.5b	**
III	*Acanthophyllum mmmicrocephalum*	0.01a	0.6±0.13a	0.11±0.1	NS
II	*Noaea mucronata*	0.14a	0.6±0.13a	0.1±0.06	NS
III	*Astragalus gossypinus*	0.06a	0.36±0.35a	0±0a	NS
III	*Andrachne rotundifolia*	0.01a	0±0a	0.09±0.	NS
II	*Scariola orientalis*	0.06b	0.7±0.24a	0.02±0.	**
II	*Denderostellera lessertii*	0.08a	0.4±0.19a	0.02±0a	NS
II	*Stachys inflata*	0.15±0.1a	0.36±0.15a	0±0a	NS
III	*Cousinia cylindracea*	0.16b	1.05±0.37a	0.1±0.19	**
III	*Acantholimon* sp.	0.1±0.05a	0±0a	0.24±0.1	NS
III	*Echinops ritrodes*	0±0b	0.36±0.1a	0±0b	**
III	*Hulthemia persica*	0±0b	16.99±2.25a	0±0b	**
II	*Stipa hohenackeriana*	1.4±0.39a	0.75±0.1b	0.07±0.	**
II	*Poa sinaica*	0.12a	0±0b	0.02±0b	**
III	*Carex stenophylla*	0.56	0.6	0	**
	Annuals	0.75a	1.76±0.23c	4.29±0.5	**
	Litter	1.32ab	9.15±1.99a	4.23±0.5	**
	Stone and pebbles	2.54ab	7.69±2.89b	38.3±2.9	**
	Bare soil	38.91	58.16	47.24	**

Significant: **p<0.01, *p<0.05 and NS: No Significant.

These species are classified as class II. Also, among the studied sites, there was no significant difference regarding the canopy cover between the species including *Noaea mucronata, Denderostellera lessertii, Acanthophyllum microcephalum, Stachys inflate*and *Acantholimon* sp. Table 2 indicates that in Khoshkerood site, the highest canopy coverwas related to *Hulthemia persica*. This species and *Noaea mucronat*a with the canopy cover computed as 70% were the dominant plant species in the site.

In this site, the second highest canopy cover was given to *C. cylindracea*. The species were put in the class III of palatability. In Kachaloo site, *A. sieberi* had the highest cover (3%). Based on data concerning the litter percent in the desired sites, it can be seen that the highest and lowest canopy cover given as 9.15 and 4.23% can be attributed to Khoshkrood and Kachaloo sites, respectively. Comparing the annuals, Nemati site had the highest canopy cover percent estimated as 9.03%.

Canopy cover of classes I, II and III in steppe and semi-steppe rangelands

Studying the plant composition of steppe and semi-steppe rangelands with regard to the palatability of existing species demonstrated that in semi-steppe rangelands, the plant species of class I constituted the composition and in steppe rangelands, the plant species of class I may not be found. Considering semi-steppe sites, species with the palatability of class I had the highest and lowest canopy cover in Pashmakan and Akhcheh sites, respectively. Though, the first and second highest canopy cover of class III plant species can be seen in Pashmakan and Akhcheh sites, respectively.

Regarding steppe rangelands, Nemati and Kachaloo sites had the highest canopy cover of class II species. In Kachaloo site, canopy cover was almost equal for the plant species of classes II and III (Fig. 1).

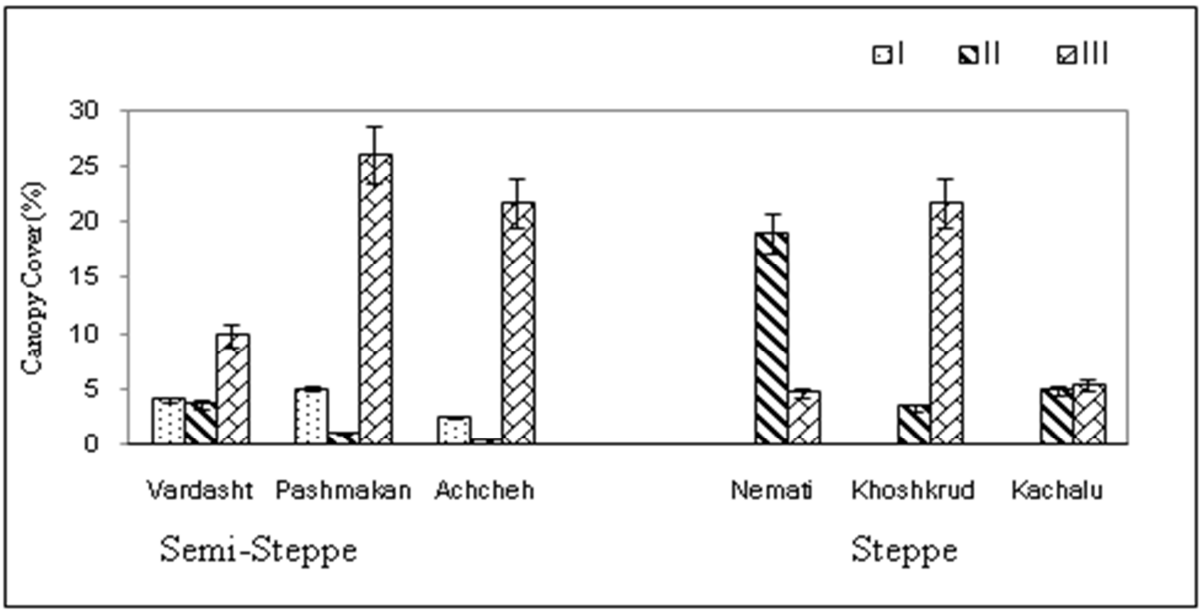

Fig. 1. Mean canopy coverage (%) of class I, class II, and class III in study sites. Error bars represents standard error of the mean.

Total canopy cover of steppe and semi-steppe sites

Comparing the data given by the canopy cover measurements indicated that total canopy cover of annuals and perennials in semi-steppe sites of Vardasht, Pashmakan and Akhcheh were given as 17.51, 32.03 and 24.58%, respectively. The highest canopy cover was attributed to Pashmakan. In steppe sites of Nemati, Khoshkerood and Kachaloo, total canopy covers were estimated as 24.25, 25.02 and 10.23%, respectively while Nematisite had no significant differences with Khoshkerood site (Fig. 2).

Plant species production with palatability classification in steppe and semi-steppe rangelands

Investigating the plant species production in steppe and semi-steppe sites with palatability classification showed that in steppe rangelands, plant species of class I could not be found and total regional production in three sites of Nemati, Khoshkerood and Kachaloo involves the plant species of classes II and III (Fig. 1).

In semi-steppe rangelands, plant species of class I were seen in the vegetation composition. The highest and lowest amounts of class I plant species were seen in Pashmakan and Akhcheh sites, respectively. The highest and lowest production of plant species of class II were found in Vardasht and Akhcheh sites, respectively. Considering steppe rangelands, Nemati and Khoshkerood sites had the highest and lowest class II production. Khoshkerood and Kachaloo sites had the highest and lowest class III production.

Results showed that total production of annuals and perennials in semi-steppe sites of Vardasht, Pashmakan and Akhcheh were given as 232.99, 331.81 and 137.5 kg ha^{-1}, respectively. The highest and lowest production was attributed to Pashmakan and Akhcheh sites, respectively. In steppe sites of Nemati, Khoshkerood and Kachaloo, total plant production were estimated as 270.83, 71.95 and 66.42 kg ha^{-1} respectively, while Nemati site had significant difference with Khoshkerood and Kachaloo sites (Fig. 3).

Range condition and trend

In semi-steppe rangelandsall of sites had moderate condition and stable trend but in steppe rangelands, Khoshkrud and Kachalu had poor condition and negative trend while Nemati had moderate condition and positive trend.

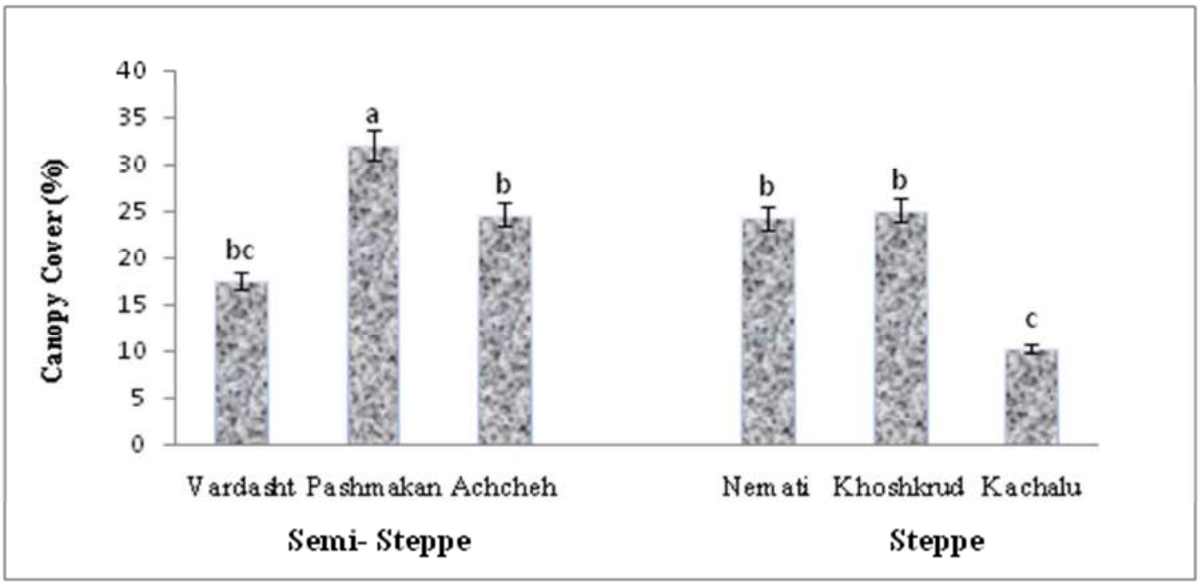

Fig. 2. Mean canopy cover (%) of total perennials in steppe and semi-steppesites. Error bars represents standard error of the mean.

Discussion

Weather fluctuations and appropriate or inappropriate range management are introduced as the elements which can considerably affect the plant composition, vegetation variations and forage production over time. Regarding the results given for semi-steppe regions with the mean precipitation of 500-600 mm, canopy cover, plant species of class I and forage production with dominant species including perennial grasses are higher as compared to the steppe sites.

But in steppe rangelands, plant speciesof class I, canopy cover and forage production were lower than semi-steppe ones so that plants of class II are put in the plant composition of these sites.

In total, the produced forage in the most sites is mainly consisted of species of class II (Arzani *et al.*, 2005).

Studying the plant composition, canopy cover and forage production of steppe rangelands indicated the fragility of these range ecosystems' species which are more likely to be destroyed due to incorrect utilization. It has been confirmed by Arzani *et al.* (1998) with respect to Poshtkooh rangelands in Yazd. Conner and Rox (1995) reported that changes in plant community of Caro shrubberies in South Africa during 1949-1971 were resulted from the precipitation variations and the effects of livestock grazing in long term periods are critical.

On the other hand, in Nemati site as a steppe rangeland having the rainfall of 200 mm, canopy cover percent of class II and forage production rate are higher than the adjacent sites and Akhcheh in semi-steppe rangelands. Here, management is able to be regarded as an important element in increasing the canopy cover percent and forage production rate.

In the mentioned site, a better situation has been created for a variety of species through implementing a suitable grazing program (delayed periodic grazing system with the moderate intensity) so that the species of *S. laricina* has had a lot of flowering shoots which will be of the accepted yield in addition to the increased plant height while reviving this species in the desired site. Yates *et al.* (2000) referred to the soil organic carbon, nitrogen sources, soil permeability, temperature and suitable moisture content in the rangelands with low grazing intensity as the reasons for improving the plant regeneration. These reasons led to the suitable regeneration of bush species and range index involving *Salsola* and sagebrush.

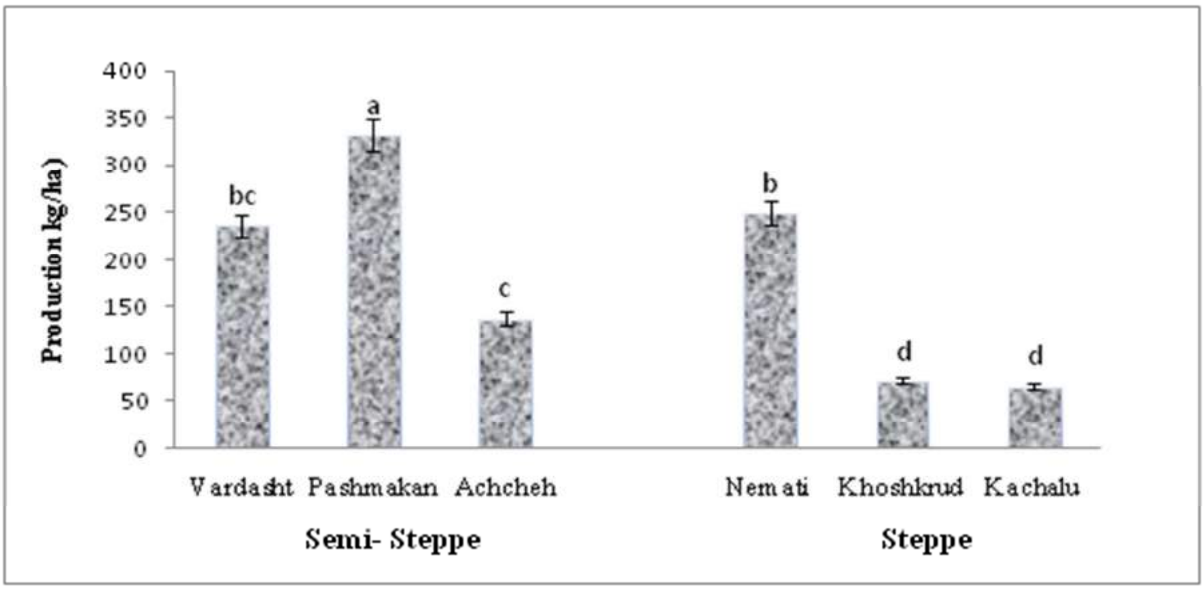

Fig. 3. Mean plant production (Kg ha^{-1}). Error bars represents standard error of the mean.

Research results demonstrated that the intensified grazing without a comprehensive program in steppe sites (Khoshkerood and Kachaloo) resulted in the changes of plant composition and vegetation structure so that over grazing led to the decreased palatable species and the increased woody and unpalatable ones. Direct impacts of livestock grazing involve the plant consumption and stepping that can destroy the composition and structure of plant communities. Over grazing may be regarded as one of the most important range destructive factors while having negative effects on rangelands through increasing the unpalatable species (O'Conner *et al.*, 2001; Tongway, 2003). The study in semi-arid areas of Sudan indicated that continuous intense grazing causing vegetation changes such as the replacement of palatable grasses by less palatable plant species. The most dominant herbaceous species in the area were *Zornia glochidiata* and *Sida cordofolia* both are less preferred by animals, indicating intensive selective grazing and hence disturbance in rangeland (Abdelrahim and Abdalla, 2015).

Through changing the structure of plant communities, grazing is able to influence the competitive interactions of plants. Also, grazing relatively decreases the use of existing resources in the community while reducing the canopy cover percent, density and number of seedlings. Changes in species composition affect the quality, quantity and variety of plant production in a specific ecosystem as the pattern of energy flow is altered (Amiri and Arzani, 2009). They explained that grazing process depending on its frequency and intensity may reduce the vegetation and litter percent and alter the species structure. Destruction of plant vegetation caused by the herbivores is more than the variations of vegetation which can occur due to the seasonal fluctuations affected by climatic factors. Grazing intensity is able to increase the woody plants followed by the prevented growth of grasses in the rangelands (Tessema *et al.*, 2011). Range condition and range trend in semi steppe rangelands were better than steppe rangelands. Thus, weather and management were two important indicators in range condition.

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