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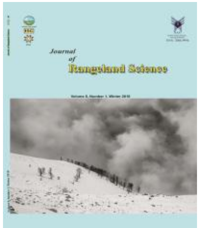

Research and Full Length Article:

The Effect of Stocking Rate on Carbon Sequestration of *Prangos ferulacea* (Case Study: Gorgou Summer Rangelands, Kohgiluyeh and Boyer-Ahmad Province, Iran)

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Abstract. Rangelands are the most important ecosystem for carbon sequestration. Knowledge of plant response to grazing is one of important requirements for rangeland management. Stocking rate is one of main factors in destruction of the vegetation cover in rangeland ecosystems. Livestock grazing has the potential to substantially alter carbon storage in grassland ecosystem. This study examined the effects of grazing management on carbon sequestrations of *Prangos ferulacea* as dominant species in summer rangeland of Gorgou summer rangelands in Kohgiluyeh and Boyer-Ahmad Province, Iran. Four sites with high, moderate, low and enclosure grazing intensity with stocking rates of 3.4, 2.9, 1.4 and 0 (Animal Unit/Ha), respectively were chosen for the study. Samples were collected from 50 plots of $1.5 \times 1m^2$ in May 2014. In each site, the carbon content of aboveground and root biomass and litter were measured by ash method and soil carbon by Walcky-Black method. Results showed that stocking rate had a significant effect on carbon sequestration of *P. ferulacea* for above and underground biomass, litter and soil carbon. For all of traits, the lowest carbon sequestration was obtained in high grazing intensity that had a significant difference with other sites. Enclosure and high grazing with average values of 42 and 6 (kg/ha) had the highest and lowest carbon sequestration amounts by *P. ferulacea*, respectively. Stocking rate of 2.9 (au/ha) was introduced as the suitable grazing intensity to protect the ability of carbon sequestration by *P. ferulacea*.

Key words: Stocking rate, Carbon sequestration, *Prangos ferulacea*

Introduction

Nowadays, the excessive exploitation of rangelands declined quality and quantity of these evaluable resources. Intensive grazing is one of the main factors in destruction of the vegetation in rangeland ecosystems (Dregne *et al.,* 1991). Khosravi Moshizi *et al.* (2015) studied the carbon sequestration in a semiarid region and found that rangeland types had a significant effect on carbon sequestration. Knowing the reaction of plants to grazing is an essential requirement for grazing management. Rangelands are the most important ecosystem for carbon sequestration; although the amount of carbon sequestration per unit area is low, they have a great potential for carbon sequestration due to their high area (Schuman *et al.*, 2002). Rangeland storage is more than 30% of soil carbon; in general, a high amount of above-ground carbon is stored in trees, bushes and grasses (Neely *et al.*, 2009). The grazing may affect their carbon stocks (Ingram *et al.,* 2008). Several studies have been found that grazing affected soil carbon increasingly (Reeder *et al.,* 2004; Schuman *et al.*, 2002) and decreasingly (Andrew and Gregory, 2006; Derner and Schuman, 2007; Yong- Zhong *et al.*, 2005). Declined vegetation cover reduced soil organic carbon stocks while increasing the soil erosion (Tanentzap and Coomez, 2011). In the steppe grasslands of northern China, the effects of grazing intensity on carbon storage were evaluated and concluded that grazing intensity linearly decreased the carbon content in 0-10 and 10-30 cm of soil profile as low grazing was significantly different from high grazing at the depth of 0-10 cm. They believed that carbon sequestration decreased while increasing the grazing intensity (He *et al.*, 2011). Asghar Nezhad *et al.* (2013) studied the effects of grazing and enclosure on carbon sequestration in *Puccinellia distans* of Gomishan rangelands, Gorgan province, Iran and found that carbon sequestration in above ground biomass was higher than underground-biomass, the amount of carbon storage in soil of enclosure was higher than the grazed rangeland and enclosure can be an effective factor to increase carbon sequestration in soil and plants. In examining the effect of grazing on carbon sequestration in semi-arid rangelands of Sisab Bojnoord, Naghipur *et al.* (2013) concluded that the total average of carbon sequestration was 38.71, 28.17 and 24.43 (ton/ha), respectively in reference, key and critical areas. In addition, they found that the increase in grazing ultimately reduced the amount of carbon sequestration in soil and plant biomass. Tamartash *et al.* (2011) also investigated the effect of enclosure on carbon sequestration in shrub lands of Semnan province, Iran. Their results showed that there was a significant difference among carbon sequestration of different organs of *Artemisia aucheri* and litter in both enclosure and non-enclosure sites. Due to the positive impact of enclosure on carbon sequestration and vegetation healthy, they recommended it for grazing management. Also, the results of Diyanati Tilaki *et al.* (2010) showed that enclosure caused an increase in carbon sequestration about 5 (T/ha) and soil was the main storage of organic carbon in rangeland. Despite the above, results of Gao *et al.* (2007) showed that soil organic carbon at 0-30 cm depth and total plant components' carbon were increased from light grazing to moderate and heavy grazing. The results indicated that higher grazing intensity had a potential to increase carbon pool of soil-plant system in the alpine meadow. In Tibetan alpine meadows, both negative (Wu *et al.*, 2009, 2010) and positive effects (Gao *et al.*, 2007) of livestock grazing on soil organic carbon were reported.

Prangos ferulacea species is a perennial herb, Monopode with the height of 50-150cm belonging to Apiaceae family and grows at the elevation of 1600-3700 m above sea level in Tehran, Mazandaran, Markazi, Kurdistan, Semnan, Isfahan, Fars, Khorasan, Hamedan, Lorestan and Kohgiluyeh and Boyer-Ahmad province, Iran (Davis, 1972). Its annual growth period is about 3 months and starts its growing of living cells of old roots in early April. *P. ferulacea* has high forage, and pharmaceutical and industrial values and it comprises as dominant species in pure community of summer rangelands (Gheytori, 1995). In terms of nutritional value, it is very nutritious and valuable because of its high protein excessive exploitation. The leaves of *P. ferulacea* like other species of the family Apiaceae usually are green and do not trap willingly for animals but flowers either in the form of dry or fresh are highly regarded for the consumption of livestock (Moghimi, 2005). The dry, yellow and red leaves of this plant may be consumed in livestock (Moghimi, 2005). In most areas of Iran, this plant like other forage species for livestock feeding is used while in Kohgiluyeh and Boyer-Ahmad province in addition to manual harvesting, grazing is in the final stage of development. Determining the appropriate stocking rate for the reservation of species condition and maintaining its performance in the field of carbon sequestration in rangeland are necessary. The purpose of the research is to evaluate the effect of different stocking rates on carbon sequestration of *Prangos ferulacea*.

Materials and Methods

Study area

The study was conducted in rangelands of Gorgoue located about 15km from Yasouj, Kohgiluyeh and Boyer Ahmad province at 51˚35′ to 51˚45′ eastern longitude and 30˚20′ to 30˚30′ northern latitude. It covers an area of 2340 ha and elevation between 2300-2476 m above sea level. According to Synoptic station data (1991-2001), the mean rainfall is 846.9 mm with an irregular distribution and the mean temperature is 15.1°C with respect to the climatic conditions as moderate towards cold based on Domarten method.

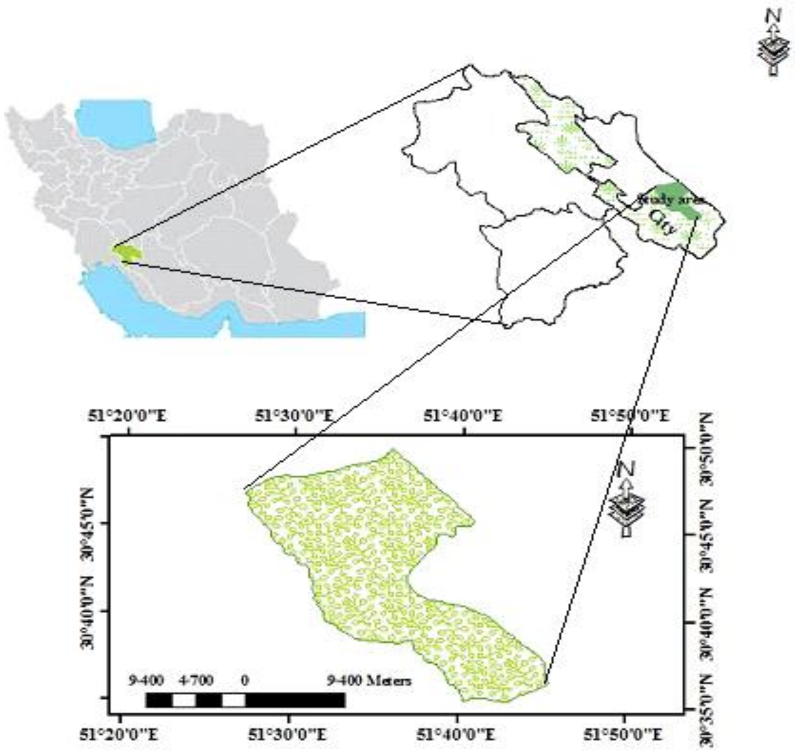

Fig 1. Position of study area

Grazing experiment and sampling method

Four adjacent experimental sites with a different grazing intensity were selected. Low grazing intensity was 1.4 Au/ha and vegetation was dominated by *Heteranthelium piliferum,* and *Poa bulbosa*. Moderate grazing intensity was 2.9 Au/ha and vegetation was dominated by *Heteranthelium piliferum* and *Poa bulbosa*. Heavy grazing intensity was 3.4 Au/ha and vegetation was dominated by *Papaver rhoeas* and *Bellevalia sp.* and enclosure was dominated by *Heteranthelium piliferum* and *Bromus tomentellus*. In each site, 50 quadrates of 1.5×1 m^2 size were plotted along 5 transects in May 2014. Double Weight Sampling was used to estimate root weight (Reid *et al.*, 1990). In this method, the estimated weight was corrected by he clipped root method based on the regression equation. 10 plants of *P. ferulacea* on each transect were harvested and their roots were gathered by excavating to determine the root/shoot ratio (Tamartash *et al.,* 2011). In each plot, all litter of *P. ferulacea* was collected from the soil surface and soil samples were taken from both depths of 0-15 and 15-50 cm (Mac Dicken, 1997).

Laboratory analyses

Litter, and above and underground biomass samples were dried, weighted and grinded; then, they were analyzed for organic carbon content using Ash method. Soil samples intended for carbon analyses were passed through a 2mm screen to remove plant crowns, visible roots and root fragments. Samples were air-dried and grinded; then, they were analyzed for total carbon by the Walkley-Black dichromate oxidation procedure (Nelson and Sommers, 1982); then, the amount of soil organic carbon was estimated by Equation 1. Bulk density also was assessed on separate soil cores (Blake and Hartge, 1986).

$$Cc = \%OC \times Bd \times D \quad (1)$$

Where:

Cc= Amount of Organic Carbon (kg/ha)

OC%= Organic Carbon

Bd= Bulk Density (g/cm^3)

D= Soil Depth (m)

All data were tested for normality using Kolmogorov-Smirnov test. The data on the carbon sequestration were analyzed by ANOVA and means comparisons were done using Duncan test. To test the estimated and clipped root biomass, a regression equation was used. All analyses were performed using SPSS19 software.

Results

The results of regression equation between the estimated and clipped root weights of *P. ferulacea* were presented in Table 1. There was a high coefficient of determination for the estimation of clipped root weight.

Table 1. Regression equation for the estimated (Y) and clipped root weights (X) of *Prangos ferulacea*

Grazing intensity	Regression equation	R^2
Enclosure	Y=1.713X+68.21	0.80
Heavy grazing	Y=0.894X+35.15	0.89
Moderate grazing	Y=2.217X+34.69	0.92
Low grazing	Y=1.25 X +38.17	0.94

Result of analysis of variance showed that grazing intensity has a significant effect on carbon sequestration in aboveground and root biomass, litter and soil in the depth of 0-15 and 15-50 cm and total carbon sequestration (Table 2).

Table 2. Analysis variance of carbon sequestration in aboveground and root biomass, litter and soil

Source of variations	F values #					
	Above ground biomass carbon	Root carbon	Litter carbon	Soil (upper) layer carbon	Soil (lower) layer carbon	Total carbon
Grazing intensity	2.909*	4.576**	5.476**	6.108**	7.197**	6.601**

* and **= Significant at 5% and 1% probability levels, respectively
#=DF of between and within groups were 3 and 196, respectively

Results of means comparison of grazing intensity for carbon of aboveground biomass indicated that the enclosure, low grazing and moderate grazing sites with average values of 0.255, 0.279 and 0.200 kg/h had a higher carbon sequestration and were ranked in the class a. In contrast, the heavy grazing site with average values of 0.003 kg/h had the lowest carbon sequestration and a significant difference with other sites (P<0.05) (Fig. 2a).

For carbon sequestration of plant root biomass, the low grazing and enclosure area with average values of 0.038 and 0.039 kg/h, respectively had a higher carbon production; there were no significant differences between them and both of them were ranked in the class a. The moderate and heavy grazing intensity areas with averages of 0.022 and 0.003 kg/h had a lower carbon sequestration and were ranked in the classes b and c, respectively (Fig. 2b).

In terms of litter carbon, the heavy grazing area with average value of 0.01 gr/h had the lowest carbon and showed significant differences with other treatments (P<0.05). The enclosure, moderate and low grazing areas with average values of 3, 2 and 1 gr/h, respectively had higher carbon sequestration and there were no significant differences between them (Fig. 2c).

In terms of soil carbon (0-15 cm), the heavy grazing area with average value of 4.3 kg/h had the lowest carbon sequestration and showed significant differences with other treatments (P<0.05). The enclosure, low and moderate grazing areas with average values of 25.8, 20, 17.9 kg/h, respectively had a higher carbon sequestration and there were no significant differences between them (Fig. 2d).

In terms of lower soil layer carbon (15-50 cm), the heavy grazing area with average value of 1.6 Kg/ha had the lowest carbon sequestration and showed significant differences with other treatments (P<0.05). In contrast, the enclosure, low and moderate grazing areas with average values of 16.2, 14.4 and 12, respectively had higher carbon sequestration and there were no significant differences between them (Fig. 2e).

In terms of soil total carbon in four areas, the enclosure, low grazing, moderate grazing and heavy grazing with average values of 42.29, 28.71, 23.02 and 5.9, respectively had significant differences with each other (P<0.05) and were ranked in different groups (Fig. 2f).

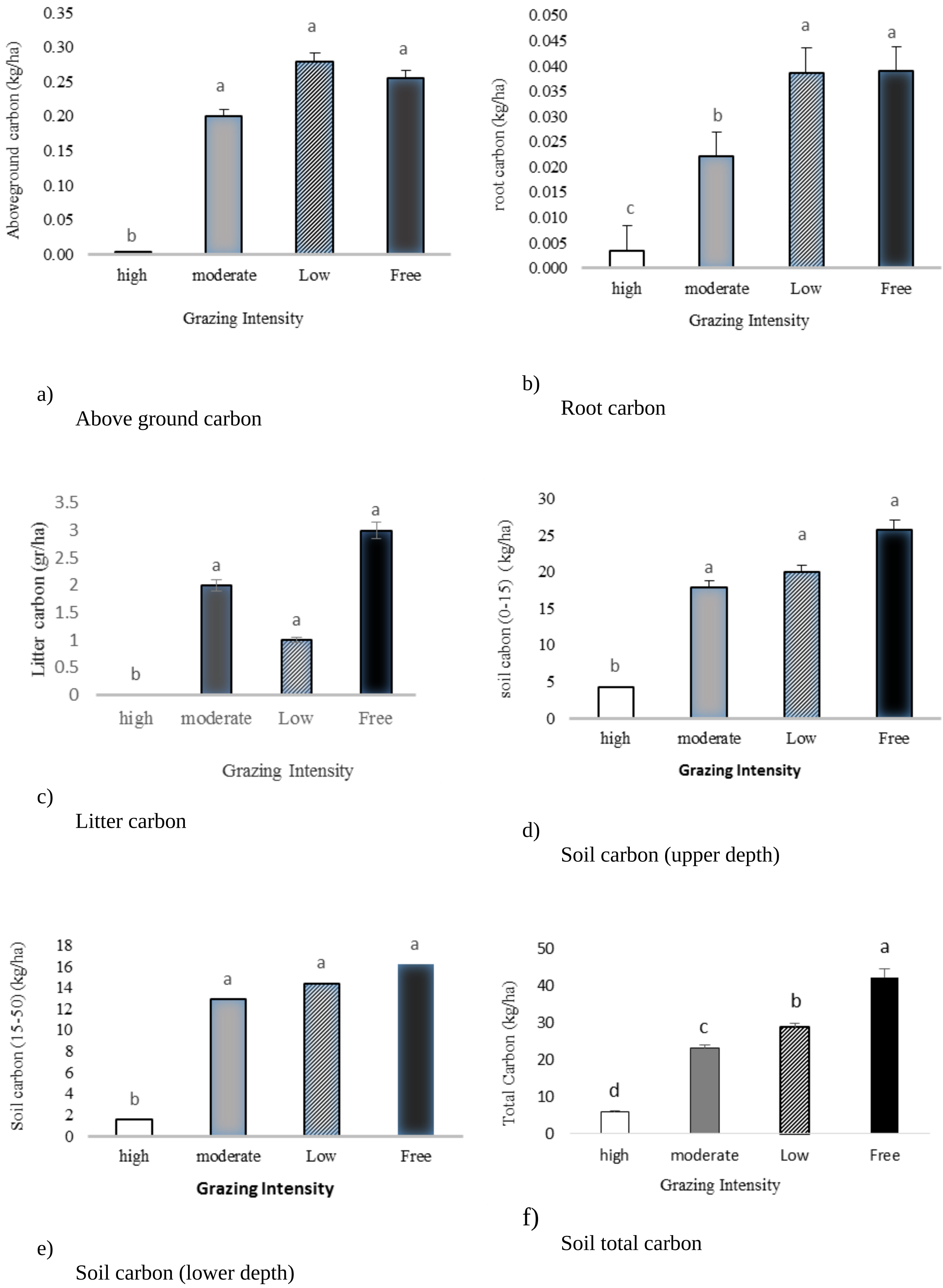

Fig. 2. Average carbon sequestration of aboveground, root, litter, soil (0-15), soil (15-50) and total carbon sequestration in heavy, moderate, low grazing and enclosure

Discussion and Conclusion

The results showed that different stocking rates influenced the amount of total carbon sequestration of *P. ferulacea* variously. So, the highest amount of carbon sequestration was rank in the enclosure area as low grazing, moderate grazing and heavy grazing areas. This result was expected since grazing decreases the plant vegetation coverage and biomass. This result was similar to the result obtained by He *et al.* (2011) that concluded that the amount of carbon sequestration was reduced through increasing the grazing in grasslands and 4.9 livestock (Au/ha) was introduced as suitable grazing intensity for maintaining the ability of carbon sequestration in the grasslands of China. Naghipour *et al.* (2013) also reported that higher and lower amounts of carbon sequestration of range plants were belonged to reference area and critical region, respectively. Livestock grazing changes carbon sequestration in soil conditions by changing habitat conditions such as changing the plant density and canopy cover, changing competition power of species, and affecting biomass of plants per unit area (Foroozeh, 2010). The results of Niknahad Gharmakher *et al.* (2015) revealed that the response of plant and soil carbon storage to the exclosure in Gomishan rangelands was positive and there was a significant difference between exclosure and grazing areas for the stored carbon of plant biomass and soil. In general, the enclosure can be known as a good way to increase carbon sequestration ability of *P. ferulacea.* Foroozeh and MirzaAli (2006) studied the impact of enclosure pasture on shoot carbon sequestration of dominant biomass and soil in Gomishan in Golestan Province, Iran and showed that protection of area had increased carbon sequestration of dominant shrub species significantly; though, some studies reported the reduction of carbon sequestration in plant species with grazing management practices. Differences in research reports may be due to differences in climate, soil characteristics, environmental conditions, and plant community composition (Han *et al.*, 2008). For example, Foroozeh *et al.* (2009) showed that enclosure reduced carbon sequestration of *Halocnemum strobilaceum* by reducing the amount of soil salinity. Most of above and underground biomass of the *P. ferulacea* was affected by grazing intensity. In this area, grazing increases the amount of above and underground biomass of *P. ferulacea* by reducing the density of palatable species such as *Bromus tomentellus* indirectly and then increasing the competitiveness of *P. ferulacea.* Ojima *et al.* (1995) studied carbon sequestration of species in enclosure, and high and alternative grazing sites and found that carbon sequestration of species in the alternative grazing was higher than other sites. This was due to the positive effects of grazing on the species growth. Results reported by Ingram *et al.* (2008) also showed that carbon sequestration in enclosure, low and high grazing sites respectively were 10.8, 13.8 and 10.9 (T/ha) so that the observed carbon sequestration of low grazing intensity was higher than enclosure. Soil carbon storage was the main source of *P. ferulacea* in the enclosure, low, medium and high grazing with 97, 96, 97 and 99% of the total carbon storage, respectively. According to research, among three components of the ecosystem (soil, plants and litter), the litter had the lowest and soil had the highest C stock (Naseri *et al.*, 2016). Also, Naghipour *et al.* (2013) concluded that soil carbon was higher than 90% of total carbon sequestration in semi-arid regions of Northern Khorasan province, Iran. In present study, carbon storage declined in the heavily grazed area. Several reasons are proposed to explain the decreases in soil carbon as: a) biomass removal by heavy grazing decreases the input of OM from aboveground and roots (Johnson and Matchett, 2001), b) grazing may decrease productivity due to decreases in soil filterability and nutrient availability (Savadogo *et al.,* 2007) and c) disruption of the structure of soil aggregates and surface crust by livestock trampling enhances soil OM decomposition and renders soil susceptible to water and wind erosion (Neff *et al.,* 2005). Aradottir *et al.* (2000) introduced the soil as main reservoir of organic carbon in rangeland ecosystems. Studies of Wei *et al.* (2011) indicated an increase in soil carbon stocks and nitrogen soil of grasslands under grazing in mountain areas. Tantezap and Coomes (2011) believe that the grazing caused the organic matter decomposition in soil by increasing respiration of living organisms in soil. Therefore, soil restoration, vegetation and also suitable grazing have a positive effect on carbon stocks (Ratjen, 2013).

Suitable grazing management can be known as a good strategy to increase the ability of carbon sequestration in rangeland ecosystems (Schuman *et al.,* 2002; Naghipour *et al.,* 2009; Ojima *et al.,* 1995). The results of present study also showed that grazing in low and moderate sites had no significant effect on carbon sequestration of *P. ferulacea* but with increasing the number of livestock in the heavy grazing site, carbon sequestration was reduced (He *et al.,* 2011). So, 2.9 (Au/ha) grazing intensity can be suitable to preserve the ability of carbon sequestration of *P. ferulacea* in the study area.

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چکیده. مراتع یکی از مهمترین اکوسیستم‌ها برای ترسیب کربن به حساب می‌آیند. آگاهی از واکنش گیاه نسبت به چرای دام یکی از ملزومات مدیریت مراتع طبیعی است. شدت چرا یکی از فاکتورهای اصلی در تخریب گیاهان در اکوسیستم‌های مرتعی می‌باشد. چرای دام‌های اهلی پتانسیل قابل توجهی را جهت تغییر ذخیره کربن اکوسیتم‌های مرتعی دارند. تحقیق حاضر به بررسی اثر مدیریت چرا و قرق در ترسیب کربن جاشیر (*Prangos ferulacea*)، می‌پردازد که یکی ازگونه‌های خوشخوراک و مهم موجود در مراتع ییلاقی استان کهگیلویه و بویراحمد می‌باشد. این مطالعه در چهار منطقه با شدت‌های چرایی سنگین، متوسط، سبک و قرق به ترتیب با نرخ دامگذاری ۳/۴، ۲/۹، ۱/۴ و بدون واحد دامی در هکتار انجام شد. کربن بیوماس هوایی و زیرزمینی و لاشبرگ گیاه جاشیر به وسیله روش احتراق و کربن خاک به وسیله روش والکی بلاک اندازه‌گیری شد. نمونه‌ها از ۵۰ پلات ۱/۵ × ۱ مترمربعی در خرداد ماه ۱۳۹۳ جمع‌آوری شدند. نتایج نشان داد که ترسیب کربن اندام هوایی و ریشه جاشیر در اثر افزایش فشار چرا به طور معنی‌داری کاهش یافته است. لاشبرگ و کربن خاک در چرای سنگین تفاوت معنی‌داری با منطقه قرق، متوسط و سبک داشت. منطقه قرق و چرای سنگین به ترتیب با ۴۲ و ۶ کیلوگرم بر هکتار بیشترین و کمترین میزان ترسیب کربن گونه جاشیر را به خود اختصاص دادند. نرخ دامگذاری ۲/۹ واحد دامی در هکتار را نیز می‌توان به عنوان شدت چرایی مناسب برای حفاظت از قدرت ترسیب کربن گونه جاشیر معرفی شد.

کلمات کلیدی: شدت چرا، ترسیب کربن، جاشیر (*Prangos ferulacea*)، کهگیلویه و بویراحمد