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How planting density and grazing intensity affect the above- and below-ground carbon pools in a dryland ecosystem?

Badehian Z.[1]*, Azarnivand H.[2]

1- Department of Forestry, Faculty of Agriculture and Natural Resources, Lorestan University, Korramabad, Iran
2- Department of Range Management, Faculty of Natural Resources, University of Tehran, Karaj, Iran

Corresponding author's E-mail: Badehian.z@lu.ac.ir

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ABSTRACT

Climate change is known as one of the most important environmental challenges. Sequestration of carbon in terrestrial ecosystems is a low-cost option that may be available in the near-term to mitigate increasing atmospheric CO_2 concentrations, while providing additional benefits. In this study, we estimated the effects of planting density and grazing intensity on the potential of *Atriplex canescens* for carbon sequestration in a rangeland in Qazvin Province, Iran. The experimental design consisted of a randomized block design, including two planting densities (2 × 2m and 4 × 4m) and four grazing intensity treatments simulated by different plant pruning intensities. We observed no significant difference between the rate (%) of organic carbon in the treatments of density, grazing intensity, and their interaction in the 0-30cm and 30-80cm soil layers. Between the treatments of height pruning, control (no pruning) and light grazing, had the highest total biomass and total carbon. The total biomass carbon content of 2370 kg.m^{-2} in the 2×2m treatment was about twice as much that of 4x4m treatment. These findings can be useful in rangeland management plans.

Key words: Carbon sequestration, Biomass, *Atriplex canescens*, Grazing intensity, Planting density.

INTRODUCTION

In recent years, arid and semi-arid regions, hereafter referred to as drylands, have been regarded as potential carbon (C) sinks (Lal 2002; Ardo & Olsson 2003; Grunzweig *et al*. 2003). Drylands cover 45% of the global land surface and, despite their low soil organic carbon (SOC) concentration; encompass 16% of the global soil C pool (Ojima *et al*. 1993; Jobbagy & Jackson 2000).

In particular, total dryland SOC reserves comprise 27% of the global SOC reserves (Ma 2005). The fact that many of the dryland soils have been degraded, may means that they are currently far from saturated with carbon and their potential to sequester C may therefore be very high (Farage *et al*. 2003). Desertification, is affecting more than two-thirds of drylands, has likely caused carbon losses of 20–30 Pg globally (Ojima *et al*. 1995; Lal *et al*. 1999). Restoring these systems through the adoption of appropriate land use practices could yield significant ecosystem carbon gains. Afforestation, as a carbon sequestration option, is eligible under the Clean Development Mechanism (CDM) of the Kyoto Protocol. This provides an opportunity to combine the efforts of preventing land degradation and reducing emissions of CO_2 gases (FAO 2000). About 15% of Iranian lands and 7-10% of global lands are affected by salinity (Khosravifard *et al*. 2006). Establishment and production of crops on these lands is often difficult, however, they have suitable potential for supporting the growth of forage species resistant to drought and salinity. Plants of the genus *Atriplex* are considered xero-halophytes for their ability to grow in dry and saline areas, which allows them to succeed in many disturbed environments (Osmond *et al*. 1980). This characteristic makes *Atriplex* spp. as a suitable plants for reclamation of highly disturbed areas (Booth 1985). *Atriplex* can be used in a wider range of applications including forage production, mitigation of desertification in arid areas, restoration of rangelands, preventing erosion and protecting wildlife, fuel usage, and due to its tolerance to salinity and harsh environmental conditions, also enhancing plant growth and carbon sequestration in arid, saline lands (Mousavi Aghdam 1986). Some studies suggested that among the saline rangeland plants, *Atriplex* (a perennial forb of the family Amaranthaceae) is considered to play a significant role on carbon sequestration in saline rangelands (Mahdavi *et al*. 2011; Vazirian *et al*. 2013; Asgari *et al*. 2013). However, different strategies of plant cultivation can influence the characteristics of the plants and their environment, for instance, differences in plant spacing might affect the development of plant biomass (Zhao *et al*. 2012). Moreover, SOC is subject to relatively rapid changes. In rangeland soils, the management system influences these changes.

Therefore, these soils play a crucial role on the climate change mitigation. Findings of a study, indicated that management practices significantly influence SOC-S in the Los Pedroches Valley (Parras-Alcántara *et al.* 2015). It is therefore imperative to gain a better understanding of planting strategy effects on growth and carbon sequestration in these arid rangelands.

Grazing is a primary use of rangelands, and well-managed grazing may stimulate above ground growth, root growth, and tillering (Derner *et al*. 1997), as well as increase in the rate of nutrient cycling, aboveground plant decomposition and annual shoot turnover for some plants (Schuman *et al*. 1999; Reeder & Schuman, 2002). In rangelands animal grazing can indirectly influence soil carbon storage and improper grazing management has been reported to lead to increased carbon emissions into the atmosphere from grassland ecosystems (Ingram *et al*. 2008).

Poor grazing practices may also lead to degraded rangelands, desertification (Huang *et al.* 2007), and additional release of C into the atmosphere. Levels of SOC content in the soil may depend on the intensity of grazing, and previous researches indicated that the effects of grazing on SOC may be site-specific. For instance, Han *et al*. (2008) studied the effects of grazing intensity on C in soils and plants in Inner Mongolia and suggested that increased grazing pressure would limit grassland productivity, but stimulate nutrient cycling, thereby resulting in a decrease in SOC. Furthermore, Ingram *et al*. (2008) compared SOC in a northern mixed-grass prairie under contrasting grazing regimes and found that SOC was significantly lower in the upper 30 cm in heavily grazed and ungrazed treatments compared to that in the lightly grazed one. Aradottir *et al*. (2000) showed that the SOC is greater than the C content of root biomass, whereas the carbon content of aboveground biomass in long term shows higher carbon storage than roots. Few related studies have been done on the effect of density in carbon sequestration. For instance, biomass production and carbon storage in short-rotation poplar plantations over 10 years were evaluated at the Hanyuan Forestry Experimental Farm, Baoying County, China. Treatments applied in a split-plot design included four planting densities (1111, 833, 625 and 500 stems.ha^{-1}) and three poplar clones (NL-80351, I-69 and I-72) The results suggest that biomass production and carbon storage potential were highest for planting densities of 1111 and 833 stems ha_1 grown over 5- and 6-year cutting cycles, respectively (Fang *et al.* 2007).

Thus, a good understanding of the effects of contrasting grazing regimes on soil and plant carbon pools is needed to support rangeland management decisions. The aims of this study were to investigate i) the effect of plant density and ii) grazing intensity on soil and plant carbon pools, and iii) to determine the contribution of different compartments (soil, above- and belowground biomass) to the total ecosystem carbon pool in an *Atriplex canescens* (Pursh) Nutt. dryland ecosystem.

MATERIALS AND METHODS

Study area

The study area (N49°35′54″, W35° 56′52″) is located in the Nowdehak rangeland, Takestan, Qazvin Province, Iran.

The average annual precipitation is 250-300 mm and the annual evaporation is about 2400 mm. The elevation of the study area is 1330 to 1750 m above sea level.

Soil texture is sandy-loamy, the effective soil depth is about 1 meter and soil acidity is 8 (Gholami *et al*. 2012).

This rangeland site covers about 76 ha, of which 2 ha is covered by *Atriplex canescens*. The plant cover of the study area includes: *Hulthemia persica* Bornm. *Astragalus schitosas, Iris songarica, Cousinia belangeri, Onosmabul botrichum, Lactuca orientalis, Fumaria asepala, Senecio Vernalis, Astragalus curvirostris, Choris peratenella, Crepis sancta, Acantho Limon* sp. and *Atriplex canescens. Atriplex canescens* is native to the western and mid-western United States. Fourwing saltbush is most common in early succession areas such as disturbed sites and active sand dunes. It is also found in more mature successions dominated by sagebrush—*Artemisia tridentata* and shadscale. *Atriplex canescens* is a perennial, dioecious, shrub (McArthur & Freeman 1982). Normally, it grows from 30 to 200 cm in height and 30 to 450 cm in crown diameter. The roots of this species extend from 5 to 15 m in alluvial sediments (Springfield 1970). This species tolerates salinity, but it is not limited to the saline soils (Hanteh 1990). The longevity of this species is variable and in natural soils, their longevity is about 10 years (Plummer 1977). *Atriplex canescens* is calcicole (Sanadgol 1994) is a C4 evergreen species (Senock *et al*. 1991). Seedling of *Atriplex canescens* were planted in the field in 1994 and sampling was conducted in 2008.

Methods

Experimental design

In this study, 72 individual shrubs of *Atriplex canescens*, were cultivated 14 years ago, in a split-plot designed blocks with completely randomized replications.

The main treatment included shrub cultivation at two levels of 2 x 2 m and 4 x 4 m to represent the effect of plant density.

Each treatment included four sub-treatment plots with different levels of pruning to represent the effect of grazing intensity classified in (i) no pruning (without grazing or control), (ii) complete pruning (heavy grazing), (iii) pruning up to 20 cm height (moderate grazing) and (iv) pruning up to 40 cm height (light grazing), were applied.

Each block totalized 8 treatments (in total 24 treatments with three replications). Three samples of *Atiplex canescens* were randomly chosen and surveyed from each plot accounting for 48 samples.

Measured variables

The height of the shrub and canopy cover was measured in each of the studied plots. Above- and belowground biomass of the *Atriplex canescens* was determined by destructive clipping. The freshly cut samples were weighted and grinded and 500 g of each sample was transferred to the lab for estimating dry weight and organic carbon percentage (McDicken 1997).

The ignition method was used, to convert biomass into organic carbon (at 375°C for 24 h) (Frozeh *et al*. 2008).

The mineral soil was sampled in two layers; (i) 0-30 cm (main root layer) and (ii) 30 -80 cm (maximum rooting depth). One sample of 500 g of each treatment was delivered to the lab according to the MacDicken (1997) method.

SOC was determined by burning it in electric furnaces. To calculate the SOC, the Walkley-Black method was used (Jafari Haghighi 2003; Nosetto *et al*. 2006).

Statistical analysis

All data were tested by ANOVA and the Duncan test was applied to determine

significant differences between treatments ($P < 0.05$).
Statistical packages used for data analysis were SPSS® v15 and Excel® 2007.

RESULTS AND DISCUSSION

Planting density and grazing intensity effects on soil organic carbon and bulk density

According to ANOVA results (Table 1), no significant difference occurred between organic carbon (%) in the treatments of density, grazing intensity, and their interaction in the 0-30 cm and 30-80 cm layers ($P < 0.05$). The mean comparison using the Duncan test in two layers showed no differences among the treatments ($P < 0.05$), however, the amount of organic carbon (%) in the first layer was higher than in the second layer for both treatments of density and grazing intensity (Fig. 1). By increase in grazing intensities from light to moderate and heavy, soil organic carbon seriously decreased from 62528 to 60822 and to 51188, respectively.

Table 1. ANOVA results for density and grazing intensity effects on soil organic carbon (%) in 0-30 cm and 30-80cm depth layers.

Source of variation		0-30cm			30-80cm		
	df	SS	MS	F test	SS	MS	F test
Density	1	0.001	0.001	0.305^{ns}	0.009	0.009	3.931 ^{ns}
Grazing intensity	3	0.062	0.021	0.931^{ns}	0.011	0.004	1.374 ^{ns}
Interaction	3	0.038	0.012	0.632 ^{ns}	0.015	0.005	0.363 ^{ns}
Error	16	0 258	0.016		0.043	0.003	
Total	23	0.359			0.078		

SS: Sum Square; MS: Mean Square; ns: non-significant.

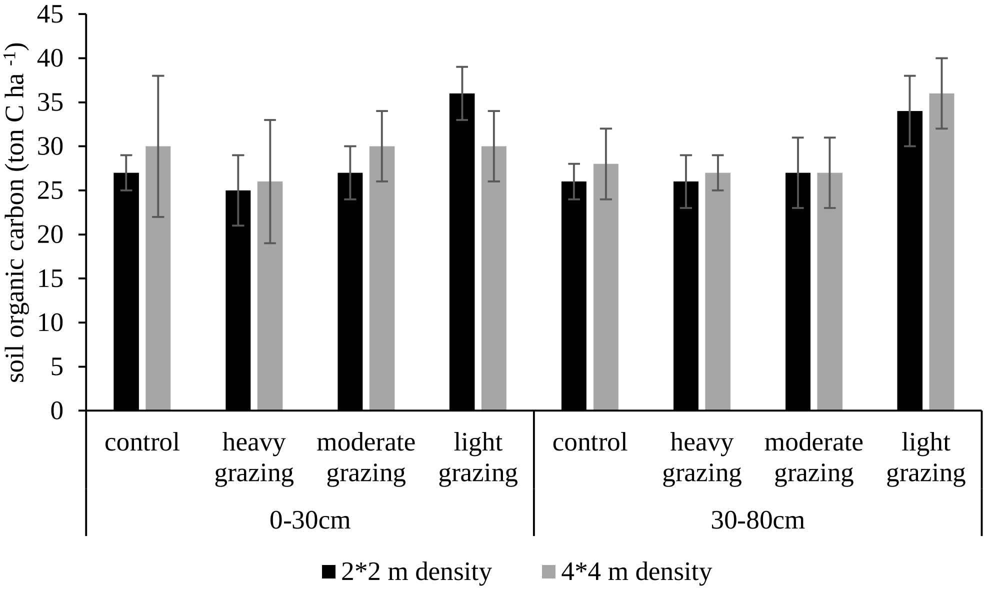


Fig 1. Comparison of the organic carbon (ton C ha^{-1}) in 0-30cm and 30-80cm depth with Duncan test ($P < 0.05$).

Results in Fig. 2 show that soil bulk density increased with each grazing intensity from light to heavy grazing, accordingly in the 0-30cm layer heavy grazing was higher value (2.05 $g.cm^{-3}$) and control treatment (no grazing) was lower values (1.82 $g.cm^{3}$) (Fig. 2).

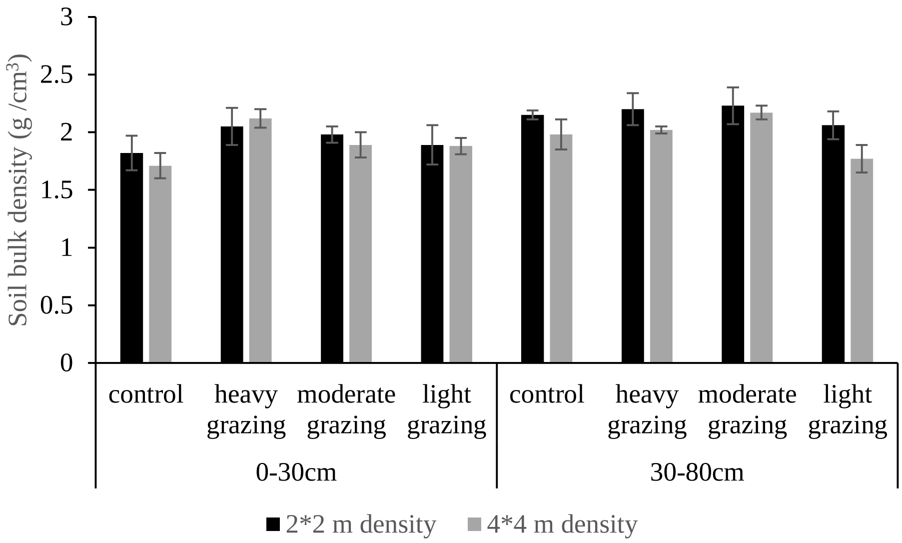


Fig 2. Comparison of the soil bulk density (g.cm^{-3}) in 0-30 cm and 30-80 cm depth using Duncan test ($P < 0.05$).

According to the results, SOC was not influenced by plant density or by the pruning treatments. Park *et al*. (2004) showed that the carbon storage in the soil is not affected by the clipping or the plant density of *Salix* spp.

In this study, SOC in the first layer of soil was higher than in the second layer which is in agreement with Rice (2000) who stated that there is an indirect relationship between the amount of SOC and soil depth in arid and semi-arid regions.

Our results were also consistent with Chen *et al*. (2012). Wang & Batkhishig (2014) stated that this could be due to of plant roots tend to be concentrated in the top humus (AO) Soil organic C both in 10-20 cm soil depth and in 20–30 cm soil depth was not significant between light grazing, medium grazing and high grazing treatments (Gao *et al.* 2007).

According to the results, due to heavy grazing, bulk density in the 0-30cm layer was higher than the other layers. While in the control treatment (no grazing), it had lower values. Zhou *et al*. (2010) stated that increased bulk densities, because of increased animal trampling, have been observed in different grazing animals in different grassland ecosystems. Our results were consistent with reports of Li *et al*. (2011) and Xu *et al*. (2014).

Planting density and grazing intensity effects on above- and belowground biomass and above- and belowground carbon biomass

Results in Table 2 show significant difference between above- and belowground biomass carbon (%) in the density treatments ($P < 0.01$). Density of 2 x 2 m with the average of 664 kg ha^{-1} resulted in a greater belowground carbon pool than in the 4 x 4 m treatment. For aboveground biomass, density of 2 x 2 m with the average of 1707 kg.ha^{-1} resulted in a greater carbon pool than the 745 kg.ha^{-1} in the 4 x 4 m density. Moreover, the grazing treatments and the interaction between the density and intensity did not significantly affect the belowground biomass carbon stock ($P < 0.05$), while a significant difference in aboveground layer was noted among the treatments of grazing intensity ($P < 0.05$). Biomass carbon stock in light grazing intensity treatment was higher (2355 kg.C.ha^{-1}) than that of the heavy grazing (581 C.kg.ha^{-1}).

Table 3 shows that there were significant differences in the average carbon content of total biomass between the treatments of density ($P < 0.01$) and between the treatments of grazing ($P < 0.05$). However, this difference is not significant for the interaction of density and grazing ($P < 0.05$).

For all grazing intensities, the density of 2 x 2 m resulted in significantly higher total biomass content than the 4 x 4 m density (shown in Fig. 3).

The highest carbon content of total biomass occurred in the light grazing treatment (3170 kg.ha^{-1}), while the lowest in the moderate treatment of pruning with 1729 Kg ha^{-1}.The results showed that in two mentioned density, aboveground biomass was higher than that of belowground. Aboveground biomass in heavy grazing intensity was lower (1332 kg ha^{-1}), than that of control and light grazing intensity, (5273 and 4450 kg ha^{-1} respectively) (Fig. 4).

Table 2. ANOVA results for density and grazing intensity effects on the carbon content of above- and belowground biomass.

Source of variation	belowground biomass				aboveground biomass		
	df	**SS**	**MS**	**F test**	**SS**	**MS**	**F test**
Density	1	916761	916761	14.652**	11101105	11101105	43.580**
grazing intensity	3	40819	13606	0.217 ns	4562644	1520881	5.971*
Interaction	3	282921	94307	1.507 ns	1834501	611500	2.401 ns
Error	40	2502776	62569		10189076	254727	
Total	47	3743277			27687326		

Square; MS: Mean Square; ns: non-significant; * and **: Significant at the 0.05, 0.01 probability levels, respectively.

Table 3. ANOVA results for density and grazing intensity effects on total biomass carbon.

Source of variation	df	SS	MS	F test
Density	1	18398178	18398178	35.307**
grazing intensity	3	5366738	1788913	3.433*
Interaction	3	3256321	1085440	2.083ns
Error	40	20843756	521094	
Total	47	47864993		

SS: Sum Square; MS: Mean Square; ns: non-significant; * and **: Significant at the 0.05, 0.01 probability levels, respectively.

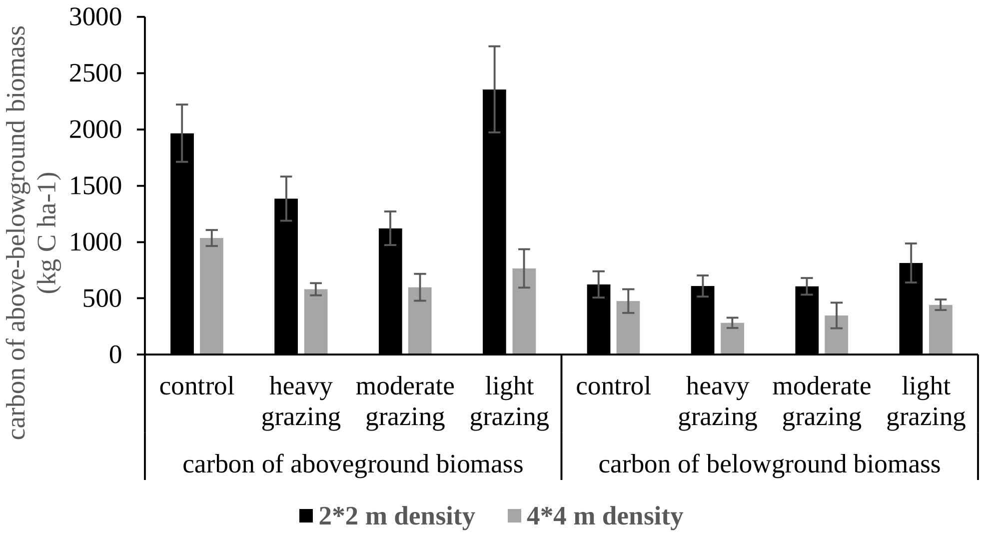


Fig. 3. Comparison of the carbon content (kg.ha^{-1}) in above- belowground biomass with Duncan test (P < 0.05).

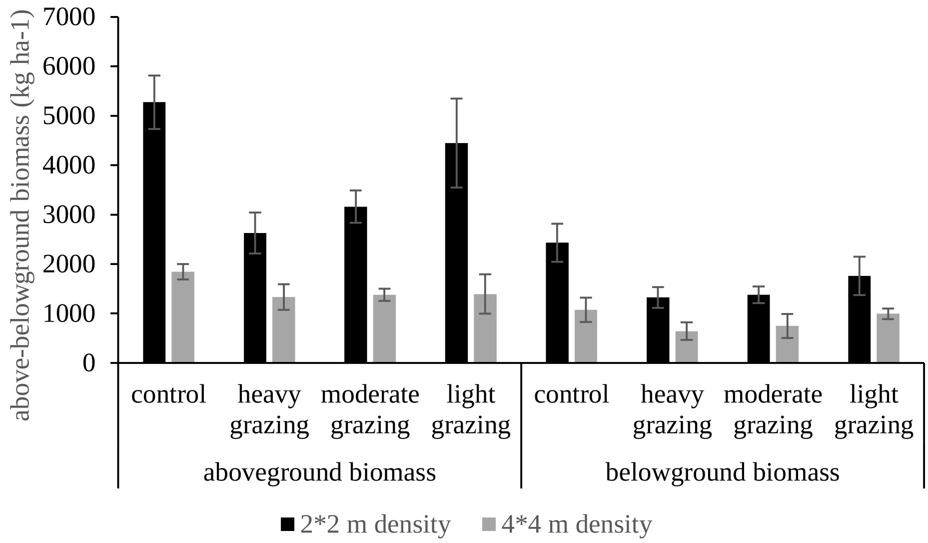


Fig 4. Comparison of the biomass (kg.ha^{-1}) in above- belowground biomass with Duncan test (P < 0.05).

The average height and volume of shrubs in the 4 x 4 m distance treatment was higher than 2 x 2 m. The height and volume of the shrubs will increase if the distances between plants increase. The biomass of the shrubs in the control was greater than among the grazing treatments, suggesting that grazing may reduce the height and volume of the shrubs. Thus protecting rangelands could enhance shrubs height and volume growth. Our study showed that the above- and belowground, significantly decreased with increased grazing intensity, which was consistent with other studies (Gao *et al*. 2009; Li *et al*. 2011). Since the carbon content was estimated as a fraction of the biomass, the results for carbon content are the same as the biomass volume. Our result was in agreement with the study of Fang *et al*. (2007) who reported that by decreasing the cultivation spacing, total biomass will be increased. It also was in agreement with the Frang *et al.* 2007 who found that biomass production and carbon storage potential were highest at the minimum spacing treatment. Our finding of greater C storage in aboveground biomass than in roots also in agreement with the studies of Aradottir *et al*. (2000); Luciuk *et al*. (2000); Abdi *et al*. (2008) and Xu *et al*. (2014). In further agreement with this observation, Mahdavi *et al*. (2011) reported that in *Atriplex lentiformis,* the C content in aboveground was higher than in belowground biomass. In contrast, other studies found that the C content in belowground was higher than in the aboveground biomass (Gao *et al*. 2007; Schuman *et al*. 2002). Our results showed that the C content in the above- and belowground biomass in the 2 x 2 m was higher than in the 4 x 4 m density. Fang *et al*. (2007) also studied the biomass production and carbon storage in *Populus* species and concluded that the C storage was higher in 3 × 3 m than in 3 × 4, 4 × 4 and 4 × 5 m densities. Park & Ohga (2004) concluded that biomass production of willow species was greater for a row spacing of 0.3 × 0.9 m in comparison with those of 0.3 × 0.3 and 0.6 × 1.1 m. Mahdavi *et al*. (2011) reported that higher carbon storage in *Artiplex lentiformis* was achieved by 2 × 2 m row spacing, in comparison with those of 4 × 4 m and 6 × 6 m.

Planting density and grazing intensity effects on total ecosystem carbon pools

Results of ANOVA on the averaged total ecosystem carbon pools in Table 4 show that there was no significant difference between treatments of density, grazing, and their interaction (P < 0.05).

The Duncan mean comparison test suggested that all treatments resulted in similar amounts of total ecosystem carbon pools (P < 0.05) (Table 5, Figs. 5 and 6).

Table 4. ANOVA results for density and grazing intensity effects on the total ecosystem carbon pool.

Source of variation	df	SS	MS	F test
Density	1	2572434	2572434	0.02 ns
grazing intensity	3	71803342	23934447	0.185 ns
Interaction	3	498106893	166035631	1.284 ns
Error	16	2069186510	129324157	
Total	23	2641669179		

SS: Sum Square; MS: Mean Square; ns: non-significant; ×× and ××××: Significant at the 0.05, 0.01 probability levels, respectively.

Table 5. Soil, above- and belowground biomass and total ecosystem carbon pools for the different planting density and grazing intensity treatments.

	Density									
	2 x 2m					4 x 4m				
Carbon pool	Control (non grazed)	Heavy grazing	Moderate grazing	Light grazing	Average	Control (non grazed)	Heavy grazing	Moderate Grazing	Light grazing	Average
Aboveground biomass (kg.ha^{-1})	5273 ± 899.90	2629 ± 327.75	3160 ± 415.11	4450 ± 541.77	3878 ± 352.33	2432 ± 386.83	1326 ± 210.12	1379 ± 165.56	1760 ± 389.96	1724 ± 836.36
Belowground biomass (kg.ha^{-1})	1845 ± 399.18	1332 ± 260.43	1377 ± 122.23	1393 ± 153.53	1487 ± 127.75	1077 ± 246.05	642 ± 105.98	748 ± 244.46	994 ± 178.3	875 ± 100.78
Soil carbon content in 0-30 cm (ton C.ha^{-1})	27 ± 2	25 ± 4	27 ± 3	36 ± 3	28 ± 2	30 ± 8	26 ± 5	30 ± 7	30 ± 4	29 ± 3
Soil carbon content in 0-80 cm (ton C.ha^{-1})	26 ± 2	26 ± 3	27 ± 4	34 ± 4	28 ± 2	28 ± 4	27 ± 4	27 ± 4	36 ± 2	30 ± 2
carbon of belowground biomass (kg C.ha^{-1})	624 ± 71.22	609 ± 55.09	607 ± 118.98	814. ± 171.20	664 ± 55.97	476 ± 104.45	442 ± 46.47	349 ± 113.70	282 ± 46.59	387 ± 44.58
carbon of aboveground biomass (kg C.ha^{-1})	1966 ± 254.26	1385 ± 194.98	1122 ± 149.64	2355 ± 382.50	1077 ± 157.75	1036 ± 155.80	581 ± 94.3 7	598 ± 73.56	766 ± 172.29	745 ± 71.84
total biomass carbon (kg C.ha^{-1})	2590 ± 323	1994 ± 222.54	1729 ± 66.22	3170 ± 549.76	2371 ± 205.21	1512 ± 259.34	1023 ± 169.31	947 ± 175.85	1048 ± 202.46	1133 ± 106.16
average total carbon sequestration (ton C.ha^{-1})	55 ± 5	53 ± 4	63 ± 2	66 ± 6	59 ± 2	60. ± 1	54 ± 5	58 ± 8	67 ± 7	60 ± 4

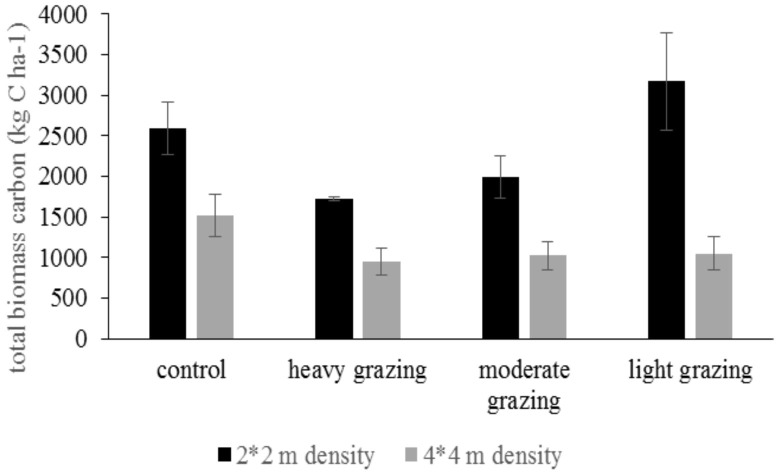
There were no significant differences ($P < 0.05$) between the total (plant and soil) carbon pools of the density and grazing. In this study, the proportion of SOC accounted for 96% of the total ecosystem carbon pool. Therefore, our results in combination with those from previous studies (Aradottir *et al*. 2000; Snorrason *et al*. 2002 and Abdi *et al*. (2008) suggest that soils are the most important C pool in this type of rangeland ecosystems. In the 2 x 2 m density treatment, total biomass and total carbon were twice as much as the density of 4 x 4 m. Among the treatments of height pruning, control (no pruning) and 40 cm height pruning (light grazing), had the highest total biomass and total carbon. In spite of the major difference between the both densities of 2 x 2 m and 4 x 4 m, the difference between their SOC and total carbon was not significant ($P < 0.05$). This can be due to gradual changes in soil carbon.

Turner *et al*. (1995) concluded that although the land use change causes rapid increase in plant carbon storage, the increase in soil carbon will be gradual. Derner & Schuman (2007) stated that light and moderate grazing in comparison with heavy grazing increase carbon sequestration. He *et al*. (2011) also reported that increase in grazing intensity will decrease the amount of carbon biomass.

Planned grazing increase yield and moderate grazing may enhance SOC as well as the potential of carbon sequestration (Conant *et al*. 2001). According to our results, we suggest that proper management of rangelands is necessary to increase the carbon sequestration in plants. In addition to the positive effect on carbon sequestration, the development of vegetation cover may also decrease the runoff and erosion, prevent the soil compaction and amend wildlife condition (Wang *et al*. 2008).

The majority of the carbon is, however stored in soils.

Therefore, any kind of biologic operation which increases the quality of the soils will likely increase the capability of these rangeland ecosystems to sequester carbon.



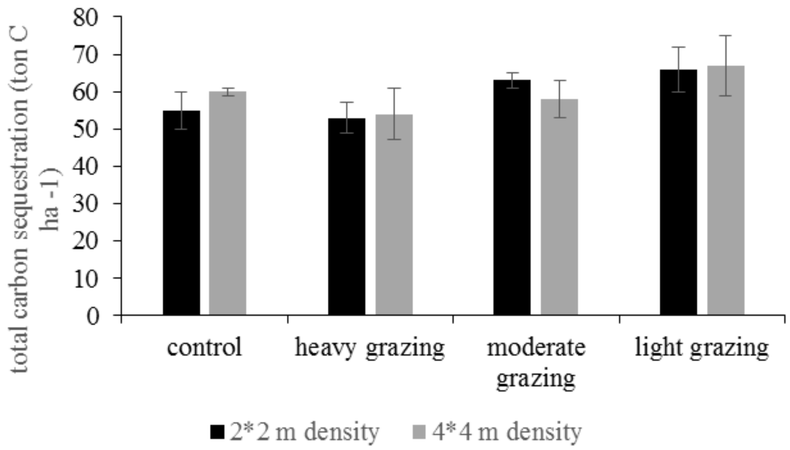


Fig. 6. Comparison of the total carbon sequestration (ton C.ha^{-1}) the two densities and 4 grazing intensities with Duncan test ($P < 0.05$).

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چگونه فاصله کاشت و شدت چرا بر میزان ذخیره کربن هوایی و زمینی اکوسیستم های خشکی تأثیر می‌گذارد؟

باده‌یان ض.[1*]، آذرنیوند ح.[2]

۱- گروه جنگلداری، دانشکده کشاورزی و منابع طبیعی، دانشگاه لرستان، ایران
۲- گروه مرتع آبخیرداری، دانشکده منابع طبیعی، دانشگاه تهران، کرج، ایران

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چکیده

تغییر اقلیم به عنوان یکی از مهمترین چالش‌های محیط زیستی شناخته شده است. ترسیب کربن در اکوسیستم‌های خشکی یک گزینه کم‌هزینه، در دسترس و کوتاه مدت است که ضمن کاهش تجمع فزاینده کربن اتمسفر، منافع دیگری را نیز به همراه دارد. در این مطالعه تأثیر تراکم کاشت و شدت چرا بر پتانسیل گوته آتریپلکس برای ترسیب کربن در مرتعی در استان قزوین- ایران مورد بررسی قرار می‌گیرد. طرح آزمایشی این بررسی یک بلوک تصادفی شامل دو تراکم کشت (۲×۲ متر و ۴×۴ متر)، و چهار شدت چرا است که با شدت‌های مختلف هرس کردن شبیه‌سازی شده است. بین میزان کربن آلی در تیمارهای تراکم، شدت چرا و برهمکنش بین آنها در لایه‌های ۰-۳۰ و ۳۰-۸۰ سانتی‌متری خاک مشاهده نشد. بین تیمارهای ارتفاع هرس، تیمار کنترل (بدون هرس) و هرس سبک نسبت به سایر تیمارها وضعیت مناسب‌تری به لحاظ بایومس کلی و کربن کل داشتند. میزان کربن کل در تیمار تراکم دو در دو ۲۳۷۰ کیلوگرم بر هکتار بوده که حدود دو برابر تیمار چهار در چهار بود. این یافته‌ها در طرحهای مدیریتی مراتع می‌تواند مورد استفاده قرار بگیرد.

* مولف مسئول