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Research Paper

The Effects of Rangeland Management Practice on Carbon Storage

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Abstract

Carbon cycle depends on the relationship between soil and plant in a rangeland ecosystem and management practices play an important role in carbon sequestration, but direct evidence is generally lacked. This study was carried out to assess the rangeland potentials for carbon storage and its sequestration in southern slopes of central Alborz rangeland, Iran. Exclosure and grazing effects on the rangeland carbon pools in soil and pasture plants were surveyed as two rangeland management practice. The data analysis was revealed that the carbon content on litter in exclosure significantly increased, by 48.5%. The carbon sequestration by aboveground biomass in exclosure was greater than that in grazing plot, on average by 17.5%. The rangeland management practice increased the root – soil carbon content ratio in the exclosure area and the main Carbon sequestration was recorded by the soil profile. This study also showed that the exclosure practice increased the biomass carbon content but there was a significant decrease in the soil carbon storage. From these results it can be concluded that the suitable rangeland management practice must be to graze up to the rangeland carrying capacity.

Keywords: rangeland management practice, carbon sequestration, soil carbon storage, grazing, exclosure.

Introduction

Climate change as a vital challenge in sustainable development causes to increase global warming and a negative effect on aquatic and terrestrial ecosystems. Global warming is recently exacerbated by greenhouse gases emission and its accumulation in the atmosphere. Carbon dioxide (CO_2) due to its significant effects on plant photosynthesis, organism breathing and climate change is one of the most effective greenhouse gases. The carbon cycle depends on the interaction between soil, water and plants in earth planet. Carbon cycle changes and CO_2 accumulation in the atmosphere cause to increase global warming (2). Carbon sequestration, the lost carbon replenishment in terrestrial ecosystems, is among the most important ecosystem services (4). About 30% of all CO_2 emission from fossil fuel burning and deforestation decrease by the terrestrial ecosystem removal (21). The deterioration of land-use or land-cover with draught conditions in semiarid regions can restrict the terrestrial carbon storage.

Rangeland management is a considerable challenge ground in animal productions for the increasing human population, ecosystem conservation, conserving or replenishing carbon stocks particularly in soil (Dean *et al.*, 2015). The review of the results from 115 studies containing over 300 data points conducted that carbon storage can be improved by sustainable management practices that among them fertilization (39% of studies) and improving grazing management (24%) can be the greatest effect (22). The rangelands have expanded in about half of the world and store more than 10% of biomass C and 10 to 30% of global SOC thereby there is a large potential to sink carbon in these land area (1). There is a positive significant interaction between SOC stocks and rangeland biomass (32) by mainly derived from plants residues including roots and leaves. It was indicated that the soil carbon can be enhanced by rangeland sustainable management practices such as soil conservation, protection and increasing soil organic matter (SOM) (9). The grazing as one of the effective factors on vegetation, soil and water conservation, desertification and SOM can be considered in carbon storage in rangelands. Optimization of the land-use, protection and grazing, is the most important effects on enhancement SOC in grassland of semiarid regions (11). It was showed that SOM and resulting carbon sequestration was differently affected in grazing with different stocking rates. Moderate and heavy stocking rates grazing increased SOC in the soil surface (0-30 cm) when the plants community composition were included the shortgrass (6). It was estimated that carbon sequestration rates were changed from 0.12 to 0.07 Mg C $ha^{-1}yr^{-1}$ for moderate and heavy stocking rates, respectively (7) Carbon uptake from the atmosphere by plants photosynthesis is arisen where biomass was decreased by grazing exclusion particularly overgrazing, thereby the quality and quantity of the biomass which is returned to the soil depended on grazing management and are decreased (3). Though some reports showed that protection management could increase carbon sequestration in rangeland (17). Despite of protecting and grazing effect, there are many factors such as soil texture, temperature, perspiration, plant community composition affect carbon storage in soils and rangelands.

Iran with 90×10^6 ha rangeland area has the great abilities to sequester carbon. In recent years, some studies have been conducted to find the rangeland capacities involved in carbon sequestration and the effective factors. However many questions remain largely unknown. Therefore this study focused on the affecting factors on soil carbon sequestration in central Alborz rangeland where the direct evidence is generally lacking.

Materials and method

Site description

This study was conducted in 50 hectare of Derazchal Fasham rangeland (320 ha) in Roodbar Ghasran area. It is located in south of Alborz mountain, Shemiranat county, Tehran city, Iran with longitude 51° 31′ to 51° 33′ E, latitude 35° 55′ to 35° 56′ N. That area is at 25 kilometer of northern site of Tehran city. The lowest and the highest height of the study area are from 1900 to 2500 m above sea level, respectively, with the main North Slope. The mean annual precipitation is 692.2 mm of which only 40% falls during November to April (dormant season). The average annual temperature is 8 with maximum and minimum monthly mean temperatures of 12.2 C and 3.7 in July and January, respectively, and a frost-free period ranging from 210 to 230 day per year. The study area climate is classified in semiarid and steppe climate based on Köppen–Geiger climate classification system (35).The study area is a part of Lar plateau and it was a lush place, known for its fine rangeland with ample water and abundant grass for the last centuries. But today, land-use practices involving the widespread overgrazing of rangelands and reduced rainfall have induced and exacerbated desertification in this landscape. The study site is an open and level natural rangeland that sustained slight degradation caused by heavy grazing by sheep, goats and cows from early 1990s. In this study, two adjacent parts of the site for sampling were selected as follows: exclosure rangeland (25 ha), Livestock had been excluded for 4 years at the time of and grazing rangeland. The dominant plant species included the perennial grasses *Astragalus subumbellatus* and *Bromus tomentellus* and classified in the fabaceae and poaceae families, respectively.

Plant and soil sampling

Two similar sites in terms of soil properties, topography and environmental features that differ only in rangeland management practice were selected. Four 50 meter transects in each site, two vertical transects and two transects in the direction to the main slope were established in a key area inside and outside the exclosure. Twenty five plots ($1m^2$) per transect were selected by random systematically method and in any plot, the number of plant individuals for each plant species was recorded and used to estimate the density of each species per unit area. The plant shoot and root of the closest plant species were collected from each plot. Thirty points in each site, grazing and exclosure were selected to obtain soil samples from two different layers, 0-25 and 25-50 cm using a soil auger (5-cm diameter).

Laboratory analyses

The carbon content of aerial and root biomass was obtained by the combustion of 10 g of oven-dried samples in an Electric furnace (after 5 h at 400°C) (McDicken, 1997). The weight loss resulting from the combustion indicates the amount of organic matter and %56 of that would be the organic carbon (Ferguson, 2003). Then, organic carbon ratio of aerial and root biomass was obtained by dividing the weight of organic carbon (g) on the weight of dry sample used in an Electric furnace. Finally, the amount of stored organic carbon in the aerial and root biomass was obtained by multiplying the organic carbon ratio of plant parts in their total dry weight.

Soil samples were air-dried and hand-sieved through a 2-mm mesh to remove roots and other debris. The soil organic matter percent (SOC) was determined by the Walkley-Black dichromate oxidation procedure (14). To estimate the mass (weight) of carbon stored in the soil, the amount of carbon per unit weight of soil (g C/kg soil) was calculated by (Equation 1).

$$OC\ (g.C.kg^{-1}\ soil) = \%OC \times 10 \qquad \text{(Equation 1)}$$

Soil organic carbon per area unit (ha) and given depth was calculated using the amount of carbon per soil weight unit (g $C.kg^{-1}$ soil).

Soil texture was measured by Bouyoucos hydrometer method and soil bulk density, is the weight of dry soil divided by the total soil volume was reported.

Collected data were subjected to analysis of variance (ANOVA) using SAS program (SAS Institute, 1998) to compute grazing and exclosure effects and their interactions. ANOVA was also done, and independent sample t-test ($P \leq 0.05$) was used to detect significant differences.

Results and Discussion:

Overall, land-use type significantly affected the plant and soil carbon content in that rangeland ($P \leq 0.05$). The results showed that it could be found that there were significant differences in vegetation type and its quantity between two study areas; however that difference was not observed in bush vegetation type. The majority of vegetation type was the bush plants in both study area. It was found that the most carbon sequestration was occurred by the aerial biomass of bush plants because their high density stems grow in the sun light and there was no competition between plants for photosynthesis (Figure 1). Therefore the protection management increased the grass and broadleaf plants density and then the soil surface was conserved by increasing the litter, plant residues and root system.

From figure 2, the rangeland management practice is an important factor on decomposition and storage of organic matter and litter in rangeland. The data analysis revealed that the rangeland management practice could significantly affected Carbon content of litter ($P\leq 0.05$). A significant increase of 48.5% was observed in carbon content of litter for exclosure (0.9×10^3 kg.ha^{-1}) compared with grazed rangeland (0.6×10^3 kg.ha^{-1}) (figure 2). The positive effect of exclosure on plant residues accumulation caused to decrease soil surface temperature then the decomposition rate of organic matter was decreased. On the other hand, the exclosure practice decreased the organic matter removal from area and caused carbon accumulation in soil profile (16).

The collected data revealed that the rangeland management practice significantly affected the soil organic carbon ($P\leq 0.05$). The significant difference was only recorded in soil surface (0 – 25 cm), although the soil samples included two different depths, 0 – 25 and 25 – 50 cm (Figure 3). It can be expected that intensive grazing with the reduction of vegetation specially grass and broadleaf plants, reduces plant residues on the soil and reduce the dynamics of soil organic matter.

The results showed that the exclosure as an effective rangeland management practice could increase the carbon content of aboveground biomass compared to grazing area. The carbon sequestration by shoot tissues per protected area unit was higher than that per grazed area unit, on average by 17.5%. The vegetation types were changed into the bushland by livestock grazing therefore the grass and broadleaf plants were increased and the biomass yield in the protected plot was higher than it in the grazed plot. The root tissue of the pasture plants is the major part (13). As shown in Figure 4, the root – shoot carbon content ratio in two studied sites was significant different ($P\leq 0.05$). These data demonstrated that the rangeland protection management increased the carbon content of the shoot tissue more than that of the root tissue (32-34). The protected area increased carbon sequestration in the shoot tissue more than in the root tissue as compared to the grazed area. The intensive grazing practice caused to change the root – shoot biomass ratio and increase the carbon content into the root biomass. The rangeland protection management caused to extend and develop the root systems and also increase the carbon sequestration by plants. The soil organic carbon was definitely provided by root exudates andits residues in the protected area. On the other hand, the soil erosion factors such as wind and water decrease the plant residues on the soil surface therefore the major pool of soil carbon in the protected area is depended on root system. The rangeland management practice caused the root tissue sequestrated carbon more than shoot tissue. Of course, there was non-significant difference in the carbon content in underground biomass between the protected (5.6×10^3 kg.ha^{-1}) and the grazed area (5.3×10^3 kg.ha^{-1}). Underground residues were more effective than aboveground ones on the soil organic carbon storage, therefore the ratio of root – shoot carbon content was decreased in the protected area compared to grazed area (Figure 4).

There is a significant increase in the root – soil carbon content ratio in the exclosure area (Figure 5). The results also indicated that the rangeland management practice affected the carbon content in the soil and pasture plants. The main Carbon sequestration was recorded in the soil profile and it was more effective than pasture plants. The exclosure as a protection management practice caused to decrease the soil surface organic carbon although there was no statistical relationship between changes in soil organic carbon with longevity of grazing management practice (Figure 3). The biomass carbon was 9.9×10^3 and 8.8×10^3 kg.ha^{-1} in the exclosure and grazing area, respectively; however the soil carbon pool decreased by 108.3×10^3 and 123.3×10^3 kg.ha^{-1} in the exclosure and grazing area, respectively. Nevertheless the soil carbon content comprised the largest proportion of total carbon storage in the soil – plant system at both studied sites (91.5 and 93.3% in exclosure and grazing area, respectively). This study showed that the exclosure practice increased the biomass carbon content but there was a significant decrease in the soil carbon storage.

Aboveground and underground litter accumulated rapidly after grazing exclusion, and this in turn led to greater soil carbon however there are many inconsistent results. Some researchers reported strong increases in soil fertility, biological activity, and carbon storage as a consequence of grazing exclusion (12,20). Others found that soil at grazed sites increased carbon storage (Reeder and Schuman 2002) or no statistically significant difference compared with soil at non- grazed sites (Nosetto *et al.*, 2006). These differences may depend on whether grazing pressure exceeds a carrying capacity of site and whether it is sufficiently far beyond that capacity that it has been greater than an ecological threshold capacity (19); outstrips the threshold, recovery is slow or impossible. The relationship between grazing intensity and carrying capacity is unclear and it may be due to plant and soil properties have not shown a consistently positive or negative response to grazing and exclosure (10). Therefore it could be essential to develop and standardize methods forgrazing pressure accurately and determine that pressure relates to a site carrying capacity and its threshold based on vegetation – removal levels rather than on animal stocking (36,37).

Conclusion

It is expected that the exclosure managemet practice can be an useful method for vegetation density recovery after intensive grazing practices and also increase potential to sequester carbon. on the other hand, the results showed that the grazing caused an significant increase in soil organic carbon. In semiarid central Alborz region, longevity and heavy grazing practice over the threshold carrying capacity of the rangeland can significantly decrease the soil organic carbon. The several draught and soil erosion has recently caused an intesified decline in soil organic carbon. It can concluded from this study that grazing – exclosure practice rotation based on vegetation density recovery can be defined as a standard and effective method for conserving the rangeland capasity.

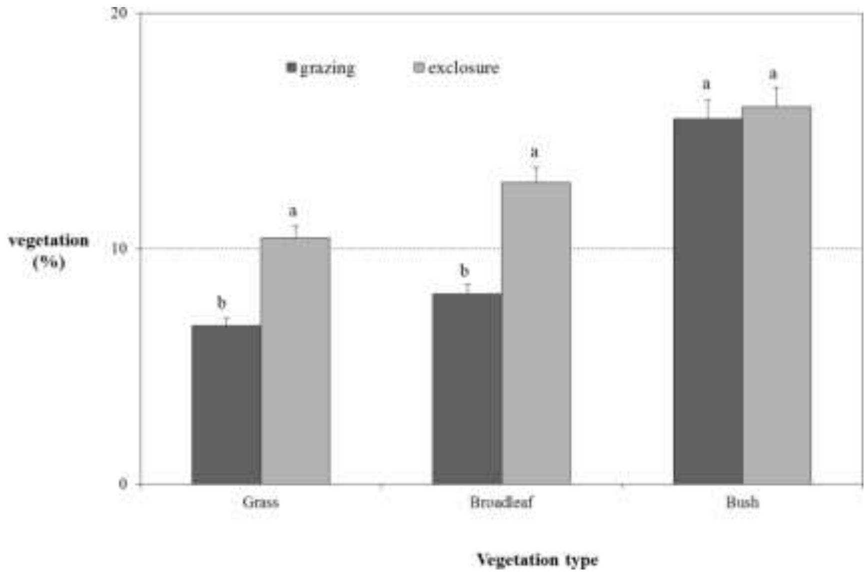

Figure 1: The vegetation type in two studied area sites. The vertical bar presented error bar.

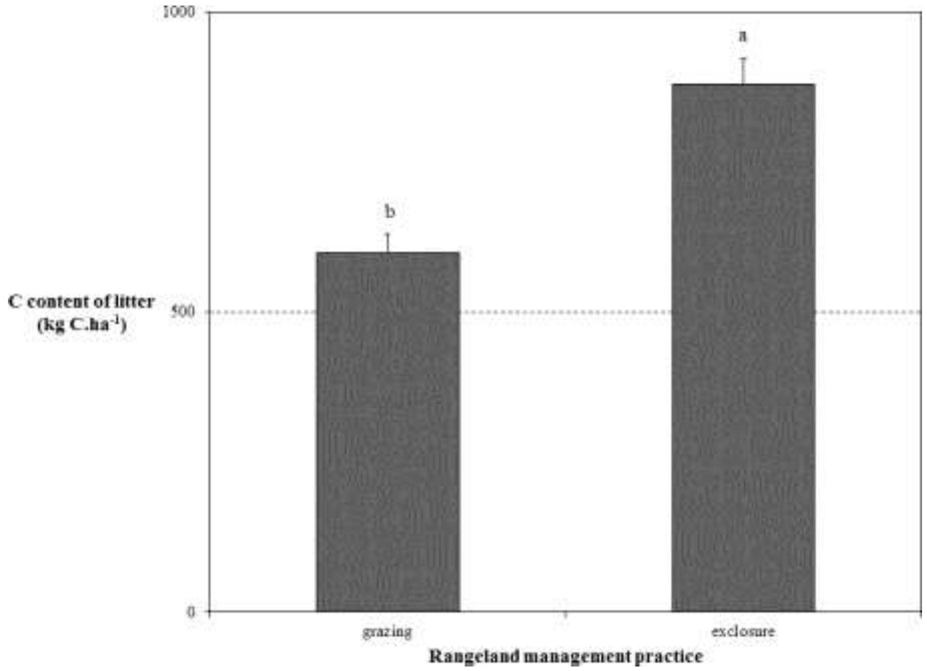

Figure 2: The rangeland management practice effect on Carbon content of litter (kg C.ha^{-1}). The vertical bar presented error bar.

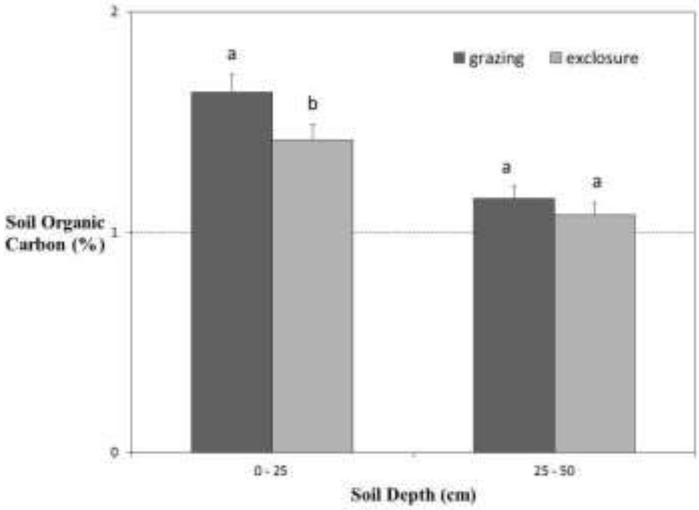

Figure 3: The soil organic carbon changes at different soil depths in two studied sites. The vertical bar presented error bar.

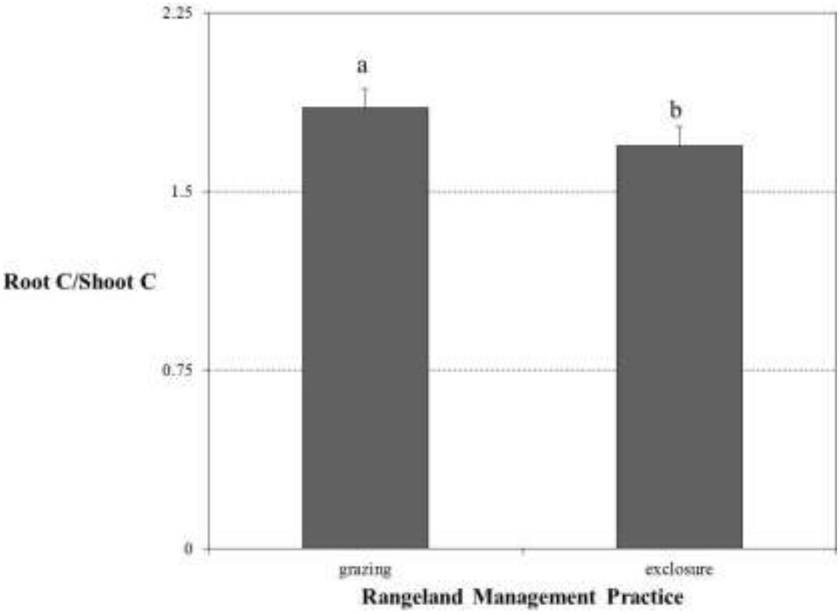

Figure 4: The rangeland management practice effect on the root carbon and shoot carbon content ratio in two studied sites. The vertical bar presented error bar.

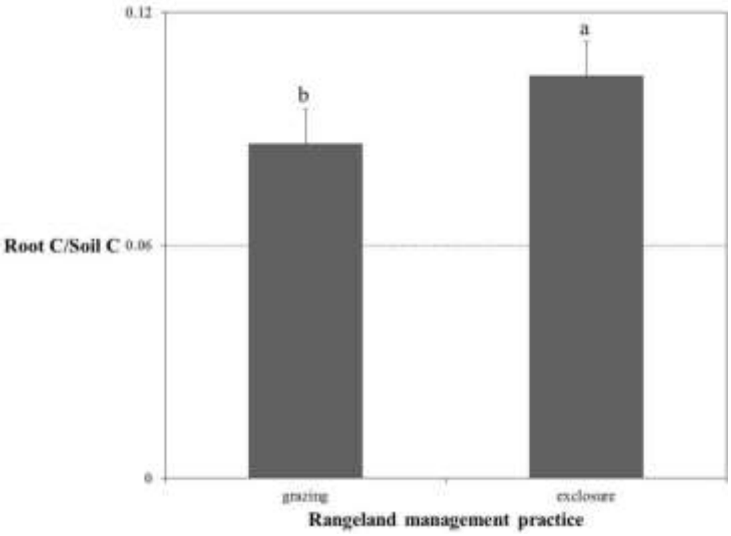

Figure 5: The rangeland management practice effect on the root and soil carbon content ratio in two studied sites. The vertical bar presented error bar.

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