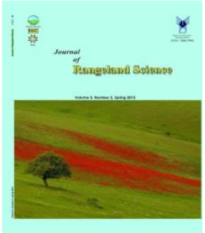
Contents available at ISC and SID

Journal homepage: www.rangeland.ir



Research and Full Length Article:

Effects of Grazing Exclusion on Plant Productivity and Carbon Sequestration (Case Study: Gomishan Rangelands, Golestan Province, Iran)

Hamid Niknahad Gharmakher[A], Isa Jafari Foutami[B], Arezou Sharifi[C]

[A]Assistant Professor of Rangeland Management Department, University of Agricultural Sciences and Natural Resources, Gorgan, Iran (Corresponding Author), Email: hamidniknahad@yahoo.com
[B]Ph.D. Student of Rangeland Management, University of Agricultural Sciences and Natural Resources, Gorgan, Iran
[C]M.Sc. Student of Rangeland Management, University of Agricultural Sciences and Natural Resources, Gorgan, Iran

Received on: 11/10/2014
Accepted on: 08/03/2015

Abstract. In recent years, rangelands have been regarded as potential carbon sinks. One of the most widely suggested options to sequester more C in rangelands is the restoration of the degraded rangelands through grazing the exclusion. In present study, the effects of exclusion on the carbon sequestration of Gomishan rangelands were investigated. Three transects were established in a key area inside and outside the exclosure. In each transect, ten plots were established systematically and in each plot, the number of plant individuals for each plant species was recorded and used to estimate the density of each species per unit area. In order to estimate the plant biomass, a few individuals of each species were sampled by the clipping and weighing method. The carbon content of aerial and root biomass were obtained by the combustion of 10 g of oven-dried samples. Five soil samples at the depths of 0–10 and 10–20 cm were taken along each transect and then, transported to the laboratory. The soil organic carbon percent was determined by the Walkley–Black method. Plant data analysis was performed by one way analysis of variance (ANOVA) and Tukey test. The rate of soil carbon sequestration inside and outside the exclosure was compared using the independent T test at significance level of 1%. Finally, the economic benefit of sequestrated carbon was estimated. The results 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. After a 20 year exclosure, the value of carbon sequestration per hectare in Gomishan rangelands was estimated as 14743 $/h. It can be argued that the education and extension of carbon sequestration in Iran will offer new incentives to restore the degraded rangelands.

Key words: Carbon sequestration, Exclosure, Rangeland, Gomishan

Introduction

Atmospheric CO2 concentration has departed from the narrow window of 180 to 280 ppm to the current 370 ppm for the first time in 420000 years (Petit *et al.*, 1999). In 2014, the mean annual concentration of CO_2 in the atmosphere was 397 ppm (NOAA, 2014). There is absolute certainty that this departure is being driven by human activities that result in CO_2 emissions from fossil fuel combustion, land use changes and cement production (Houghton *et al.,* 2001). Soils hold Carbon over three times as much as the atmosphere (Lehmann and Joseph, 2009) more than the Earth's vegetation and atmosphere and have the capacity to hold much more Carbon (Lal, 2004). C stocks in the terrestrial ecosystems have been greatly depleted since the beginning of the Industrial Revolution (Fig. 1) with the changes in land use and deforestation responsible for the emission of over 498 Gt of CO_2 to the atmosphere (IPCC, 2000), approximately half of which has been lost from soils (IPCC, 2000; Lal, 1999). Each ton of C stored in soils removes or retains 3.67 tons of CO_2 from the atmosphere. Concerns about the effects of the radiative forcing of CO_2 and other human driven greenhouse gas emissions on the climate system have brought the United Nations under the Framework Convention on Climate Change and associated Kyoto Protocol to initiate what has become the most complex international negotiation ever a single environmental issue: human induced changes on climate patterns and variability. A second concern is the potential effects of altered climate and atmospheric composition on the terrestrial and aquatic ecosystems, particularly ecosystem services such as net primary production and water quality and quantity which human societies rely upon for their welfare and development (Canadell, 2002).

Carbon sequestration in terrestrial ecosystems (lithosphere) is defined as the ability of trees, other plants and the soil to absorb carbon dioxide from the atmosphere and store it as carbon in wood, roots, leaves and soil (Rice *et al.*, 1994). Carbon sequestration synthetic method is expensive and in U.S.A, its costs were estimated around 100 to 300 $ per ton of carbon (Finer, 1996; Varamesh, 2009). While such untested technologies as geologic and deep ocean sequestration schemes have been proved to be physically possible, the economic, environmental and social costs associated with these technologies remain uncertain. For the immediate future, sequestration in terrestrial ecosystems via natural processes remains the viable and ready to implement options and is regarded as one of the most cost effective processes (Fynn *et al.*, 2010).

Rangelands comprise the largest and most diverse land resource in the world (Reeder and Schuman, 2002) and cover more than 50 percent of the land surface area of Iran (Eskandari *et al.*, 2008) and up to half of the land surface area worldwide (Lund, 2007). Because of rangelands extent, a small change in soil carbon (C) stocks across rangeland ecosystems would have a large impact on greenhouse gas (GHG) accounts (Follett *et al.*, 2001). In rangelands, low and highly variable precipitation inputs constrain the plant productivity limiting the economic alternatives to the grazing activities where irrigation is not feasible (Noy-Meier, 1973). The traditional management of these rangelands often associated with stocking density over the carrying capacity has resulted in floristic and physiognomic changes, losses of soil organic carbon, increase of bare soil and eventually, desertification (Golluscio *et al.,* 1998; Lal, 2002). Restoration attempts have been hardly implemented because the low economic return per unit area of these systems makes them a risky investment (Glenn *et al.,* 1998). The emergence of a prospective carbon market as a tool to promote carbon sequestration and offset the increasing atmospheric carbon dioxide concentration may offer new incentives to restore the degraded rangelands, especially in those places where land degradation has led to a decline in the economic yields (Prince *et al.,* 1998). Mahdavi *et al.* (2011) stated that if we compare the value of the carbon sequestration of Iran steppes (13.66×10^7\$) with that of the produced forage of the grasslands all over Iran (5350×10^5\$), we will gain the economic appreciation of the carbon sequestration.

One of the most widely suggested option to sequester more C in rangelands is the rangeland restoration by grazing exclusion (Nosetto *et al.*, 2006). Studies of grazed soils worldwide have shown both increases (Schuman *et al.,* 1999; Reeder *et al.,* 2004) and decreases (Derner *et al.*, 1997; Yong-Zhong *et al.*, 2005) in carbon storage and accumulation as compared to the adjacent non-grazed soils. Milchunas and Lauenroth (1993) conducted a review of 34 studies involving the grazed and non-grazed sites around the world and found that 40% of them reported a decrease and 60% reported an increase in soil carbon as the result of grazing exclusion. Since carbon sequestration rate is a function of plant species and their growth characteristics, physiological and biological conditions of the soil, previous storage of carbon in the soil, restoration and management method, climatic conditions, especially precipitation rate and soil properties, environmental response to the changes in rangeland management in terms of carbon sequestration vary in different regions (Derner and Schuman, 2007; Post and Kwon, 2000; Schuman *et al.*, 1999). Other studies show that certain grazing management practices such as rotational grazing and moderate stocking rates can greatly improve the rangeland ability to sequester carbon effectively (Conant *et al.,* 2001; Schuman *et al.,* 2001). According to Raiesi and Riahi (2014), there is increasing evidence that soil organic C storage and turnover rate are influenced by herbivores and grazing management practices in the rangeland ecosystems and a significant change in the abiotic and biotic factors following extensive grazing would directly or indirectly influence soil C storage capacity and the activity and diversity of soil biota (Qi *et al.,* 2011; Zou *et al.,* 2007). Grazing effects are particularly evident in dry rangelands (Ghorbani *et al.,* 2012; Smith *et al.,* 2012) where limited resources (i.e. low residue input sand available water) are rather common (Smith *et al.,* 2012). Hence, the dry rangelands are ecologically fragile and have been led to the desertification by mismanagement but could be restored by the exclosure grazing practices (Jeddi and Chaieb, 2010; Qi *et al.,* 2011).Therefore, providing incentives to manage rangelands sustainability as carbon sinks offers large-scale carbon sequestration opportunities.

Here, we explore the response of a rangeland to sequester carbon by the means of rangeland exclusion. The objectives of the present study were (1) to investigate the response of plant and soil carbon storage to the exclusion grazing and (2) to quantify C storage in the plant–soil system in Gomishan rangelands on the exclosure and grazing areas.

Materials and Methods

Study area

The study area consists of a 37963 ha rangeland located in the Western Golestan province at an altitude between -24 and -11 m above sea level. The area lies at 54° 1′ to 54° 2′ longitude and 37° 8′ to 37° 11′ latitude (Fig. 2). The topography in this region is flat. Its mean annual temperature is 16.6ºC and the climate is semi-arid with the mean annual *Halocnemum strobilaceum, Aeluropus littoralis* and *Aeluropus lagopoides* and accordingly, we selected the replicated exclosure of 20 years which are paired with the adjacent open grazing lands.

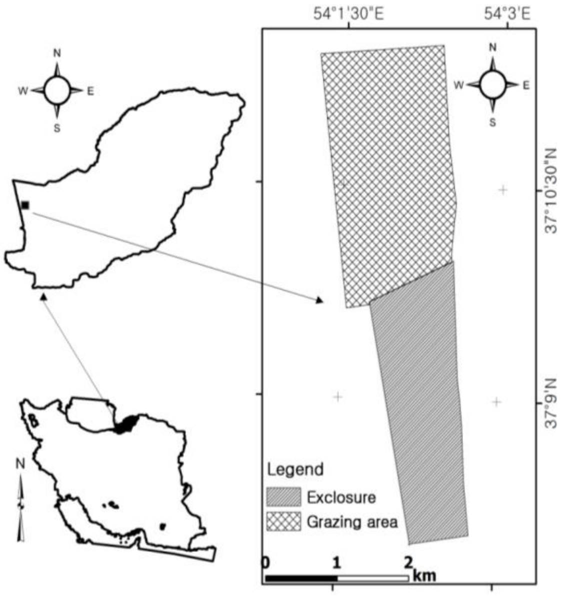


Fig. 1. Location map of the study area in north of Iran

Sampling method

Three transects (the length of 250 m and intervals of 100 m) were established in a key area inside and outside the exclosure. In each transect, ten plots ($2m^2$) were established systematically (Forouzeh, 2007). In each plot, the number of plant individuals for each plant species was recorded and used to estimate the density of each species per unit area. In order to estimate the mean fresh weight of plants, a few individuals of each species were sampled by the clipping and weighing method. The moisture content of aerial and root biomass was calculated after drying 500 g of each sample in an oven (after 24 h at 70°C) and used to calculate their total dry weight by applying this ratio to the amount of wet weight of precipitation of 343 mm mainly in the autumn and winter. The growth form of this region is shrubs and grasses and the dominant plant species are *Halostachys blanyesiana, Puccinellia distance,* (Mirzaali *et al.*, 2006). The exclosure (300 ha) was established two decades ago aerial and root biomass which had been measured in the field.

In each key area, five soil samples at the depths of 0–10 and 10–20 cm were collected along each transect (total of 30 (3×5×2) soil samples per each key area) and transported to the laboratory.

Plants organic carbon

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 500°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 (Birdesy, 1996 and 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 organic carbon

In the laboratory with plant materials and other debris removed, the soil samples were air-dried and sieved to pass a 0.5-mm screen. The soil organic carbon percent (SOC) was determined by the Walkley–Black method (Walkley, 1947; Nelson and Sommers, 1982). 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).

$OC_{(gc/kg\ soil)} = \%OC \times 10$ (Equation 1)

Soil organic carbon per unit area (ha) and given depth was calculated using the amount of carbon per unit weight of soil (g C/kg soil), Soil bulk density and soil sampling depth by the help of Equation 2, (Lemma *et al.*, 2006).

$SC = e \times Bd \times OC_{(gc/kg\ soil)} \times 10$ (Equation2)

Where

SC= the amount of soil carbon (Ton/ha) in given depth

OC= the amount of carbon mass in soil (g C/kg soil)

Bd= Soil bulk density (g/cm^3)

E= Soil depth (m)

Data analysis

Before subjecting the data to a statistical analysis, the uniformity of the obtained data was checked (Verdoodt *et al.*, 2009). Then, data analysis was performed by one-way analysis of variance and Tukey test at a significance level of 1%. The rates of soil carbon sequestration inside and outside the exclosure were compared using the independent T test that was performed by $SPSS_{16}$. Finally, the economic benefit of carbon sequestration was calculated.

Results

Plant composition, density and productivity

The results indicated that exclosure had a significant impact on plant characteristics (Table 1). No individual plants of *Halostachys caspica, Puccinellia distance* and *Aeluropus littoralis* species were observed outside the exclosure. Inside the exclosure, *Puccinellia distance* and *Halocnemum strobilaceum* had the highest and lowest densities, respectively. Furthermore, *Halostachys caspica* and *Halocnemum strobilaceum* had the highest and lowest proportions of the aerial and root dry matter. According to the results, outside the exclosure, *Polypogon monspeliensis* and *Halocnemum strobilaceum* were the dominant species. The aerial and root dry matters were produced mainly by *Polypogon monspeliensis* (Table 1).

Table 1. Comparison of estimated quantity of plant biomass on exclosure and grazing areas

Area	Plant species	Aerial DM (g/plant)	Root DM (g/plant)	Plant Density (Per ha)	Aerial DM (g/ha)	Root DM (g/ha)	Total DM (kg/ha)
Exclosure	*Puccinellia distance**	19.47	6.59	19000	369930	125210	495.14
	*Aeluropus littoralis**	6.32	5.04	15250	96380	76860	173.24
	*Halostachys caspica**	100.0	60.70	5100	510000	310000	820.00
	Polypogon monspeliensis	6.45	2.76	12083	77935	33349	111.28
	Halocnemum strobilaceum	25.50	13.80	1650	42075	22770	64.84
Grazing area	*Polypogon monspeliensis*	6.08	2.33	39325	239096	91627	330.72
	Halocnemum strobilaceum	32.20	18.60	1370	31784	25482	57.26

*No individual plants were available in outside of enclosure

Plant carbon sequestration rate in exclosure and grazing area

The mean carbon sequestration rates (kg/ha) of plant biomass on the exclosure and grazing areas are shown in Table 2. Inside the exclosure, the mean estimated carbon sequestration rate in the plant biomass ranged from 22.49 (kg/h) in *Halocnemum strobilaceum* to 410 (kg/h) in *Halostachys caspica* and outside the enclosure, it ranged from 26.81 to 181.68 (kg/h) for *Halocnemum strobilaceum* and *Polypogon monspeliensis*, respectively (Table 2). Statistical analysis revealed that there were significant differences ($P<0.01$) between plant species in terms of estimated carbon sequestration rate (Table 2).

Soil carbon sequestration rate in exclosure and grazing area

The results revealed that there was a significant difference ($P<0.01$) between organic carbon of two studied soil depths in the exclosure but such difference was not observed in the grazing area ($P>0.01$). It can be argued that changes in the composition and density of the dominant plant species and accumulation of their litter have led to this significant difference as compared to the grazing area. The results indicated that the estimated soil carbon sequestration rates on the exclosure and grazing area were 71.78 and 52.45 (ton C/ha), respectively. There was 19.33 (ton C/ ha) difference between total soil organic carbon of two areas (Table 3). Two-sample t-test of the overall soil organic carbon mean incorporating two depths revealed significant differences (*P*<0.01) due to the exclosure (Table 3).

Table 2. The Mean of estimated carbon sequestration rate (kg/ha) of plant biomass on the exclosure and grazing area

Area	Plant species	Aerial Biomass OC%	Root Biomass OC%	Aerial OC (g/plant)	Root OC (g/plant)	Total OC (g/plant)	Plant Density (Per ha)	Total OC (kg/ha)
Exclosure	*Puccinellia distance**	48	43	9.34	2.81	12.15	19000	230.8 [b]
	*Aeluropus littoralis**	53	43	3.35	2.16	5.51	15250	84.02 [c]
	*Halostachys caspica**	50	47	46.3	34.09	80.39	5100	410.0 [a]
	Polypogon monspeliensis	52	47	3.35	1.29	4.64	12083	56.06 [d]
	Halocnemum strobilaceum	47	29	9.63	4.02	13.63	1650	22.49 [e]
Grazing area	*Polypogon monspeliensis*	55	55	3.34	1.28	4.62	39325	181.6 [a]
	Halocnemum strobilaceum	50	42	11.76	7.81	19.57	1370	26.81 [b]

*No individual was observed in outside of enclosure

The means of total OC with the different letters were significantly different based on Tukey method P< 0.01

Table 3. The Mean of soil carbon sequestration rate (ton/ha) on exclosure and grazing area in two soil depths

Area	Soil depth	Soil OC (%)	Soil OC (g /kg soil)	Bulk density (g /cm^3)	Soil OC (ton/ha)	Total Soil OC (ton/ha)	Difference (ton/ha)
Exclosure	0-10	6.08	60.82	0.69	42.12 [a]	71.78 [a]	19.33
	10-20	3.65	36.48	0.81	29.66 [b]		
Grazing area	0-10	4.06	40.58	0.61	26.87 [a]	52.45 [b]	
	10-20	3.38	33.78	0.76	25.58 [a]		

The means of soil OC and total OC of area with different letters were significant based on T test P< 0.01

Economic values of carbon sequestration

Considering that carbon forms 27% of the weight of atmospheric carbon dioxide (atomic mass of carbon and Oxygen are 12 and 16, respectively), so there is 270 kg carbon per atmospheric carbon dioxide. As a result, each ton of the sequestered carbon is equivalent to 3.7 tons of atmospheric carbon dioxide. With reference to the mean value of carbon sequestration (i.e. $200 per ton) (Varamesh, 2009) and the increase of 73.71 ton/ha (Table 4) carbon sequestration on this exclosure, it can be argued that the value of carbon sequestration per ha in Gomishan exclosure will equal to 14743 $/h over 20 years which is equivalent to 737.15 $ per year.

Table 4. The economic value of carbon sequestration over 20 years

	Carbon (Ton/ha)	Atmospheric CO_2 (Ton)	Economic Value ($/h)
Differences in carbon sequestration by vegetation between inside and outside of the exclosure	0.594	2.19	439
Differences in carbon sequestration by soil between inside and outside of the exclosure (0 – 10 cm)	15.25	56.44	11288
Differences in carbon sequestration by soil between inside and outside of the exclosure (10 – 20 cm)	4.076	15. 08	3016
Total			14743

Discussion and Conclusion

The results revealed that the response of plant and soil carbon storage to the exclosure is positive in Gomishan rangelands and there are significant differences between the total amounts of the stored carbon of plant biomass and soil on the exclosure and grazing areas. Comparison of the mean annual value of carbon sequestration (737.15 $/ha) and grain yield of dry-land farming (800 kg/ha) in the study area represents an economic advantage of carbon sequestration project to the dry-land farming. Our results are in agreement with studies that had shown the increases (Schuman *et al.,* 1999; Reeder *et al.,* 2004; McIntosh *et al.,* 1997) and in contrast with those that had shown the decreases (Derner *et al.,* 1997; Yong-Zhong *et al.,* 2005) in carbon storage and accumulation as compared to the adjacent non-grazed soils. Schuman *et al.* (2001) mentioned that around 90% of C in rangeland systems is located in the soil and most of SOC is found in the top of soil profile as a result of the presence and influence of biotic processes (Conant *et al.,* 2001). The plant species have an enormous influence on the carbon sequestration. In rangelands, above-ground biomass and litter have been proved to be increased after grazing the removals (McIntosh *et al.,* 1997). After 20 years, the exclosure has benefited from the greater varieties of plant species, higher canopy cover, lower death rate of plants, higher litters and finally, the reduction in the number of plant-free areas. If the vegetations are improved, the litters increase in number and the soils become fertilized; then, the amount of carbon in the plant-soil system will definitely increase (Mahdavi *et al.,* 2011). Increased plant cover can increase C influx through a higher and more efficient use of resources for primary production. Grazing exclusion is particularly likely to increase C uptake where overgrazing has decreased the biomass productivity, thereby decreasing the quantity and quality of the biomass that is returned to the soil (Oesterheld *et al.,* 1999; Su *et al.,* 2005; Pei *et al.,* 2008). In addition to C uptake shifts, grazing exclusion can favor C sequestration through the reduction of C losses if higher ground cover reduces SOC decomposition and soil erosion. The slower C turnover rates associated with wood carbon allocation and the cessation of biomass removal by livestock may also decrease C losses in exclosures, respectively (McIntosh *et al.,* 1997; Schlesinger, 1997).

Rangelands have a high potential for C sequestration if input of organic matter into the soil and slower decomposition of soil organic matter can be promoted through the use of ‘‘best-management practices’’ (Shrestha and Stahl, 2008) because soil in many of them receives low carbon input and tends to be degraded, poorly managed or not managed at all (Kimble *et al.,* 2001). The rate of C sequestration is determined by the net balance between C inputs and C outputs. C inputs and outputs are affected by the management and by two biotic processes –production of organic matter in the soil and decomposition of organic matter by the soil organisms. The biotic processes are strongly controlled by physical, chemical and biological factors including biome, climate, soil moisture, nutrient availability, plant growth and erosion. (Derner and Schuman, 2007; Post *et al.*, 2001; Svejcar *et al.,* 2008; Ingram *et al.,* 2008). Soil CO_2 is the main end product of the decay of SOC. Under aerobic conditions, CO_2 is produced by the respiration of bacteria and protozoa in the guts of insects, bacteria and fungi in the soil. Soil CO_2 production accelerates with temperature and exposure of SOM to air in pore spaces and on the surface of the soil. When decomposition and soil CO_2 production can be slowed, the net rate of soil C accumulation and storage may be increased.

Bio sequestration will not solve all the problems contributing to global warming. However, combined with the increased energy efficiency and decreased industrial emissions, projects that enhance greenhouse gas sequestration will play a key role in mitigating the effects of climatic changes. Many co-benefits associated with the increasing levels of soil C suggest the prospect of win–win scenarios for rangeland managers, climatic changes mitigation and ecosystem services. Optimizing the uptake of sequestration activity depends on the design and implementation of the protocol since incentives to implement the desired changes in management practices will be generated. There are two motivating factors likely to encourage the rangeland managers to adopt C sequestration practices. The first one is the range of biophysical benefits - SOC gains improve soil quality through better water holding capacity (this factor is of critical importance in Iranian rangelands, most of which experience less than 250 mm annual precipitation), fertility and biodiversity (Haynes and Naidu, 1998; Loveland and Webb, 2003; Evrendilek *et al.*, 2004) and have a stabilizing effect on soil structure that can prevent from the erosion (Boix-Fayos *et al.*, 2001). Carbon gains in plant and litter pools are often associated with runoff reduction and infiltration and soil moisture increase (Rostagno *et al.*, 1991; Abril and Bucher, 2001). In addition, lower soil temperatures associated with higher ground cover act to decrease the decomposition rate of the soil organic matter (Archer, 1995). The second factor is the increased financial benefit – rangeland managers could benefit from the revenues achieved from the sale of emission reductions credits resulting from the increased soil C sequestration.

The issue of global warming is now a major and unavoidable element of world energy policy. However, the implementation of an international agreement on limiting the releases of greenhouse gases (and particularly CO_2) is a complex matter with major geopolitical and economic implications. It can be argued that the education and extension of carbon sequestration will offer new incentives to restore the degraded rangelands. Though, the bill of outlines of a mandatory cap and trade system for Iran is unclear. Regardless, if legislation is passed, significant incentives will arise for Iranian rangeland managers (and dry-land farmers) to develop the offset projects.

Literature Cited

Abril, A. and Bucher, E. H., 2001. Overgrazing and soil carbon dynamics in the western Chaco of Argentina. *Applied Soil Ecology*. 16: 243–249.

Archer, S., 1995. Tree–grass dynamics in a *Prosopis*-thornscrub savanna parkland: reconstructing the past and predicting the future. *Ecoscience.* 2 (1): 83–99.

Birdesy, R. A., 1996. Regional estimate of timber volume and forest carbon for fully Stocked timberland, Averse management after final clear cut harvest in forest and global change. Volume 2, Forest Management Opportunities for Mitigating Carbon Emissions. Sampson, Eds. R.N., Hair, D. American Forest, Washington. D.C.

Boix-Fayos, C., Calvo-Cases, A., Imeson, A. C. and Soriano-Soto, M. D., 2001. Influence of soil properties on the aggregation of some Mediterranean soils and the use of aggregate size and stability as land degradation indicators. *CATENA.* 44 (1): 47–67.

Canadell, J. G., 2002. Land use effects on terrestrial carbon sources and sinks. Science in China. 45: P: 1-9.

Conant, R. T., Paustian, K. and Elliott, E. T., 2001. Grassland management and conversion into grassland: effects on soil carbon. *Ecological Applications*, 11: 43–355.

Derner, J. D., Briske, D. D. and Boutton, T. W., 1997. Does grazing mediate soil carbon and nitrogen accumulation beneath C4 perennial grasses along an environmental gradient? *Plant Soil*, 191 (2): 147–156.

Derner, J. D. and Schuman, G. E., 2007. Carbon sequestration and rangelands: A synthesis of land management and precipitation effects. *Jour. Soil and Watershed Conservation*, 62(2): 77-85.

Eskandari, N., Alizadeh, A. and Mahdavi, F., 2008. Range management policies in Iran. Poneh publications, Tehran, Iran. 190 P. (In Persian).

Ferguson, D. F., 2003. Carbon Sequestration on Idaho Agriculture and Forest lands. Technical Report of Idaho Soil Conservation Commission, P: 30-35.

Follett, R. F., Kimble, J. M. and Lal, R., 2001. The potential of U.S. grazing lands to sequester carbon and mitigate the greenhouse effect. Boca Raton, Florida, USA, Lewis Publishers, CRC Press. 422 pp.

Finer, L., 1996. Variation in the amount and quality of litterfal in a *Pinus sylvestris* L. stand growing on a bog. *Forest Ecology and Management*, 80: 1-11.

Forouzeh, M. R., 2007. Effect of exclusion on carbon sequestration potential of *Halocnemum strobilaceum* and *Halostachys caspica* (Case study: Gomishan rangelands). *Watershed Management Research*, 85: 22-28 (In Persian).

Fynn, A. J., Alvarez, P., Brown, J. R., George, M. R., Kustin, C., Laca, E. A., Oldfield, J. T., Schohr, T., Neely, C. L. and Wong, C. P., 2010. Soil carbon sequestration in USA rangelands. *Integrated Crop Management*, 11: 57-104.

Ghorbani, N., Raiesi, F., Ghorbani, S., 2012. Bulk soil and particle size-associated C and N under grazed and ungrazed regimes in Mountainous arid and semi-arid rangelands. *Nutr. Cycl. Agroecosyst*, 93: 15–34.

Glenn, E., Stafford Smith, M. and Squires, V., 1998. On our failure to control desertification: implications for global change issues, and a research agenda for the future. *Environmental Science & Policy*, 1(2): 71–78.

Golluscio, R. A., Deregibus, V. A. and Paruelo, J. M., 1998. Sustainability and range management in the Patagonian steppes. *Ecologı´a Austral.*, 8: 265–284.

Haynes, R. J. and Naidu, R., 1998. Influence of lime, fertilizer and manure applications on soil organic matter content and soil physical conditions: a review. Nutrient Cycling in Agro Ecosystems, 51 (2): 123–137.

Houghton, J. T., Ding, Y. and Griggs, D., 2001. Climate Change, 2001, the Science of Climate Change. Cambridge: Cambridge University Press.

Ingram, L. J., Stahl, P. D., Schuman, G. E., Buyer, J. S., Vance, G. F., Ganjegunte, G. K., Welker, J. M. and Derner, J. D., 2008. Grazing impacts on soil carbon and microbial communities in a mixed-grass ecosystem. *Soil Sci. Soc. Am. Jour.*, 72: 939-948.

Evrendilek, F., Celik, I., Kilic, S., 2004. Changes in soil organic carbon and other physical soil properties along adjacent Mediterranean forest, grassland, and cropland ecosystems in Turkey. *Jour. Arid Environments*, 59 (4): 743–752.

IPCC (Intergovernmental Panel on Climate Change), 2000. Land use, land-use change, and forestry. *In:* R.T. Watson *et al.*, eds. Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK,. 377 pp.

Jeddi, K. and Chaieb, M., 2010. Changes in soil properties and vegetation following livestock grazing exclusion in degraded arid environments of South Tunisia. *Flora*, 205:184–189.

Kimble, J. M., Follett, R. F. and Lal, R., 2001. Introduction: the characteristics and extent of US grazing lands. In: Follett, R. F., Kimble, J. M., Lal, R. (Eds.), The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate Greenhouse Effect. Lewis Publishers, BocaRaton, FL, pp. 3–20.

Lal, R., 1999. Soil management and restoration for C sequestration to mitigate the accelerated greenhouse effect. *Prog. Environ. Sci.*, 1: 307–326.

Lal, R., 2002. Soil carbon dynamics in cropland and rangeland. *Environmental Pollution*, 116: 353–362.

Lal, R., 2004. Soil carbon sequestration to mitigate climate change. *Geoderma*, 123: 1–22.

Lehmann, J. and Joseph, S., 2009. Biochar for environmental management: an introduction. In: Lehmann, J. and Joseph, S. (eds.) Biochar for Environmental Management: Science and Technology. Earthscan Publ., London, pp. 1-12.

Lemma, B., Kleja, D. B., Nilsson, I. and Olsson M., 2006. Soil carbon sequestration under different exotic tree species in the southwestern highlands of Ethiopia. *Geoderma*, 136: 886-898.

Loveland, P. and Webb, J., 2003. Is there a critical level of organic matter in the agricultural soils of temperate regions: a review. *Soil and Tillage Research*, 70 (1): 1–18.

Lund, H. G., 2007. Accounting for the world's rangelands. *Rangelands*, 29: 3–10.

Mahdavi, M., Arzani, H., Mesdaghi, M., Mahdavi, KH., Mahmodi, J. and Alizadeh, M., 2011. Estimation of Soil Carbon Sequestration Rate in Steppes (Case Study: Saveh Rudshur Steppes). *Jour. Rangeland Science*, 1(3): 175-182.

McDicken, K. G., 1997. A guide to monitoring carbon storage in forestry and agro forestry projects. Winrock International Arlington, VA, USA. 87pP.

Milchunas, D. G. and Lauenroth, W. K., 1993. A quantitative assessment of the effects of grazing on vegetation and soils over a global range of environments. *Ecol. Monogr*., 63: 327–366.

Mirzaali, M., Mesdaghi, M. and Erfanzadeh, R., 2006. The study of effects of exclosure on vegetation and soil surface in saline ranges of Gomishan, Golestan province. *Jour. Agric. Sci. Natur. Resour.*, 13(2): 104-201. (In Persian).

Nelson D. W. and Sommers, L. E., 1982. Total carbon, organic carbon, and organic matter. In: Page, A.L., Miller, R. H., Keeney, D. R. (Eds), Methods of Soil Analysis. Part 2. Chemical and Microbial Properties. 2nd Ed. *Agronomic,* 9: 539-579.

Nosetto, M. D, Jobbagy, EG, and Paruelo, J. M., 2006. Carbon sequestration in semi-arid rangelands: comparison of *Pinus ponderosa* plantations and grazing exclusion in NW Patagonia. *Jour. Arid Environments,* 67:142–156

NOAA (The National Oceanic and Atmospheric Administration)**,** 2014. Mauna Loa Observatory. Scripps CO_2 Data. http://co₂now.org.

Noy-Meier, I., 1973. Desert ecosystems: environment and producers. Annual Review of Ecology and Systematic, 4: 25–51.

Oesterheld, M, Loreti, J, Semmartin, M. and Paruelo, J. M., 1999. Grazing, fire, and climate effects on primary productivity of grasslands and savannas. In: Walker LR (ed) Ecosystems of disturbed ground. Elsevier, Amsterdam, pp 287–306.

Pei, S. F., Fu, H. and Wan, C. G., 2008. Changes in soil properties and vegetation following exclosure and grazing in degraded Alxa desert steppe of Inner Mongolia, China. *Agriculture, Ecosystems & Environment,* 124:33–39.

Petit, J. R., Jouzel, J. and Raynaud, D., 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature,* 399: 429-436.

Post, W. M. and Kwon, K. C., 2000. Soil carbon sequestration and land-use changes: processes and potential. *Global Change Biol.,* 6: 317–327.

McIntosh, P. D., Allen, R. B. and Scott, N., 1997. Effects of exclosure and management on biomass and soil nutrient pools in seasonally dry high country, New Zealand. *Jour. Environmental Management,* 51: 169–186.

Post, W. M., Izaurralde, R. C., Mann, L. K. and Bliss, N., 2001. Monitoring and verifying changes of organic carbon in soil. *Climatic Change*, 51: 73–99.

Prince, S. D., Brown de Colstoun, E. and Kravitz, L. L., 1998. Evidence from rain-use efficiencies does not indicate extensive Sahelian desertification. *Global Change Biology*, 4 (4): 359–374.

Qi, S., Zheng, H., Lin, Q., Li, G., Xi, Z. and Zhao, X., 2011. Effects of livestock grazing intensity on soil biota in a semi arid steppe of Inner Mongolia. *Plant Soil,* 340:117–126.

Raiesi, F., Riahi, M., 2014. The influence of grazing exclosure on soil C stocks and dynamics, and ecological indicators in upland arid and semi-arid rangelands. *Ecological Indicators,* 41: 145–154.

Reeder, J. D. and Schuman, G. E., 2002. Influence of livestock grazing on C sequestration in semi-arid mixed-grass and short-grass rangelands. *Environmental Pollution,* 116: 457–463.

Reeder, J. D., Schuman, G. E., Morgan, J. A. and Lecain, D. R., 2004. Response of organic and inorganic carbon and nitrogen to long-term grazing of the shortgrass steppe. *Environmental Management,* 33 (4): 485–495.

Rice, C. W., Garcia. F. and Hampton, C., 1994. Soil microbial response in tall grass prairie to elevated Co2. *Plant and soil,* 165: 62-75.

Rostagno, C. M., Del Valle, H. F. and Videla, L., 1991. The influence of shrubs on some chemical and physical properties of an aridic soil in north-eastern Patagonia, Argentina. *Jour. Arid Environments,* 20 (2): 179–188.

Schlesinger, W. H., 1997. Biogeochemistry: An Analysis of Global Change. Academic Press, New York. 588pp.

Schuman, G. E., Reeder, J. D., Manley, J. T., Hart, R. H. and Manley, W.A., 1999. Impact of grazing management on the carbon and nitrogen balance of a mixed-grass rangeland. *Ecol. Appl.*, 9 (1): 65–71.

Schuman, G. E., Herrick, J. E. and Janzen, H. H., 2001. The dynamics of soil carbon in rangelands. pp. 267-290. In: Follett, R.F., J.M. Kimble, and R. Lal (eds.). The Potential of US Grazing lands to Sequester Carbon and Mitigate the Greenhouse Effect, Lewis Publishers, Boca Raton, FL .

Shrestha, G. and Stahl, P.D., 2008. Carbon accumulation and storage in semi-arid sagebrush steppe: effects of long-term grazing exclusion. *Agriculture, Ecosystems and Environment*, 125:173–181.

Smith, J. G., Eldridge D. J. and Throop, H. L., 2012. Landform and vegetation patch type moderate the effects of grazing-induced disturbance on carbon and nitrogen pools in semi-arid woodland. *Plant and Soil*, 360:405-419.

Su, Y. Z., Li, Y. L., Cui, J. Y. and Zhao, W. Z., 2005. Influences of continuous grazing and livestock exclusion on soil properties in a

Varamesh, S., 2009. Effectuality of forestation on soil carbon sequestration and mitigate climate change. First International Conference of the World Soil Erosion and Conservation. May 27-30, 2009. Tara Mountain. Serbia.

Verdoodt, A., Mureithi, S. M., Ye, L. and Van Ranst, E., 2009.Chrono sequence analysis of two enclosure management strategies in degraded rangeland of semi-arid Kenya. *Agriculture, Ecosystems and Environment*, 129: 332-339.

Walkley, A., 1947. A critical examination of a rapid method for determining organic carbon in soils effects of variation in digestion condition and of inorganic soil constituents. *Soil*, 63: 251-264.

Yong-Zhong, S., Yu-Lin, L., Jian-Yuan, C. and Wen-Zhi, Z., 2005. Influences of continuous grazing and livestock exclusion on soil properties in a degraded sandy grassland, Inner Mongolia, northern China. *CATENA*, 59 (3): 267–278.

Zou, C., Wang, K., Wang, T. and Xu, W., 2007. Overgrazing and soil carbon dynamics in eastern Inner Mongolia of China. *Ecol. Res.*, 22: 135–142.

degraded sandy grassland, Inner Mongolia, northern China. *Catena*, 59: 267–278.

Svejcar, T., Angell, R., Bradford, J. A., Dugas,W., Emmerich,W., Frank, A. B. Gilmanov, T. Haferkamp, M. Johnson, D. A., Mayeuzx,H., Mielnick,P., Moragan,J., Saliendra, N. Z., Schuman, G. E., Sims, P. L. and Snyder, K., 2008. Carbon Fluxes on North American Rangelands. *Rangeland Ecology and Management*, 61: 465-474.

بررسی اثرات قرق بر تولید گیاهی و ترسیب کربن (مطالعه موردی: مراتع گمیشان، استان گلستان)

حمید نیک نهاد قرماخر [الف]، عیسی جعفری فوتمی[ب]، آرزو شریفی [ج]

[الف] استادیار گروه مرتعداری دانشکده مرتع و آبخیزداری دانشگاه علوم کشاورزی و منابع طبیعی گرگان، ایران (نگارنده مسئول)،
پست الکترونیک: Hamidniknahad@yahoo.com
[ب] دانشجوی دکترای علوم مرتع گروه مرتعداری دانشکده مرتع و آبخیزداری دانشگاه علوم کشاورزی و منابع طبیعی گرگان، ایران
[ج] دانشجوی کارشناسی ارشد گروه مرتعداری دانشکده مرتع و آبخیزداری دانشگاه علوم کشاورزی و منابع طبیعی گرگان، ایران

تاریخ دریافت: ۱۳۹۳/۰۷/۱۹
تاریخ پذیرش: ۱۳۹۳/۱۲/۱۷

چکیده. در سال‌های اخیر، مراتع به‌عنوان جاذب بالقوه کربن مطـرح شـده‌انـد. احیـا مراتـع تخریب یافته از طریق اعمال قرق از متداول‌ترین روش‌های پیشنهاد شده بـه‌منظـور ترسـیب بیشتر کربن در مراتع می‌باشد. در این پژوهش، اثرات قرق بر ترسیب کربن در مراتع گمیشـان بررسی شده است. بدین منظور، در مناطق کلید داخل و خارج از قرق سه ترانسکت و در طـول هر ترانسکت ده پلات به‌طور سیستماتیک مستقر گردید و در هرپلات تعداد پایه‌هـای گیـاهی هر گونه گیاهی به‌منظور برآورد تراکم آن در واحد سطح ثبت گردید و جهت بـرآورد بیومـاس گیاهی نیز، تعدادی از پایه‌های هرگونه گیاهی از طریق روش قطع و توزین نمونه‌بـرداری شـد. میزان کربن اندام‌های گیاهی از طریق سوزاندن نمونـه‌هـای ۱۰ گرمـی خشـک شـده در آون، به‌دست آمد. در هر منطقه کلید و در طول هر ترانسکت، ۵ نمونه خاک از عمق‌های ۱۰-۰ و ۲۰-۱۰ سانتیمتر برداشته شد و به آزمایشگاه منتقل گردید و درصد کربن آلی خاک از طریـق روش والکلی و بلاک به‌دست آمد. تجزیه و تحلیل داده‌های گیاهی از روش تجزیه واریانس یک‌طرفه (ANOVA) و آزمون توکی در سطح اطمینان یک درصد و مقایسه کربن ترسیب شـده در خـاک منطقه قرق و خارج از قرق نیز از طریق آزمون تی مستقل و با استفاده از نرم افزار $SPSS_{16}$ انجام شد و در نهایت فایده اقتصادی کربن ترسیب یافته، برآورد گردید. نتایج نشانگر آن اسـت کـه پاسخ ذخیره کربن خاک و گیاه در مراتع گمیشان به اعمال قرق مثبت می‌باشد و بـین منطقـه قرق شده و خارج از قرق تفاوت معنی‌داری در مقدار کل کربن ذخیـره شـده در کـل بیومـاس گیاهی و نیز خاک وجود دارد. پس از ۲۰ سال اعمال قرق، ارزش کربن ترسیب شـده در مراتـع گمیشان، ۱۴۷۳۴ دلار در هکتار برآورد گردید. آمـوزش و تـرویج ترسـیب کـربن در ایـران، می‌تواند ارایه‌کننده مشوق‌های جدیدی درخصوص احیا مراتع تخریب یافته باشد.