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Effect of Fire and Rangeland Banqueting on Soil Carbon Sequestration in Atbatan Summer Rangelands, East Azerbaijan Province

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ABSTRACT

Aims In recent years, global warming has increased the importance of carbon sequestration. The present study was conducted to survey the effect of banqueting and fire on soil organic carbon (SOC) sequestration in Atbatan rangelands of Bostanabad District.
Materials & Methods For this purpose, using systematic-random strategy, composite soil samples were taken from fire happened 2 years ago (in 2 aspects of east and west), banqueting constructed 25 years ago (in 2 aspects of north and south), and control sites. The SOC was measured and results were analyzed, using two-way ANOVA.
Findings On the contrary of interaction effect, the main effects of aspect and fire were significant on SOC. The SOC of the control site with 28.9 t/ha was higher than the fire site with 21.76 t/ha. The average SOC in the eastern aspect was higher than the western aspect as such the average amount of SOC in western and eastern aspects were 28.94 t/ha and 21.72 t/ha, respectively. Banqueting had an increasing significant effect on SOC, as such SOC of the treatment site was 34.47 t/ha compared to the control site with 22.21 t/ha. The SOC in the northern and southern aspects was not significantly different, and the SOC of southern and northern aspects equaled 28.45 t/ha and 28.23 t/ha, respectively.
Conclusion In conclusion, according to the results of the study, the occurrence of fire in rangelands can reduce the amount of SOC. The rangeland banqueting increases the amount of SOC in both aspects.
Keywords Carbon Sequestration; Soil; Banqueting; Fire; Atbatan Rangelands

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Introduction

Rangelands, as one of the most important renewable sources of natural ecosystems, play a vital role in supplying various ecosystem services such as soil carbon sequestration. In many places, these ecosystems are destroyed over time through unproductive exploitation [1]. Improvement and rehabilitation of rangelands can enhance vegetation and soil characteristics quantitatively and qualitatively [2]. In the implementation of rangeland improvement and rehabilitation practices, the goals such as more forage production and upgrading rangeland fertility and soil conservation are followed [3]. These operations mainly focus on increasing vegetation cover, which may ultimately change the accumulation rate of carbon in aerial and underground biomass as well as soil [4].

The construction of banquet in the rangelands via reducing the slopes of the hillside and creating a barrel and stack with seeding on the walls are a series of operations implemented to increase productivity in the rangelands, ultimately enhance the ecosystem's ability to absorb and store carbon. In these areas, increasing water availability for plants will increase plant production, soil conservation, and reduce soil erosion [5]. Aradottir *et al.* [4] in northern rangelands of Iceland showed that the restoration of degraded lands leads to increase carbon sequestration in the plants aerial and underground organs and soil. Also, they found the amount of carbon sequestration varies from 0.1 to 0.5 ton hectare^{-1} year^{-1}, depending on the type of plant species and restoration method.

Rich [6] investigated the effects of banqueting after 20 years of implementation. The results showed that soil carbon storage did not show significant changes in both treatment and control areas, but *Agropyron* sp. coverage was 27% and 5% in treatment and control sites, respectively.

Li *et al.* [7] and Gammoh [8] state that the nutrient utilization of plants and carbon sequestration has been increased with rangeland improvement practices. The results of a study conducted by Niknahad Gharmakher *et al.* [9] revealed that the response of plant and soil carbon storage to the restoration practices of exclosure in Gomishan rangelands was positive and there was a significant difference between exclosure and grazing areas for the stored soil carbon.

In a study on determining the effects of grazing and fire on soil and vegetation properties by Akhzari *et al.* [10], it was found that the highest and the lowest above-ground biomass production (630 and 117 kg ha-1), Shannon-Wiener diversity index (2.37 and 1.07), soil total organic carbon (18.34 and 6.66 g kg-1), and soil porosity (69.43 and 57.74%) values were found in the unburned rangelands with 2000 m distance from the water source and the one year post burned rangelands with 10 m distance from the water source, respectively.

Naseri *et al.* [11], in a study aimed at estimating C stocks in 3 treatments including natural rangelands (NR), Pit- seeding by *Agropyrum elongatum* (PS), and abandoned dry farming (ADF) in Kardeh basin Mashhad, Iran found significant differences between treatments for total C stocks (soil+biomass+litter). NR and ADF management with the average values of 535.32 and 177.14 (t.ha^{-1}) had the highest and lowest C stocks, respectively. Singh [12] found that the construction of rainwater harvesting methods and seeding *Emblica officinalis* in southern Indian rangeland in 5 years would increase vegetation cover and increase soil parameters such as nitrogen and carbon storage.

Kashi *et al.* [13] in order to evaluate the effects of land use changes on soil organic carbon (OC) and nitrogen stock (N), in 2 sites of rangelands (*Astragalus parrowianus* and *Acantholimon erinaceum*) and 1 site of walnut garden in northwest of Shahmirzad, Semnan province, Iran found no significant difference of soil OC among garden and rangelands, but there was a significant difference for N and higher values were obtained in the garden site.

Ehsani *et al.* [14] in studying the variation of carbon sequestration in *Halocnemum strobilaceum* and soil under livestock grazing in salt lands of Golestan Province, Iran found that the sum of underground and aboveground biomass C in light grazing site was more than the heavy and moderate grazing sites, which were about 1.17, 1.07, and 0.567 t.ha^{-1}, respectively. The amount of soil C for the mentioned sites was 162.56, 137.39, and 80.76 t.ha^{-1}, respectively. The soil C comprised more than 99% of ecosystem total stored C (biomass and soil C) in each site. In terms of total ecosystem C, the heavy and moderate grazing site had about 84.37 and 32.20 t.ha^{-1} less C compared to light grazing site.

Fire, as an ecological factor, can have negative or positive effects on the ecosystem components and has importance for planners from point of view of natural resource management. The effects of fire on the ecosystem depend on season, repetition, type, and severity of the fire [15]. The fire has major effects on soil organic factors. Since organic matter in soil has a main effect on soil fertility, therefore, this factor should be carefully considered and studied [16]. The fire may be prescribed (controlled) or accidental (wild), and in some cases, is counted as an improvement factor for vegetation and soil [17].

Incidental fires release a large amount of carbon into the atmosphere as carbon dioxide and affect carbon storage in the soil [18]. The burning of litters and plant materials releases the minerals and as a result, increases plant nutrients in the soil and reduces the amount of carbon in the soil. Some studies have also shown that grazing, fires, and fertilization have increased the amount of carbon in Great Plains in the United States [19]. Attaeian [20] in estimation of aboveground biomass carbon sequestration potential in the rangeland ecosystems of Iran, stated that considering the total rangeland area (≈ 84.8 million hectares) and productivity of Iran, 11770.011 Gg C y^{-1} carbon is stored in above-ground biomass annually, providing at least 5885 Gg organic C sequestration potential.

Gómez-Rey *et al.* [21] have investigated the effect of controlled fire on soil chemical properties in the northwest of Spain, indicating that the amount of phosphorus, ammonium, nitrogen, and calcium increased after the fire. Also, they did not find any changes in the amount of carbon and nitrogen due to high levels of carbon and nitrogen in the studied soils. Badía *et al.* [16] in studying the effect of incidental fires on the values of soil parameters in the northeast of Spain found that the amount of calcium, magnesium, potassium, ammonium, nitrate, and phosphorus 1 week after a fire has increased significantly, but the other results of the study showed that the organic carbon storage of soil after a week has decreased. García-Corona *et al*. [22] states that with increasing heat, the amount of soil moisture storage capacity and organic matter is reduced.

Thornley and Cannell [23] also reported that long-term fire could reduce the productivity and soil carbon and, on the other hand, release carbon and nitrogen to the atmosphere. Pathak *et al.* [24], in a research aimed at determining the effect of fire suppressions for destroying the *Imperata cylindrica* invader species in grasslands, found the amount of carbon storage in soil and surface biomass in fire site after 300 days from the occurrence of fire is about 44% and 14% higher carbon related to non-fire, respectively.

Review of studies shows that the response of soil carbon storage in banqueting operations strongly depends on the type of vegetation and environmental factors and, on the other hand, the effect of the fire on the carbon soil sequestration is not fully understood in natural ecosystems, especially in arid and semi-arid rangelands, and the effect of firefighting on soil organic carbon depends on factors such as type and severity of fire, soil moisture, and soil type [25]. Therefore, this study was carried out to investigate the effects of banqueting construction and fire on the amount of soil carbon sequestration.

The rangelands of Atbatan district of Bostanabad are part of the semi-steppe region. For restoration, the rangelands of the region, the banqueting rehabitation operation with seeding of *Bromus tomentollus* has been carried out. In part of the region, fire occurred in 2014, and according to local investigations, the fire occurred in the area are unintentional due to people's negligence. The purpose of this study was to investigate the amount of organic carbon sequestrated in the studied sites, including various fire treatment and banquet construction. Our hypotheses suggest that 1) rangeland banqueting can help to improve soil carbon reserves and 2) fire occurrence leads to decrease soil carbon reserves in the semi-arid regions such as Atbatan rangelands.

Materials and Methods

Study area: The study was carried out in the Atbatan rangelands of Bostan Abad district, located 75 km far from Tabriz and 7 km far from Bostanabad with geographical coordination of 37°52′ 10′′ to 37°53′ 20′′ N and 46°53′ 1′′ to 46°52′ 42′′ E (Figure 1). The region has milder summers and cold winters with the annual rainfall of 300 mm. Ambrotermic curve of the study area are presented in Diagram 1. The dominant plants in the rangeland include *Stipa barbata* Michx., *Astragalus gossypinus* Fisch., and *Artemisia fragrans* Willd. In the Atbatan rangelands, biomechanical operations of banquet with seeding of the species Bromus tomentellous Boiss. has been done in both northern and southern aspects. The fire has occurred in the east and west aspects. The approximate time of fire treatment was in 2014 and the banqueting with seeding was conducted about 25 years ago. Therefore, 4 above treatments were selected as study sites. In order to investigate the effect of each treatment on soil carbon sequestration, the control areas were selected for each treatment, taking into account environmental factors being similar to treated areas adjacent with each treatment. Therefore, due to the availability of these conditions in Atbatan rangelands and regarding the objectives of current research, 8 sites (including 4 treatment sites and 4 control sites) were considered in this region to study the effects of rangeland banqueting and fire occurrence on soil organic carbon reservation.

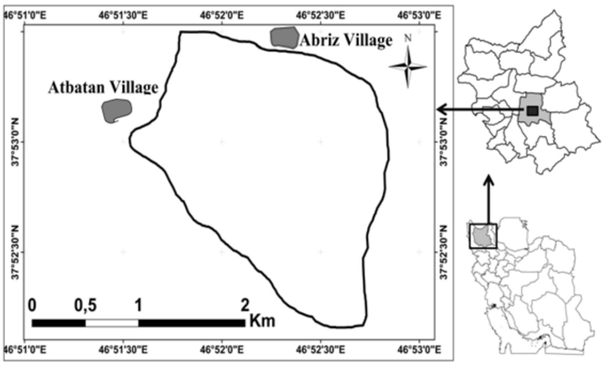

Figure 1) Location of study area in the country and the East Azerbaijan province

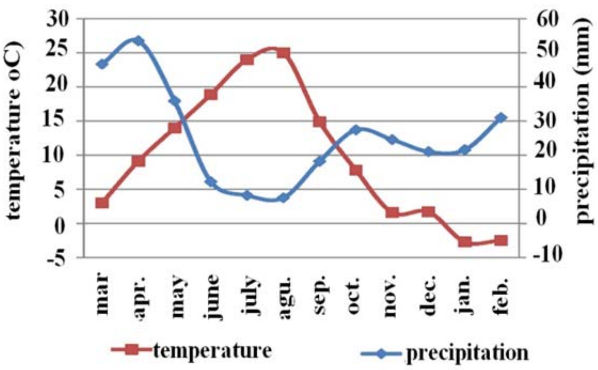

Diagram 1) Ambrotermic curve of the study area

Soil sampling: In each of the sites, with random-systematic strategy, three 30-meter transects were established in each site. Three soil profiles were digged at the beginning, middle, and end of each transect, and from a depth of 0-30 cm (root depth of dominant species), soil samples were taken. Then, the first, middle and end samples were mixed together and a composite sample was extracted. Finally, in this study, 24 soil samples were taken from sites. The soil samples were dried in shade and passed with 0.5 millimeter sieve, and transferred to the laboratory for carbon measurements. In addition to 24 soil samples, by a metal cylinder, soils samples in the middle of each transect were taken to measure the bulk density of the soil. The soil samples taken from the cylinder were passed through 2 mm sieve after drying in the oven for 24 hours, and the gravel was obtained for the samples. Finally, using cylinder data and gravel quantity, the bulk density of soil without gravel was obtained in grams per cubic centimeter by dividing the weight of the sieved soil on the volume of the cylinder [26].

Laboratory measurement and soil organic carbon calculations: Regarding the locating the study site in semi-arid region, the organic carbon content of the soil was determined by Walkly and Black method [27, 28]. To improve the results and increase the accuracy, each soil sample was analyzed 3 times and an average of them was extracted. There are some uncertainties in the carbon stock estimates in the soil, which may lead to errors in carbon stock assessment plans over time and place including elimination of soil gravel [29, 30]. In order to calculate the mass of carbon with the amount of organic carbon content and soil bulk density without gravel, the equation 1 was used [31].

Equation 1:

$$SOC = D.OC.BD.100$$

SOC, the amount of carbon mass per hectare and the specified depth (30 cm in this study), BD, bulk density of soil without gravel in grams per cubic centimeter, OC, organic carbon in percent, and D, the depth is equivalent to calculating the soil in meters.

Statistical analysis: Kolmogrov-Smirnov test was used to test the data normality and the Levene's test was used to examine the homogeneity of variances. In order to investigate the effect of the banquet construction on the amount of carbon sequestration and to assess the main effects of the factors, two-way analysis of variance with two factors of aspect (two northern and southern aspects) and the banqueting factor (two levels including the banqueting and control site) were used. Also, for analyzing the amount of soil organic carbon in the fire site and assessing the significant effects of the fire and aspect factors and the interaction, two-way analysis of variance with two factors of aspect (at two levels to the west and east aspects) and the fire factor (in two levels of fire site and control site) were used. In order to compare the means, Tukey's comparison test was used. All analyzes were performed with the Minitab version 17.

Findings

Results of the analysis of carbon storage changes due to fire: The results of two-way analysis of variance for the amount of soil organic carbon in the fire occurred area (Table 1) showed that the main effects of the site aspect and treatment (fire and without fire) on the amount of carbon was significant ($p<0.05$).

Table 1) Two-way analysis of variance of the soil organic carbon in aspect and fire treatment

Variable	F	Sig
Aspect	5.64*	0.045
Treatment	5.5*	0.047
Aspect*Treatment	0.09ns	0.76

*Significant difference at 5% level and ns no significant difference

In other words, there was a significant difference in the soil organic carbon content at the 5% level between the studied aspects and the fire treatments. The interaction of site aspect in treatment (fire), based on the results of two-way analysis of variance, was not significant. It can be stated that the fire had a significant effect regardless of aspect on carbon content of soil.

The results of the average carbon in the fire site and its control site are presented in Diagram 2.

As shown in Diagram 1, there was a significant difference between the fire treatment (28.9 t/ha) and control site (21.76 t/ha) in terms of the organic carbon at 5% level, and fire burning had caused a significant reduction in soil carbon storage. The result of the average organic carbon storage in the western and eastern slopes related to the main effects of the site is presented in Diagram 3.

As shown in Diagram 2, the average organic carbon of the western slopes (28.98 t/ha) and east (21.72 t/ha) was significantly different at 5% level, and the average carbon in the west aspect was more than the eastern aspects.

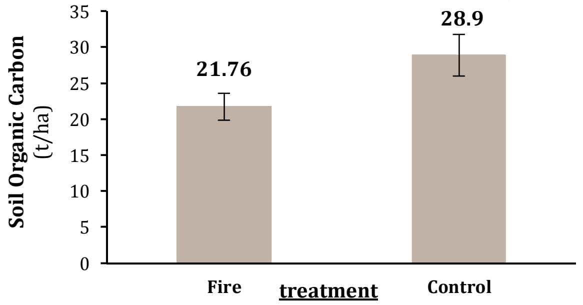

Diagram 2) Comparison of the mean soil carbon mass in fire and control sites by Tukey's comparison test

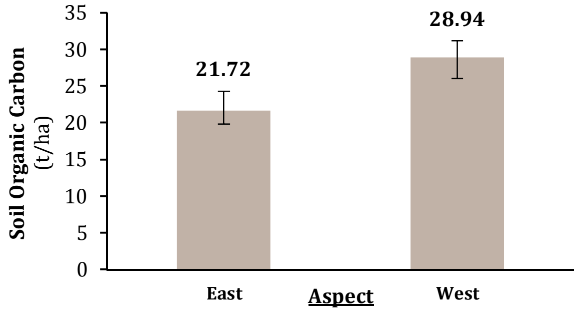

Diagram 3) Comparison of the mean soil carbon in the western and eastern aspects in the fire treatment by Tukey's comparison test

Analysis of soil carbon change due to the construction of the banquet: The results of analysis of two-way variance of the amount of soil organic carbon in the studied sites (Table 2) showed that the main effect of the site (hillside direction) on the amount of carbon storage was not significant. In other words, there was no significant difference between the studied aspects in terms of soil organic carbon, but the main effect of treatment (banqueting and control) on carbon content was significant. The interaction of the site (aspect) in the treatment site (banqueting) was not significant. This implied that the variation of the aspect did not have a significant effect on the trend of carbon changes in the treatments, and it can be noted that banqueting could affect the carbon content of the soil regardless of the aspect.

Table 2) two-way analysis of variance of soil organic carbon in aspect and banqueting treatment

Variable	F	Sig
Aspect	0.002ns	0.965
Treatment	6.15*	0.038
Aspect*Treatment	1.41ns	0.268

* There is significant difference at level of 5% and ns there is no significant difference

The results of the average organic carbon storage in the sites of banqueting and its control are presented in Diagram 4.

Based on Diagram 5, the average organic carbon storage in the control site (22.21 t/ha) was significantly lower than the banqueting site (34.47 t/ha; α<5%) and, therefore, construction of the banquet increased soil carbon storage.

As shown in Diagram 4, there was no significant difference between the mean organic carbon of northern (28.23 t/ha) and south aspects (28.45 t/ha; α> 5%). In other words, the slope had no effects on soil organic carbon.

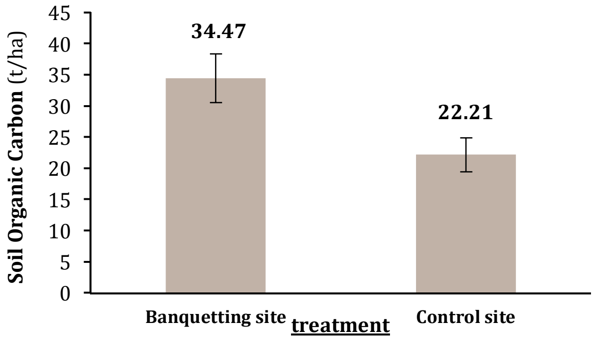

Diagram 4) Comparison of the mean soil carbon in banqueting and control sites by Tukey's comparison test

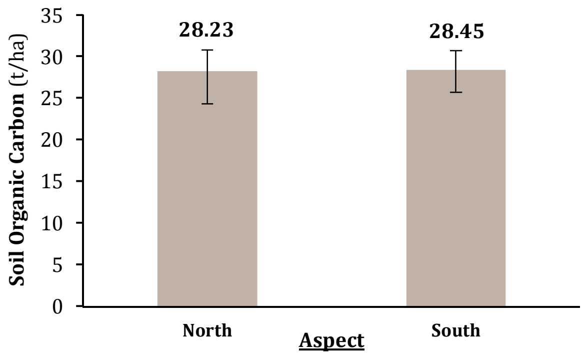

Diagram 5) Comparison of the mean soil carbon in the northern and southern aspects in banqueting treatment by Tukey's comparison test

Discussion

Rangelands contain more than a third of global carbon stock and play a major role for carbon sequestration [28]. Fire is one of the major factors affecting rangelands, which occurred in uncontrolled and controlled (prescribed) manner [32, 33].

In the studied rangeland sites, the amount of sequestrated carbon has been affected by aspects and fire factors as the amount of stored carbon in the fire site equals 21.72 tons per hectare and in adjacent control site equals 28.9 tons per hectare. Therefore, it is concluded the occurred fire has released a large amount of carbon as carbon dioxide, and reduced the carbon storage of soil in comparison with control site.

Regardless of the aspect, this situation is significantly due to burning of litters and plant materials and the release of organic carbon to the atmosphere. Most studies have investigated the effect of fire on soil organic matter, and have reported a decrease in soil carbon amount after the fire [28, 34, 35]. The burning of vegetation and organic matter in the surface horizon of the soil humus (O horizon), and the reduction of plant carbon entering the soil in the fire areas have been introduced as the reason for this fact [28, 36].

Studies by Certini [37]; Verma and Jaykumar [38] about the effect of fire on soil properties suggest that the fire reduces the amount of organic material in the soil and leads to the destruction of the soil structure. In another study, Fernández *et al.* [39] examined the effect of severe fire on the soil organic carbon and concluded that if the combustion temperature is between 250-350°C, more than 50% of the soil organic matter will be lost. In addition, the temperatures of more than 350°C cause a loss of 100% in organic carbon.

It is needed to determine the temperature created by the fire in this region to predict soil organic carbon loss in modeling researches. According to Nazari *et al.* [40], with increasing fire intensity, the percentage of organic carbon and total nitrogen in the soil decreases and the amount of available phosphorus is increased. Also, Augustine *et al.* [41] believes that the annual burning increases soil inorganic N availability throughout the growing season, which was associated with increased soil temperature and a reduction in aboveground N in C_3 plants.

Also, based on the research conducted by Gómez-Rey *et al.* [21], the amount of phosphorus, ammonium, nitrogen, sodium, potassium, copper, and zinc will increase after the fire. The amount of calcium, magnesium, potassium, ammonium, and nitrate will significantly increase a week after the fire at a depth of 1 cm. Other studies on fire consequences have shown that fire may have a decreasing or increasing effect on carbon balance [42- 44]. In this regard, it is stated if the amount of carbon added from biomass exceeds the amount of carbon in the soil, this could lead to an increase in soil carbon, and although the amount of organic carbon precipitated by the fire in the soil decreases, for reasons such as the addition of semi-burned plant residues and dead roots due to perennials and dead plants, ground floor may increase total carbon storage [45].

There are other reports on the effect of reducing biomass and litter carbon by the fire and the lack of effect on the soil carbon content due to the low fuel content and the low temperature of the fire [46].

According to the findings of this research, the amount of stored carbon in the banqueting site, regardless of the aspect, is 47.43 tons per hectare and in the control area, it is 21.22 tons per hectare. In other words, the construction of the banquet has increased the amount of soil organic carbon. There is no significant difference between organic carbon stored in both northern and southern aspects. It is observed that the construction of the banquet, due to increased vegetation and increased atmospheric carbon dioxide capture potential, increases the carbon storage of soil organic matter; this result is consistent with a study conducted by Naghipour borj and Farokhnia [47]. Other studies have approved that rehabitation of land with banquet has increased vegetation biomass and consequently carbon sequestration [48, 49]. Particularly, the planting of *Bromus tomentellus* seeds in the study sites has also increased the speed of this process. Li *et al.* [7] and Gammoh [8] also argue that the use of rainwater harvesting methods can increase the potential use of plants from rainwater and nutrients, and it leads to increase carbon sequestration capacity of soils. Singh *et al.* [12] found that the construction of rainwater harvesting structures and *Emblica officinalis* seedlings in Southern Indian rangelands would increase vegetation cover and increase soil parameters such as NO_3-N and carbon storage in five years. Tavakoli, [50] has stated that the conservation of natural vegetation or restoration of degraded lands by suitable plants has good potentials for carbon sequestration. Other studies showed that higher carbon sequestration occurs in the soil restored by biological and mechanical activities [51].

It is recommended to avoid any kind of destruction and fire that has a negative effect on the absorption of carbon dioxide in the atmosphere. Also, the construction of the improvement of the banquet that enhances vegetation and accumulation of soil carbon are suggested.

Conclusion

In conclusion, according to the results of the study, the occurrence of fire in rangelands can reduce the amount of organic carbon of the soil. The implementation of banquet construction in rangelands increases the amount of organic carbon in the soil, and in both aspects, it increases the amount of organic carbon in the areas under construction.

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References

1- Azarnivand H, Zare Chahuki MA. Range improvement. Tehran: University of Tehran; 2008. [Persian]

2- Jangju M. Improvement and development of rangeland. Mashhad: Academic Center for Education Culture and Research; 2009. [Persian]

3- Lu D, Moran E, Mausel P. Linking Amazonian secondary succession forest growth to soil properties. Land Degrad Dev. 2002;13(4):331-43.

4- Aradóttir ÁL, Svavarsdóttir K, Jónsson ÞH, Guðbergsson G. Carbon accumulation in vegetation and soils by reclamation of degraded areas. Icel Agric Sci. 2000;13:99-113.

5- Jahantigh M, Pessarakli M. Utilization of contour furrow and pitting techniques on desert rangelands: Evaluation of runoff, sediment, soil water content and vegetation cover. J Food Agric Environ. 2009;7(2):736-9.

6- Rich TD. Effects of contour furrowing on soils, vegetation and grassland breeding birds in North Dakota. In: John Ralph C, Rich TD, Pacific Southwest Research Station. Bird conservation implementation and integration in the Americas: Proceedings of the Third International Partners in Flight Conference, March 20-24, 2002,

Asilomar, California. 1st Volume. Albany CA: USDA Forest Service Pacific Southwest Research Station; 2005. pp. 496-503.
7- Li WQ, Xiao-Jing L, Ajmal Khan M, Gul B. Relationship between soil characteristics and halophytic vegetation in coastal region of North China. Pak J Bot. 2008;40(3):1081-90.
8- Gammoh IA. A mechanized system for establishment of forage shrubs in water harvesting micro-catchment structures. Int J Bot. 2011;7(2):145-53.
9- Niknahad Gharmakher H, Jafari Foutami I, Sharifi A. Effects of grazing exclusion on plant productivity and carbon sequestration (Case study: Gomishan rangelands, Golestan province, Iran). J Rangel Sci. 2015;5(2):122-34.
10- Akhzari D, Pessarakli M, Mahmoodi F, Farokhzadeh B. Effects of grazing and fire on soil and vegetation properties in a semi-arid rangeland. Ecopersia. 2015;3(1):901-16.
11- Naseri S, Tavakoli H, Jafari M, Arzani H. Impacts of rangeland reclamation and management on carbon stock in North East of Iran (Case study: Kardeh basin, Mashhad, Iran). J Rangel Sci. 2016;6(4):320-33.
12- Singh G, Khan AU, Kumar A, Bala N, Tomar U K. Effects of rainwater harvesting and afforestation on soil properties and growth of Emblica officinalis while restoring degraded hills in Western India. Afr J Environ Sci Technol. 2012;6(8):300-11.
13- Kashi H, Abdipoor M, Arastoo B. Impacts of land use changes on soil carbon and nitrogen stocks (Case study: Shahmirzad lands, Semnan province, Iran). J Rangel Sci. 2016;6(2):156-67.
14- Ehsani SM, Sheidai Karkaj E, Alilou F. Variation of carbon sequestration in Halocnemum strobilaceum and soil under livestock grazing (Case study: Salt lands of Golestan province, Iran). Ecopersia. 2017;5(3):1875-86.
15- Foster CN, Barton PS, Robinson NM, MacGregor CI, Lindenmayer DB. Effects of a large wildfire on vegetation structure in a variable fire mosaic. Ecol Appl. 2017;27(8):2369-81.
16- Badía D, Martí C, Aguirre AJ, Aznar JM, González-Pérez JA, De la Rosa JM, et al. Wildfire effects on nutrients and organic carbon of a Rendzic Phaeozem in NE Spain: Changes at cm-scale topsoil. Catena. 2014;113:267-75.
17- Mesdaghi M. Rangeland management in Iran. 2nd Edition. Mashhad: Imam Reza International University; 2003. [Persian]
18- Thomey ML, Ford PL, Reeves MC, Finch DM, Litvak ME, Collins SL. Climate change impacts on future carbon stores and management of warm deserts of the United States. Rangel. 2014;36(1):16-24.
19- Mortenson MC, Schuman GE, Ingram LJ. Carbon sequestration in rangelands interseeded with yellow-flowering alfalfa (Medicago sativa ssp. falcata). Environ Manag. 2004;33 Suppl 1:S475-81.
20- Attaeian B. Estimation of aboveground biomass carbon sequestration potential in the rangeland ecosystems of Iran. Ecopersia. 2016;4(1):1283-94.
21- Gómez-Rey MX, Couto-Vázquez A, García-Marco S, González-Prieto SJ. Impact of fire and post-fire management techniques on soil chemical properties. Geoderma. 2013;195-196:155-64.
22- García-Corona R, Benito E, de Blas E, Varela ME. Effects of heating on some soil physical properties related to its hydrological behavior in two north-western Spanish soils. Int J Wildland Fire. 2004;13(2):195-9.
23- Thornley JH, Cannell MG. Long-term effects of fire frequency on carbon storage and productivity of boreal forests: A modeling study. Tree Physiol. 2004;24(7):765-73.
24- Pathak K, Jyoti Nath A, Sileshi GW, Lal R, Kumar Das A. Annual burning enhances biomass production and nutrient cycling in degraded Imperata grasslands. Land Degrad Dev. 2017;28(5):1763-71.
25- González-Pérez JA, González-Vila FJ, Almendros G, Knicker H. The effect of fire on soil organic matter--a review. Environ Int. 2004;30(6):855-70.
26- Blake GR. Bulk density. In: Blake CA. Methods of soil analysis, part 1: Physical and mineralogical properties, including statistics of measurement and sampling. Blake CA, editor. Madison WI: American Society of Agronomy; 1965. pp. 374-90.
27- Nelson DW, Sommers LE. Total carbon, organic carbon, and organic matter. In: Sparks L. Methods of soil analysis, part 3: Chemical methods. Soil Science Society of America, American Society of Agronomy, editors. Madison WI: Soil Science Society of America; 1996. pp. 961-1010.
28- Lal R. Soil carbon sequestration to mitigate climate change. Geoderma. 2004;123(1-2):1-22.
29- Ellert BH, Bettany JR. Calculation of organic matter and nutrients stored in soils under contrasting management regimes. Can J Soil Sci. 1995;75(4): 529-38.
30- Tian G, Granato TC, Cox AE, Pietz RI, Carlson CR Jr, Abedin Z. Soil carbon sequestration resulting from long term application of biosolids for land reclamation. J Environ Qual. 2009;38(1):61-74.
31- Deng L, Sweeney S, Shangguan Z. Long-term effects of natural enclosure: Carbon stocks, sequestration rates and potential for grassland ecosystems in the Loess Plateau. Clean Soil Air Water. 2014;42(5):617-25.
32- Bowman DMJS, Balch JK, Artaxo P, Bond WJ, Carlson JM, Cochrane MA, et al. Fire in the earth system. Science. 2009;324(5926):481-4.
33- Mataix-Solera J, Cerdà A, Arcenegui V, Jordán A, Zavala LM. Fire effects on soil aggregation: A review. Earth Sci Rev. 2011;109(1-2):44-60.
34- Abril A, Barttfeld P, Bucher EH. The effect of fire and overgrazing disturbers on soil carbon balance in the Dry Chaco forest. For Ecol Manag. 2005;206(1-3):399-405.
35- Neff JC, Harden JW, Gleixner G. Fire effects on soil organic matter content, composition, and nutrients in boreal interior Alaska. Can J For Res. 2005;35(9):2178-87.
36- Granged AJP, Jordán A, Zavala LM, Muñoz-Rojas M, Mataix-Solera J. Short-term effects of experimental fire for a soil under eucalyptus forest (SE Australia). Geoderma. 2011;167-168:125-34.
37- Certini G. Effects of fire on properties of forest soils: A review. Oecologia. 2005;143(1):1-10.
38- Verma S, Jayakumar S. Impact of forest fire on physical, chemical and biological properties of soil: A review. Proc Int Acad Ecol Environ Sci. 2012;2(3)168-76.
39- Fernández I, Cabaneiro A, Carballas T. Carbon mineralization dynamics in soils after wildfires in two Galician forests. Soil Biol Biochem. 1999;31(13):1853-65.
40- Nazari F, Hosseini V, Shabanian N. Effect of fire severity on organic carbon, total nitrogen and available phosphorus of forest soils (Case study: Marivan). Iran J For Poplar Res. 2012;20(1):25-37. [Persian]
41- Augustine DJ, Brewer P, Blumenthal DM, Derner JD, von Fischer JC. Prescribed fire, soil inorganic nitrogen dynamics, and plant responses in a semiarid grassland. J Arid Environ. 2014;104: 59-66.
42- Wiedinmyer C, Hurteau MD. Prescribed fire as a means

of reducing forest carbon emissions in the Western United States. Environ Sci Technol. 2010;44(6):1926-32.

43- Hebel CL, Smith JE, Cromack K. Invasive plant species and soil microbial response to wildfire burn severity in the Cascade Range of Oregon. Appl Soil Ecol. 2009;42:150-9.

44- Whelan A, Mitchell R, Staudhammer C, Starr G. Cyclic occurrence of fire and its role in carbon dynamics along an edaphic moisture gradient in longleaf pine ecosystems. PLoS One. 2013;8(1):e54045.

45- Zhao H, Tong DQ, Lin Q, Lu X, Wang G. Effect of fires on soil organic carbon pool and mineralization in a Northeastern China wetland. Geoderma. 2012;189-190:532-9.

46- Jones R, Chambers JC, Johnson DW, Blank RR, Board DI. Effect of repeated burning on plant and soil carbon and nitrogen in cheatgrass (Bromus tectorum) dominated ecosystems. Plant Soil. 2015;386(1-2):47-64.

47- Naghipour borj AA, Farokhnia S. The effect of fire on carbon sequestration of soil and plant biomass in Semi-Steppe rangelands of Central Zagros region, Iran. J Plant Ecosyst Cons. 2017;5(10):39-51. [Persian]

48- Post WM, Kwon KC. Soil carbon sequestration and land-use change: Processes and potential. Glob Chang Biol. 2000;6(3):317-27.

49- Mofidi M, Jafari M, Tavili A, Alijanpour A. Effect of Three rangeland improvement practices on vegetation properties in Emam Kandi Rangelands, Urmia. Watershed Manag Res. 2017;29(4):30-9.

50- Tavakoli H. Potential of carbon sequestration of Hammada salicornica vegetation type in desert areas (Case study: South Khorasan, Iran). J Rangel Sci. 2016;6(1):24-32.

51- Yousefian M, Mahdavi Kh, Mahdavi M, Tamartash R. Evaluation of enclosure effects on soil carbon storage (Case study: Rangeland of Shahtappeh-Chah Mahmood and Chiro in Semnan province). J Rangel Sci. 2011;2(1):439-48.