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Carbon pool capacity of plant species *Calligonum comosum* L. and *Haloxylon ammodendron* (C.A.Mey.) bunge in Mirjaveh plain

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Abstract

Rangelands are one of the most important terrestrial ecosystems in terms of carbon sequestration. In this study, the amount of carbon pool was measured and compared during the year 2021 in the habitats of *Haloxylon ammodendron* and *Calligonum comosum* in Mirjaveh plain, Sistan and Baluchestan Province. The research was based on a completely randomized design. Above and belowground biomass was harvested along 100 m transects. In order to determine the soil carbon pool of plant species, sampling was performed from three depths (0-15, 15-30 and 30-45 cm). The amount of soil and plant organic carbon, bulk density and carbon storage of plant and soil were measured. Data were analyzed using SPPSS.20. The results showed that in both habitats, the highest and lowest amounts of organic carbon and soil carbon pool were related to depths 0-15 and 15-30 cm, respectively. Results showed that in both habitats, soil carbon pool, bulk density, and organic carbon had the maximum levels in the 0-15 cm soil layer. In *C. comosum* habitat, Cp in the 0-15 cm depth was more than the same soil depth in *H. ammodendron* habitat. For both plants, Cp in the belowground biomass was significantly more than the aboveground biomass ($p<0.01$). In particular, our study showed that *C. comosum* has more potential to store carbon compared with *H. ammodendron*. The use of shrubs in biological practices can increase the carbon pool in arid areas.

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Introduction

Carbon (C) stock in rangeland ecosystems is an essential part of the global C cycle. Statistics show that between 10-30% of organic carbon (OC) in the world is stored in rangelands (Feyisa et al., 2017; Hu et al., 2020; Tessema et al., 2020). Thus, rangelands have an essential role in regulating the C cycle and global climate change (Shirzai et al., 2020). Consequently, studying soil C dynamics and its controlling factors in rangeland ecosystems helps to understand and evaluate the C cycle and climate changes (Yang et al., 2020).

Since the beginning of the industrial revolution in the mid-19th century, the amount of CO_2 in the atmosphere has risen from 280 to 365 parts per million and is expected to reach 600 parts per million in the 21th century. This causes the annual temperature of the earth to rise to 1- 4.5°C (Shirzai et al., 2020). The amount of CO_2 in the atmosphere has increased by about 31% since 1750 due to use of fossil fuels and soil degradation, which are the main reasons for global warming and climate change (Conant et al., 2017; Hashemi Rad et al., 2018). In this regard, increasing C pool (Cp) in plant biomass and soils is the simplest and the most economically viable solution to reduce atmospheric CO_2 (Mohammadi et al., 2018).

In Iran, rangelands are of significant socio-economic and ecological advantages. Management practices for rangeland rehabilitation include techniques that increase soil fertility, vegetation cover and environmental conservation (Moghbeli et al., 2021). Biological restoration in arid rangelands can be utilized to increase C levels in the soil, suggesting potential strategies for Cp (Ghasemi Nejad Raeeni and Sadeghi, 2018).

Although the accumulation of C in the arid rangelands is low, if corrective operations are carried out, the rangelands can approximately absorb one billion tons of OC, which is equivalent to about 20 million tons of oil (UNDP, 2000; Tessema et al., 2020). Tree and shrub planting must meet ecological and social needs and, where appropriate, prevent wind and water erosion (Ebrahimi et al., 2019).

In Iran, some studies have considered the importance of biological practices as suitable management tools for increasing soil Cp and reclamation of degraded rangelands. Souri et al. (2020) investigated the C storage capacity of *Artemisia sieberi* under the influence of exclusion and livestock grazing in Kalat Sadat Abad area, Sabzevar. Their results showed that the exclusion area had more Cp than the grazing area. Miri Panah (2017) studied the amount of soil Cp in Mehran plain, Ilam. The results showed that the habitat of *Prosopis juliflora* had more Cp than the habitat of *Eucalyptus camaldulensis* at soil surface layers. For the plants, the maximum Cp was measured in the stem and branches, respectively.

The arid area of Mirjaveh is one of the steppe rangelands of Sistan and Baluchestan Province, Iran. Since 1990, large parts of the area have been planted with perennial plants to combat wind erosion. However, little research has focused on the impacts of biological restoration of soil Cp in desert rangelands in Iran. The objective of the study was to determine the effects of biological restoration using two native plants *Calligonum comosum* L. and *Haloxylon ammodendron* (C.A.Mey.) Bunge, on Cp of the plant-soil components. In spite of difficulty of measuring Cp of belowground biomass for perennial species we have implemented this measurement. Our hypotheses were: (1) Cp at belowground parts of both plants is more significant than aboveground parts, and (2) soil Cp in *C. comosum* habitat is higher than that of *H. ammodendron* habitat.

Materials and Methods

Study area

The area is situated in the East of Sistan and Baluchestan (latitudes 29° 58′ 12′′–28° 55′ 03′′ N and longitudes 60° 08′ 03′′–61° 47′ 05′′E). The regional climate of the area is dry (using Köppen method). The average annual rainfall and temperature are around 30 mm and 22.60°C, respectively. The mean elevation of the site is 858 m. The region has an ordinary plain landscape, covered with shrubs and bushes (Figure 1). Wind erosion and land degradation are common environmental challenges in the region. The soil has sandy texture with electrical conductivity (ECe) and pH around 5.03 dS m^{-1} and 8.66, respectively. The soil calcium carbonate ($CaCO_3$) was measured at around 388 g kg^{-1}. Soil in the area is low in potassium (99 mg kg^{-1}) and phosphorous (1.77 mg kg^{-1}) content (Report of Rangeland Improvement, Mirjaveh, Sistan and Baluchestan, 2015).

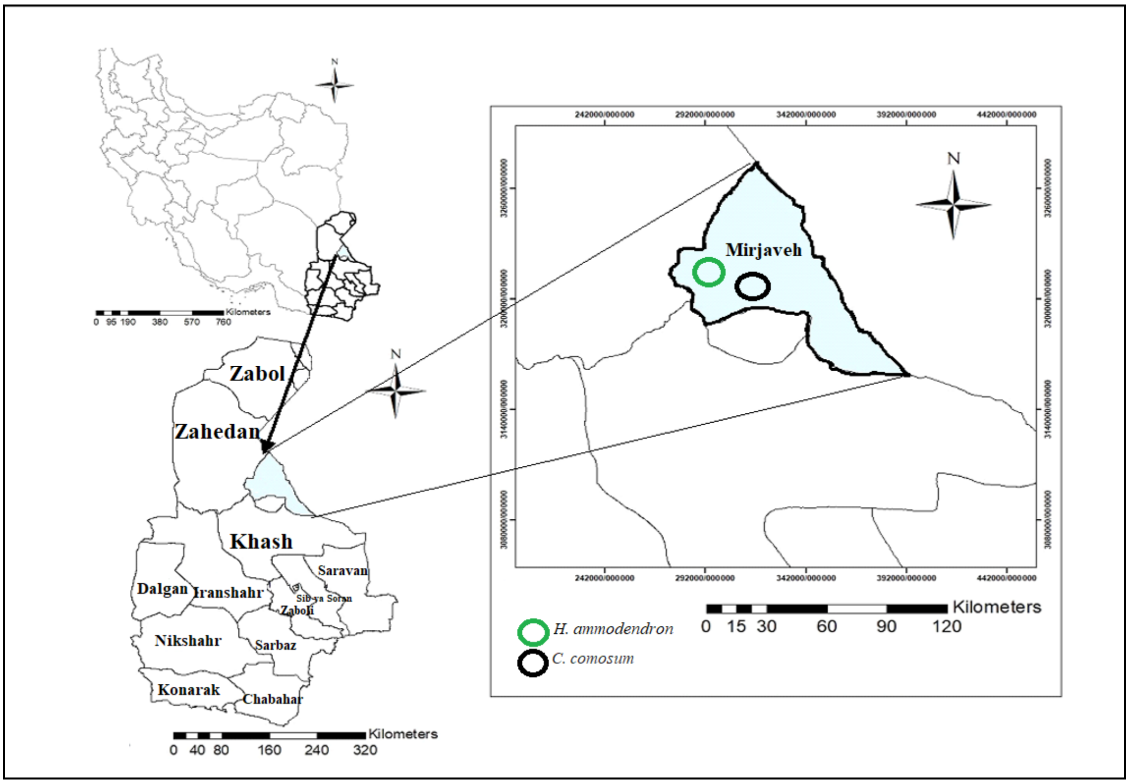

Figure 1. The location of sampling in Mirjaveh rangeland

Sampling method

We selected two habitats (pure stand of *C. comosum* and *H. ammodendron*) that underwent succession for 20 years (artificial perennial plants). There was no difference between topography, soil and landscape features between the selected areas. Data sampling (randomized complete block design) was implemented in March (2020) along the transect lines (100 m) (Arzani and Abedi, 2015) within quadrats (10m×10m). Six transect lines were placed in a systematic random method and along each transect within quadrats with 25 m intervals, all aboveground biomass of each species were removed and put into plastic bags (24 samples). The aboveground parts of the plants were oven-dried (70°C, 48 hr) and weighed to measure the dry mass. In order to measure the belowground Cp, plant' roots were sampled at five points (30 samples) along the transects under canopy of plant species (within quadrats) using an auger from depth 0-15 cm to 30-45 cm (Mirlashkari, 2016). Root samples were washed with tap water and then dried in oven (70°C for 48 hr). Plant Cp was measured by dry combustion method (MacDicken, 1997). Soil samples (36 samples) were collected from three layers (0–15, 15–30, 30–45 cm) at the beginning and end of each transect. The soil samples passed through sieve (0.16 mm) to remove roots and debris. Volumetric ring method used to determine soil bulk density (BD) (Wu et al., 2010). Organic carbon was determined using dichromate oxidation (Nelson and Sommers, 1996). The soil carbon pool was calculated using the formula: Cp=BD×SOC×D (Deng et al., 2013, Wang et al., 2014). In this formula, Cp equals the soil carbon pool (kg m^{-2}); BD indicates bulk density (g cm^{-3}); SOC shows soil organic carbon (g kg^{-1}), and D is depth of soil sample (m).

Data analysis

Statistical analysis consisted of one-way ANOVA and T-test (using SPSS. 18.0). We used Kolmogorov-Smirnov test to check data normality. The Levene's test ($p < 0.05$) was used to check the homogeneity of the data, and logarithmic transformation was performed when necessary. Duncan multiple range test was performed to test significant differences among Cp in soil layers.

Results

Soil Cp

Results showed that OC, Cp and bulk density among different soil layers of *C. comosum* habitat were significantly different ($p<0.01$) (Table 1). A similar result was obtained for the soil under cover of *H. ammodendron* ($p<0.05$). The mean comparison (Table 2) proved that in *C. comosum* habitat, the 0-15 cm depth had significantly higher OC ($p<0.01$), when compared with the other two depths, but it was not significantly different between the 15-30 and 30-45 cm layers. Bulk density followed the same pattern. The Cp value was the highest in the depth 0-15 cm, but it had no significant difference between the 15-30 and 30-45 cm depths.

Mean comparison (Table 2) showed that in habitat of *H. ammodendron*, OC and Cp were greater in 0-15 cm depth compared with the 15-30 and 30-45 cm depths. The results proved that bulk density had significantly higher values in the 0–15 cm soil layer ($p<0.05$), compared with the other two depths. The results showed more bulk density in depth 0-15 cm compared with the other two depths (Table 2).

Table 1. Analysis of variance of soil OC, Cp and bulk density at *C. comosum* and *H. ammodendron* habitats

	Soil properties	SOV	df	Mean squared	F	Sig
C. comosum	OC (%)	Between group	2	0.03	3.12	0.00**
		Among group	15	0.002		
	Cp (ton ha^{-1})	Between group	2	53.28	3.03	0.00**
		Among group	15	576.45		
	Bulk density (g cm^{-3})	Between group	2	0.01	4.32	0.00**
		Among group	15	0.005		
H. ammodendron	OC (%)	Between group	2	0.02	4.55	0.05*
		Among group	15	0.001		
	Cp (ton ha^{-1})	Between group	2	24.04	3.80	0.05*
		Among group	15	2.45		
	Bulk density (g cm^{-3})	Between group	2	0.75	4.89	0.05*
		Among group	15	0.05		

S.O.V = Source of variations
* p< 0.05, ** p< 0.01

Table 2. Soil Cp at *C. comosum* and *H. ammodendron* habitats

	Soil depth (cm)	OC (%)	Cp (ton ha^{-1})	Bulk density (g cm^{-3})
C. comosum	0-15	0.30±0.022^{a}	17.23±1.46^{a}	1.72±0.57^{a}
	15-30	0.20±0.045^{b}	12.16±2.21^{b}	1.64±0.38^{b}
	30-45	0.19±0.40^{b}	12.65±2.50^{b}	1.69±0.054^{ab}
H. ammodendron	0-15	0.27±0.02^{a}	15.14±1.64^{a}	1.29±0.28^{a}
	15-30	0.20±0.02^{b}	12.35±1.53^{b}	0.69±0.21^{b}
	30-45	0.18±0.02^{b}	11.42±1.51^{b}	0.72±0.14^{b}

*Means± SE. Means with same letters are not significantly differences (p‹ 0.05).

Cp in plant biomass

Carbon pool in the aboveground and belowground biomass is shown in Table 3. It was found that *C. comosum* had significantly higher belowground content of carbon than Cp in the aboveground parts ($p<0.01$). In general, Cp in belowground biomass of *C. comosum* was significantly more than the aboveground biomass ($p< 0.01$). The same result was found for *H. ammodendron.* This result supported our first hypothesis. It also demonstrated that although Cp in aboveground biomass of *H. ammodendron* was more than that of *C. comosum*, there was no significant difference between Cp of aboveground biomass ($p> 0.05$) for the two species. Belowground biomass of *C. comosum* showed the highest Cp ($p< 0.01$).

Table 3. Carbon pool (ton ha^{-1}) in aboveground and belowground parts of plant species

Habitat	Cp of aboveground biomass (ton ha^{-1})	Cp of belowground biomass (ton ha^{-1})
C. comosum	1.58±0.64^{B-b}	5.09±0.70^{A-a}
H. ammodendron	1.67±0.20^{B-b}	3.62±0.53^{B-a}

*Means± SE. In each row different lower case letters show significant differences among Cp of above and belowground biomass (p‹0.05). In each column different capital letters show significant differences among Cp of above and belowground biomass (p‹0.05).

The comparison of soil Cp of plant habitats is shown in Figure 2. The amount of Cp was found to be significantly more in 0-15 cm depth of *C. comosum* habitat ($p<0.05$) than the *H. ammodendron* habitat, while no significant differences were seen between 15-30 and 30-45 cm depths of both habitats. In general, the soil under cover of *C. comosum* had more Cp than the *H. ammodendron* habitat which supports our second hypothesis.

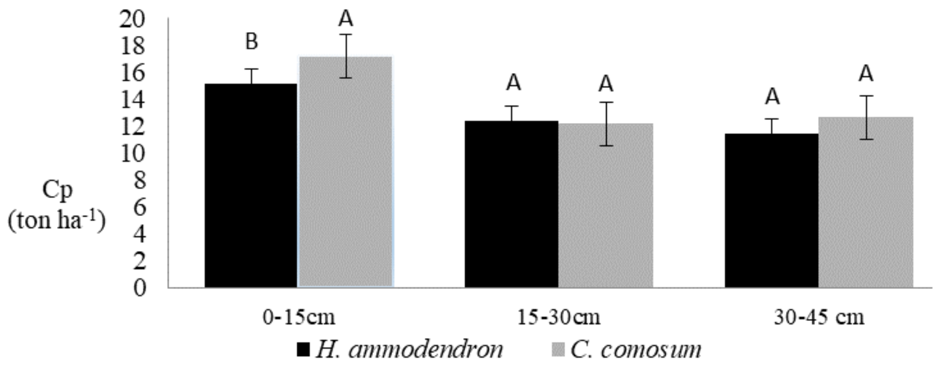

Figure 2. Soil Cp (ton ha^{-1}). Different capital letters indicate significant differences between soil depth. Values represent mean and standard errors

Discussion

This study showed that the highest amount of Cp belonged to the topsoil of both habitats and with increasing soil depth, the amount of Cp decreased significantly. High canopy cover, litter and, more root volume in this soil layer led to increased Cp in the surface depth (Kamali et al., 2020; Shirzai et al., 2021). Woomer et al. (2004) stated that more than 60% of soil C is accumulated at the depth of 20 cm.

Ghasemi Nejad Raeeni and Sadeghi (2018), studied of Cp in the soil of *Z. atriplicoides* and *Gymnocarpus decander* habitat, and found that the highest Cp was related to the depth 0-15 cm soil. The high amount of Cp at a depth 0-15 cm may be caused by the fact that most of the soil organic matter derived from decomposition of dead roots as well as conversion of microbial biomass to organic matter occurs at this depth (Dianati Tilaki et al., 2009). Yang et al. (2020) noted that litter and plant roots are important in increasing soil C storage. The researchers reported that high C storage in the topsoil was due to mycorrhizae and carbohydrate secretions from the plant roots and litter in the soil surface. Hu et al. (2020), in a study on the effects of litter decomposition on soil Cp in the China plateau stated that the addition of plant litter and root carbohydrate secretions significantly increased C to the soil.

Soil Cp is positively correlated with bulk density (Hill et al., 2003). In their research, Garten and Charles (2020) stated that soil bulk density is one of the crucial factors in estimating soil Cp capacity. In the present study, the bulk density at depth 0-15 cm was more significant than the bulk density at depths 15-30 and 30-45 cm. The soil bulk density is a relative characteristic that plays essential role in estimating the amount of soil C storage (Shirzai et al., 2020). The soil with a higher bulk density has a higher C content; as in fact, the bulk density consists of the weight of solid particles and solutes in soil's pores (Ponce Hernandez et al., 2004; Tessema et al., 2020).

The results showed that the amounts of Cp in the belowground biomass were higher than the aboveground part. This can be attributed to the high amount of woody tissue of the roots compared to the aboveground parts of the plants (Capuana, 2020; Rigi Pardad, 2021). In arid rangelands, the belowground biomass of the plants has the highest share of total biomass while aboveground biomass has a small proportion of the plant biomass (Foroozeh et al., 2008; Joneidi Jafari et al., 2013). The roots system in *C. comosum* and *H. ammodendron* is thick with woody tissues (Mirlashkari, 2016; Rigi Pardad, 2021). Plant organs with woody tissue have a more remarkable ability to store C (Lashani Zand et al., 2016; Tessema et al., 2020; Motamedi et al., 2020). In this regard, other studies have acknowledged that with higher ratio of woody tissues in the plants, their ability to uptake C increases (Tessema et al., 2020; Motamedi et al., 2020). Increasing the share of the root increases C entrance into the soil (Moghbeli, 2016). Mirlashkari (2016) cited that Cp in the *Z. eurypterum* was higher in the roots than the shoots. The type of plant species and even different organs of a plant have different potentials for Cp. The performance of plants to store C is a function of various factors such as morphological traits, including plant root height, canopy cover, plant density, plant distribution pattern, topographic characteristics, soil properties and management factors (such as livestock grazing and rangeland exclusion) (Post and Kwon, 2000; Conti and Diaz, 2013; Mirlashkari, 2016). Expansion of vegetation cover will reduce and modify the amount of CO_2 in the atmosphere by increasing photosynthetic levels and eventually increasing the level of C uptake (Souri et al., 2020). Mirlashkari (2016), in the investigation of the impacts of exclusion on the soil Cp in Jonabad rangeland, Zahedan, Iran, reported that Cp was higher in the site with more vegetation biomass than the grazed site.

The results showed that *C. comosum* has more OC storage capacity in the soil of the study area than *H. ammodendron.* One of the reasons for the high soil Cp in the habitat of *C. comosum* can be the high volume of the root of this plant species compared to *H. ammodendron*. Total Cp has a positive and significant relationship with total aerial biomass, total underground biomass, amount of plant litter, and SOC (Honda et al., 2000). The results of the study by Zimming et al. (2012) on rangeland carbon assessment showed that Cp in the soil is strongly influenced by management, climate change, and soil properties. It is interesting to note that the production and decomposition of plant can affect ecosystem function (Windham, 2001) and consequently, affect carbon input to the soil (Tessema et al., 2020). The high C input derived from high root biomass in rangelands can increase soil organic matter content, as an essential factor for increased SOC (Farage et al., 2004). Therefore, increasing the efficiency and root inputs in rangelands is important in increasing Cp (Tessema et al., 2020). Kuzyakov (2002) noted that more belowground biomass protects soil microbial community and metabolic activity, due to contribution to the soil's organic matter decomposition and C input.

Conclusion

The results showed that restoration practices using *C. comosum* greatly enhanced the C stock capacity compared with *H. ammodendron* and resulted in Cp enrichment in Mirjaveh rangeland. Carbon storage capacity varied based on the plant species, plant organs and soil depth. The results showed that the Cp in the roots of both plants was higher than the aboveground parts. The results also indicated that *C. comosum* has more Cp capacity in the soil of the study area than *H. ammodendron*. Overall, we suggest that more investigations are needed on the C stock potential of arid rangelands when designing biological practices. The impacts of plant species and improvement practices on C storage need to be investigated. Soil sampling to greater depths need to be considered. The methods to stabilize C stored in the soil and their effects need to be studied so that C is not easily released into the atmosphere via soil disturbance.

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References

Arzani, H., and Abedi, M. 2015. Rangeland assessment, Vegetation Measurment. University of Tehran Press. 2. 305p.

Capuana, M. 2020. A review of the performance of woody and herbaceous ornamental plants for phytoremediation in urban areas. iForest Bio-geosciences and Forestry. 13(2), 139-151.

Conant, R.T., Cerri, C.E.P., Osborne, B.B., and Paustian, K. 2017. Grassland management impacts on soil carbon stocks: a new synthesis. Ecological Applications. 27(2), 662-668.

Conti, G., and Diaz, S. 2013. Plant functional diversity and carbon storage e an empirical test in semi-arid forest ecosystems. Journal of Ecology. 101(1), 18-28.

Deng, L., Shangguan, Z.P., and Sweeney, S. 2013. Changes in soil carbon and nitrogen following land abandonment of farmland on the Loess plateau, China. PLoS One. 8, e71923.

Dianati Tilaki, Gh., Naghi pour borj, A.A., Tavakkoli, H., Haidarian Agha Khani, M., and Saeed Afkhamoshoara, M.R. 2009. Effect of enclosure on soil and plant carbon sequestration in semi-arid rangeland of northern Khorasan. Journal of Iranian Range Management Society. 3, 668-679. (In Persian)

Ebrahimi, M., Mohammadi, F., Fakhireh, A., and Bameri, A. 2019. Effects of *Haloxylon* spp. of different age classes on vegetation cover and soil properties on an arid desert steppe in Iran. Pedosphere. 29(5), 619-631.

Feyisa, K., Beyene, S., Angassa, A., Said, M.Y., de Leeuw, J., Abebe, A., and Megersa, B. 2017. Effects of enclosure management on carbon sequestration, soil properties and vegetation attributes in East African rangelands. Catena. 159, 9-19.

Foroozeh, M.R., Heshmati, G.H., and Mesbah, H. 2008. Comparing carbon sequestration potential of three shrub species *Heliantemum lippii*, *Dendrostellera lessertii* and *Artemisia sieberi* (case study: Gareh Bygone, Fasa). Journal of Environmental Studies. 34, 65-72. (In Persian)

Garten, J., and Charles, T. 2002. Soil carbon storage beneath recently established tree plantations in Tennessee and South Carolina, USA. Biomass and Bioenergy. 23(2), 93-102.

Ghasemi Nejad Raeeni, M., and Sadeghi, H. 2018. Evaluation of carbon sequestration in soil and plant organs of *Zygophyllum atriplicoides* and *Gymnocarpus decander* (Case study: Saleh-Abad, Hormozgan). Iranian Journal of Range and Desert Research. 24, 699-707. (In Persian)

Hashemi Rad, M., Ebrahimi, M., and Shirmohammadi, E. 2018. Land use change effects on plant and soil properties in a mountainous region of Iran. Journal of Environmental Science Management. 21(2), 47-56.

Hill, M.J., Braaten, R., and McKeon, G.M. 2003. A scenario calculator for effects of grazing land management on carbon stocks in Australian rangelands. Environmental Modeling and Software. 18(7), 644-672.

Honda, Y., Yamamoto, H., and Kajiwara, K. 2000. Biomass information in central Asia. Center for Environmental Remote Sensing, Chiba University. 263, 1-33.

Hu, A., Angerer, J., Duan, Y., Xu, L., Chang, S., and Fujiang Hou, X. 2020. Effects of terrain on litter decomposition and nutrient release in typical steppe of Eastern Gansu Loess Plateau. Rangeland Ecology and Management. 73(5), 611-618.

Joneidi Jafari, H. 2013. Relationship between root biomass and soil organic carbon: Case Study of arid shrub lands of Semnan province. Desert. 18, 173-176.

Kamali, N., Soori, M., Eftekhari, A., and Ashoori, P. 2020. Protection levels and distribution of organic carbon in size fractions of soil (case of: Salook, North Khorasan). Journal of Rangeland. 14 (1), 85-94. (In Persian)

Kuzyakov, Y. 2002. Review: Factors affecting rhizosphere priming effects. Journal of Plant Nutrition and Soil Science. 165(4), 382-396.

Lashani Zand, M., Parvizi, Y., Ebrahimi, L., Masoudi, B., and Rafiee, B. 2016. Investigation and comparison of carbon sequestration with regard to biological operations in the two regions Rimele Khorramabad and Abkandari Koohdasht. Journal of Range and Desert Research. 23(2), 219-230. (In Persian)

MacDicken, K.G. 1997. A guide to monitoring carbon storage in forestry and agro forestry project. Winrock international institute for agricultural development forest carbon monitoring program, 91p.

Miri Panah, Z. 2017. Investigation of carbon sequestration in plant organs and soil of hand-planted and natural species (case study: Mehran plain, Ilam). M.Sc. thesis, Natural Resources, University of Ilam, Iran. (In Persian)

Mirlashkari, F. 2016. The Impact of long-term grazing exclusion and different grazing intensity on some vegetation characteristics, soil carbon pool and nitrogen pool in Joonabad rangeland-Zahedan. M.Sc Thesis, University of Zabol, Iran. (In Persian)

Moghbeli, Z. 2016. Effect of different grazing intensity on organic carbon storage and soil nitrogen storage in rangeland of Varamin, Jiroft. M.Sc Thesis, University of Zabol, Iran. (In Persian)

Mohammadi, T., Dastorani, M.T., Azimzadeh, H.R., and Jafarpoor, A. 2018. Study of watershed management biological practices on soil carbon sequestration (case study: Kelestan Watershed-Fars Province). Iranian Journal of Watershed Management Science and Engineering. 12 (41), 31- 40. (In Persian)

Motamedi, J., Ebrahimi, Sh., and Sheidai Karkaj, E. 2020. Relationship between carbon storage of *Astragalus brachyanus* species with plant characteristics, habitat characteristics and rangeland management, Rajan, West Azerbaijan. Journal Range and Watershed Management. 73(2), 423-438. (in Persian)

Nelson, D.W., and Sommers, L.E. 1996. Total carbon, organic carbon, and organic matter. In: Bartels, J.M. (Ed.), Methods of soil analysis. Chemical Methods. Soil Science Society of America, Madison, Wisconsin, pp. 961-1010.

Ponce Hernandez, R., Koohafkan, P., and Antoine, J. 2004. Assessing carbon stocks and modeling win- win scenarios of carbon sequestration through land-use change. Food and Agriculture Organization of the United Nations. 166p.

Post, W.M., and Kwon, K.C. 2000. Soil carbon sequestration and land-use change, processes and potential. Global Change Biology. 6(3), 317-327.

Report of Rangeland Improvement, Mirjaveh, Sistan and Baluchestan, 2015. Agriculture and Natural Resources Center, Sistan and Baluchestan, 127p. (In Persian)

Rigi Pardad, M. 2021.Comparison of ability of carbon sequestration in soil and plant organs of two plant species of *Calligonum comosum* and *Haloxylon ammodendron* in Mirjaveh Plain. M.Sc Thesis, University of Zabol, Iran. (In Persian)

Shirzai, M., Ebrahimi, M., and Saberi, M. 2020. Carbon sequestration in *Artemisia sieberi*, Leuchonassi Rangeland of Zahedan city. The 7th Scientific Congress on the Development and Promotion of Architecture and Urbanism in Iran. (In Persian)

Souri, M., Fayyaz, M., Kamali, N., Ashuri, P., and Nateghi, S. 2020. The carbon storage capacity of the *Artemisia sieberi* under the enclosure (Kalat Sadat Abad, Sabzevar city). Journal of Plant Research (Iranian Journal of Biology). 32 (4), 736-748. (In Persian)

Tessema, B., Sommer, R., Piikki, K., Soderstrom, M., Namirembe, S., Notenbaert, A., Tamene, L., Nyawira, S., and Paul, B. 2020. Potential for soil organic carbon sequestration in grasslands in East African countries: A review. Grassland Science. 66, 135-144.

UNDP. 2000. Carbon sequestration in the desertified rangelands of Hossein Abad, through community based Management, program coordination. 1-7.

Wang, D., Wu, G.L., Zhu, Y.J., and Shi, Z.H. 2014. Grazing exclusion effects on above- and below ground C and N pools of typical grassland on the Loess Plateau (China). Catena. 123, 113-120.

Windham, L. 2001. Comparison of biomass production and decomposition between *Phragmites australis* (common reed) and *Spartina patens* (salt hay grass) in brackish tidal marshes of New Jersey, USA. Wetlands. 21(2), 179-188.

Woomer, P.L., Tourc, A., and Sall, M. 2004. Carbon stocks in Senegal's Sahel Transition Zone. Journal of Arid Environment. 59(3), 499-510.

Yang, X., Xu, M., Zhao, Y., Bio, T., Ren, W., and Shi, Y. 2020. Trampling disturbance of bio crust enhances soil carbon emission. Rangeland Ecology and Management. 73(4), 501-510.

Zhiming, Q., Bartling, P.N.S., Ahuja, L.R., Derner, J.D., Dunn, G.H., and Ma, L. 2012. Development and evaluation of the carbon–nitrogen cycle module for the GPFARM-Range model. Computers and Electronics in Agriculture. 83, 1-10.