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Assessing and comparing carbon sequestration in a number of halophyte species

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Abstract

Rangelands cover extended areas and therefore are of great importance for carbon sequestration. This was the principal concern of this study in *TezKharab* region in Iran to be studied. To settle the question upon the role of rangelands in carbon sequestration, dominant halophyte species of the region namely *Atriplex veruciferum* and *Halocnemum strobilaceum* were studied. Carbon content of saline and non-saline sites with the same climate and topographic characteristics were compared to identify the role of salinity in carbon sequestration. To this end, dominant vegetation type which is *Kochia prosterate* from non-saline site of the region was selected. Soil and vegetation sampling follows the systematic approach. Totally 30 soil samples (0-40 centimeters depth) and 90 samples from different plant tissues were taken to the laboratory. Result showed miningful differences among sequestrated carbon of plant tissues, total biomass of species, saline and non-saline sites and the control plot (saline and non-saline control plot) which is covered by no vegetation cover. Sequestrated carbon in stem tissues of three species was higher than the amount, sequestrated in leaves and root tissues. *K. prostrate* compared with *At. Veruciferum* with 201.05 kg per hectare and *Ha.Strobilaceum* with 192.82 kg per hectare, sequestrated more carbon exceeding 211.05 kg per hectare. The underlying soil of *Ko. Prostrate* sequestrated more carbon in excess of 96.75 tones per hectare.

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Introduction

Rapid and uncontrolled growth of greenhouse gasses specially CO_2 during recent decades has raised the widespread concern about the climate change and its consequences, thus concerted effort has put into practice to harness the industrial pollutants and pool carbon into the soil (Paustian *et al.*, 2000). Climate change, environmental implications such as local precipitation pattern alterations and cloudiness, melting of glaciers and sea levelrise, droughts, land deterioration and finally terrestrial and aquatic ecosystems losses are amongst outstanding consequences of global warming (Thomas, 2008). Environmental and economic consequences of these likely phenomena, has caused a controversial debates amongst world's scientists and authorities and persuade them to make sure that global CO_2 concentration, various measures will be taken (Palumboa *et al.*, 2004). Olsson and Ardo, 2006 believe that enhancing carbon sequestration in soil media and vegetation constitute of terrestrial ecosystems which will further sequestrate carbon through promoting biomass production in a longer run, is likely to be the most widely accepted solution in order to lower the CO_2 level. William. 2002 also argues that sequestrating carbon into vegetation biomass and underlying soil is the cheapest and simplest way to taper off the amount of CO_2. Carbon sequestration could be defined as the transformation of atmospheric CO_2 into other carbon stores with longer duration (with geologic, oceanic, terrestrial bases) that will come in leaps and bounds to cope with climate change resulting from greenhouse gases emission. Regarding chemical interactions during mineralization of CO_2 and the process of conversion into stable compounds, carbon sequestration is thought of as a natural phenomenon in terrestrial ecosystems (such as soil, trees and other vegetation convers) relying on plant photosynthesis, biomass production and then soil development (Lal, 2009).

Given the circumstances, natural ecosystems like rangelands (including grasslands, scrublands, deserts and tundra) which cover up at upward of half of lands and encompass more than one third of global carbon reservoirs (Schuman *et al.*, 2002) have key significance in carbon sequestration. Rangelands have high potential in carbon sequestration and noticing the negligible biomass production compared with forests, but thanks to their vast expansion, they could play a key role in carbon sequestration (Luciuk, 2000). However, carbon sequestration is under control of natural and anthropogenic elements (Bronick and Lal, 2005). Mortenson and Schuman, 2004 maintain that carbon sequestration potential could change according to plant species, milieu and managerial behaviors in such a way that different plant species could express different capability for carbon sequestration and there is a direct link between sequestrated carbon and plant species and moreover, different plant tissues.

Signing an international treaty, Iran has made a vow to take considerable managerial measures to promote the carbon sequestration capability in natural ecosystems (Jafari, 2009). This study has aimed at the determination and comparison of carbon sequestration in canopy cover, underground tissues and biomass of halophyte species namely *Atriplex veruciferum*, *Halocnemum strobilaceum* and non-halophyte species namely *Kochia prosterata*. There is a great lack of investigation of this kind in Iranian salt lands and deserts which encompass vast areas with rich diversity and endemic species. The current study area is Lake Urmia watershed playing an important role in defining surrounding climate, wildlife and ecotourism and which is surrounded by expanded salt lands.

Materials and methods

Study area and data analysis

In this study, two study sites of saline and non-saline soils were selected. The first site lies between 37 23 29 N and 45 17 17 E, 25 km away from Urmia and in the vicinity of the lake Urmia. The second is situated in 37 21 56 N and 45 13 39 E geographic coordination (Fig. 1). The minimum altitude difference from sea level is 1115 peaking at 1300. The study area is about

500 hectares and the average precipitation is 299 mm. To carry out the current research, two sites dominated with *Atriplex verucifrum* and *Halocnemum strobilaceum* in the vicinity of the lake Urmia and one site dominated by *Kochia prostrata* together with two control plots lacking these plant species near study sites were selected in such a way that control sites are similar to the study sites in topographic (slope, aspect and altitude) and climatic characteristics. It is worth noting that all sites were kept enclosed. After identifying vegetation types of almost pure vegetation stands of abovementioned species, in each type, ten quadrates along three transects each 100m in length were placed in a random-systematic method. Number of plots was determined with respect to the milieu and the acreage of the area and according to statistical methods. Plot size was determined according to the minimum area method (Mesdaghi, 2007). Given the high vegetation density and the associated species, the *Atriplex verucifrum* vegetation type was measured using a 1 x 1 plots while for *Halocnemum strobilaceum*, *Kochia prostrata* types 1 x 2 plots were determined best and in each plot, density, vegetation cover percentage, stone and pebbles percentage and bare ground were measured. Afterwards, in order to measure canopy cover and underground biomass, sampling was carried out. Thus, ten vigorous plants with appropriate appearance were selected as the representatives of associated vegetation type. Stems and leaves of the sampled plants were separated and put into separate bags. Then, the earth was dug and underground tissues were cut. Tissues taken from leaves, stems and roots were dried in open air for some days, and the dry matter was weighed using a scale. To determine organic carbon, the samples were burnt in the stove (McDicken, 1997). In order to do this, samples were grind up, and then from each sample, one gram was separated. These samples were heated for a 24 hour period in 375 centigrade degree in an electric stove. The aftermath was weighed. The difference between the primary and secondary weights shows the organic matter existing in the samples. Given organic matter value and using equation 1(Birdsey, 2000) the organic carbon in each sample was determined individually.

OC=0.54OM: (1)

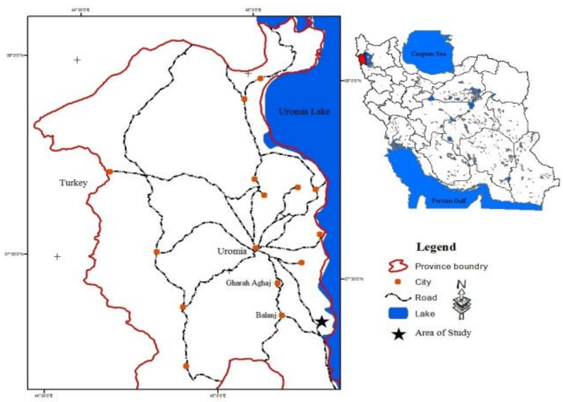

Fig. 1. Location of study sites in Iran.

Next, conversion coefficient was calculated through dividing organic carbon to primary dry matter weight.

Then, six profiles were dug all 0-40 cm in depth in each site and under the bushes. Finally the soil samples were taken to the laboratories and after drying them in open air, the samples were sieved with the mesh of 2mm. the soil particles with dimension of less than 2 mm were taken apart into clay, silt and sand using the hydrometer method(Gee and Bauder, 1982). Thereafter, soil bulk density was determined using the clog method. in the chemical analysis of soil, total nitrogen was measured according to the Kjeldal method (Bremmer and Mulvaney, 1982), and ECe, pH and carbonate calcium equivalent (CCE) percentage (Sparks, 1996) Organic matter and organic carbon were also determined following the Walkley & Black method (Walkley and Black, 1934). Eventually, soil organic carbon per unit area was calculated according to the following formula:

Cc=10000 x c (%) Bd x e (2)

Where Cc is the carbon contetnt per kg per hectare, c shows the amount of carbon in a certain soil depth, Bd expresses the bulk density of soil in kg per cubic centimeter and finally e is the soil depth in centimeter.

Filed and laboratory data were fed to Excel for each treatment and data were tested for normality before statistical analysis using the Anderson Darling test (Steel and Torrie, 1980). Thereafter, the result were analyzed using SPSS v. 9.0, independent T-student test and one-way variance analysis. To compare averages, to ascertain whether there are significant differences between the treatments, Duncan test was applied.

Results and discussion

Carbon conversion coefficient for different tissues and the average total carbon content in each plant

Carbon conversion coefficient for three tissues, for the three species show significant differences between the tissues (Table 1). In addition, the result demonstrates that the highest value for the carbon conversion coefficient belongs to *At.verruciferum* (0.581) and lowest value is related to the leaves of *Ko.prostrata* with total amount of 0.359. in such a way that the roots of all species owns the maximum amount of carbon conversion coefficient compared to the other tissues and on the other hand, leaves has the lowest amount (Table 1). There is also a significant difference ($P \le 0.01$) between the average carbon conversion coefficients of the species. *Ko.prostrata* has significantly lower carbon conversion coefficient with the amount of 0.46 compared to the others and *Ha.strobilaceum* posses the highest carbon conversion coefficient with total amount of 0.515. average carbon conversion coefficient is derived from the carbon conversion coefficient of the tissues belonging to leaves, stems and roots (Table 1).

Table 1. Descriptive statistics of carbon conversion coeff. For different plant tissues and total carbon conversion coeff.

Tissues	Species		
	Atriplex verruciferum	*Halocnemum strobilaceum*	*Kochia prostrata*
Leaves	0.397±0.02	0.412±0.05	0.395±0.01
Stems	0.515±0.03	0.552±0.04	0.467±0.02
Roots	0.581±0.02	0.579±0.01	0.521±0.04
Total carbon conversion coeff.	0.498±0.013	0.515±0.019	0.46±0.023

Similar alphabets denote the lack of difference between the treatments in one percent level of confidence and between total carbon conversion coeff in five percent level of confidence.

Table 2. comparison of dry matter and stored carbon for different plant tissues applying Duncan test.

Species	Tissues	Dry weight (Kg.ha-1)	Stored Carbon (Kg.ha-1)
Atriplex verruciferum	Leaves	36.93±2.13c	14.7±1.6c
	Stems	215.1±8.2a	110.82±8.9a
	Roots	131.3±8.49b	76.33±5.9b
	Total	201.51±7.58c	201.05±7.79b
Halocnemum strobilaceum	Leaves	73.72±3.59c	30.38±2.93c
	Stems	193.42±8.46a	106.69±3.4a
	Roots	96.22±3.03b	55.74±2.62b
	Total	614.93±14.81a	192.82±4.94c
Kochia prostrate	Leaves	90.86±6.02c	35.89±2.41c
	Stems	206.41±7.39a	96.4±7.17a
	Roots	151.32±5.55b	78.75±6.1b
	Total	378.85±12.62b	211.05±11.75a

Similar alphabets denote the lack of difference between the treatments in five percent level of confidence.

Comparing dry matter and stored carbon between tissues and plants

Results demonstrate that there is a substantial difference ($P \le 0.01$) for the drymatter and the carbon content of the tissues of the three species. *At.verruciferum* has the lowest amount of carbon content for leaves with the amount of 14.70 kg per hectare, though the highest amount of carbon is stored in stems of the plants with the numerical value of 110.82 per hectare. On top of that, stems and leaves with the total dry matter of 56 and 10 percent respectively represent the highest and lowest among all (Table 1). In case of *Ha.strobilaceum* there is a significant difference ($P \le 0.05$) between the average dry matter and stored carbon for various tissues. Stems of *Ha.strobilaceum* with the average amount of 106.69 $kg.ha^{-1}$ has stored the highest level of carbon and the roost of this plant has stored 55.74 $kg.ha^{-1}$ carbon and stands in the second level of the hierarchy and eventually leaves of *Ha.strobilaceum* has stored the minimum level of carbon among the plants (that is 30.38 $kg.ha^{-1}$). The ordering of three tissues for the total biomass for *Ha.strobilaceum* is begun with stems making up 54 percent, then ended with leaves having 20 percent of the total biomass (Table 1). In case of *Ko.prostrata*, the results reveal that the highest amount of carbon storing takes place in stems (that is 96.40 $kg.ha^{-1}$) and leaves only just make up the 36.89 $kg.ha^{-1}$ of stored carbon. To put it another way, stems comprising 46 percent and leaves comprising 20 percent are the primary and secondary sources of the total biomass (Table 2). Results also indicate that there is a significant difference between the dry matter and stored carbon for the three plants in the confidence level of 5 percent. *Ha.strobilaceum* represents the highest amount of drymatter with an average of 614.93 $kg.ha^{-1}$. *Ko.prostrata* with the dry matter of 378.85 is in the middle of the species, and *At.verruciferum* with the average numerical value of 201.51 $kg.ha^{-1}$ represent the lowest amount of dry matter compared with the other two species. Yet *Ko.prostrata* stores the highest level of carbon (that is 211.05 $kg.ha^{-1}$). The next rank goes to *At.verruciferum*(that is 201.05 $kg.ha^{-1}$).*Ha.strobilaceum* is found to be at the lowest rank having the average numerical value of 192.82 $kg.ha^{-1}$ (Table 2).

Table 3. Total carbon weight in the studied sites.

Site	Biomass Carbon ($ton.ha^{-1}$)	Soil Carbon ($ton.ha^{-1}$)	Total Carbon
At.verruciferum	0.201	72.868	73.069
Ha.strobilaceum	0.193	58.27	58.46
Ko.prostrata	0.211	96.75	96.96
Saline control site	-	39.4	39.4
None-saline control site	-	61.26	61.26

Effects of salinity and site dissimilarities on soil carbon content

To compare the effects of site salinity on soil carbon sequestering for saline sites of *Ha.strobilaceum* and *At.verruciferum* and non saline site of *Ko.prostrata*, one-way variance analysis were done, Findings testify a significant difference ($P \leq 0.05$) among these sites concerning soil carbon content (Fig. 2). Non saline site dominated with *Ko.prostrate* denotes the highest stored carbon with an average numerical value of 96.75 $kg.ha^{-1}$ and is followed by the saline sites dominated by *At.verruciferum* and *Ha.strobilaceum*. The sites dominated by *At.verruciferum* and *Ha.strobilaceum* has stored 72.868 and 53.27 $kg.ha^{-1}$ carbon in their soils respectively.

Table 4. multi range analysis of Duncan test for soil characteristics in the studied sites.

Treatments	Soil texture			Calcium Carbonate Equivalent (CCE)(%)	Nitrogen (%)	pH	ECe (dS/m)	Bulk density (gr/cm^3)
	Sand	Silt	Clay					
At.verruciferum	47.13±4.94a	28.67±2.4b	24.2±4.7b	14.17±0.34a	0.19±0.01a	8±0.073c	9.4±0.081c	1.19±0.043b
Ha. Strobilaceum	32.47±3.63b	43.33±3.29a	24.2±1.53b	15±0.26a	0.13±0.013bc	8.2±0.029b	36.48±2.05a	1.2±0.036b
Saline control site	20.33±1.92c	39.67±1.5a	40±1.42a	13.68±1.1a	0.1±0.01c	8.3±0.029a	28.38±0.71b	1.4±0.026a
Ko.prostrata	25.67±2.69bc	38±1.37a	36.33±1.89a	8.47±1.13c	0.15±0.02b	7.7±0.039d	1.9±0.048d	1.2±0.04b
Non-saline control site	49.47±2.67a	37±1.53a	13.53±1.2c	11.25±0.5b	0.21±0.009a	7.18±0.027e	1.4±0.097d	1.35±0.034a

Similar alphabets denote the lack of difference between the treatments in five percent level of confidence.

Effects of the presence of Kokhia prostrata on the none-saline sites' underlying soil

Effects of *Kokhia prostrata* on soil stored carbon in none-saline sites results obtained from the analysis of soil carbon content (per ton per hectare in depth of 0-40 cm) in this site is brought into figure three. Provided by the results, soil carbon content of this site compared with control site which is lacking any vegetation cover, shows a significant difference ($p<=0.05$). By comparison, stored carbon in this site which is in excess of 96.75 ton per hectare shows the highest amount compared with that of control site storing 61.26 ton per hectare.

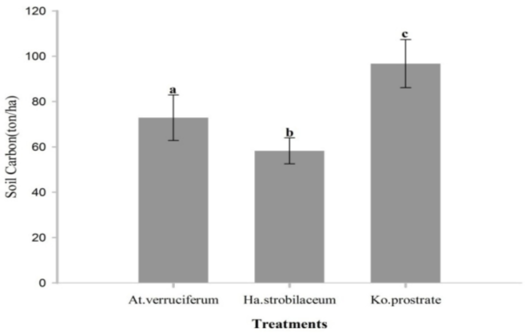

Fig. 2. Comparing total stored carbon for saline and non-saline sites in the study.

Effects of the presence of At.verruciferum and Ha.strobilaceum on the saline sites' underlying soil

Findings corroborate a significant difference ($P \leq 0.05$) between the soil carbon content of the two sites dominated with *At.verruciferum* and *Ha.strobilaceum* . Figure two illustrate the soil carbon content culminating in 58.27 $ton.ha^{-1}$ for *At.verruciferum*(and is followed *Ha.strobilaceum* with the numerical value of 58.27 $ton.ha^{-1}$) and reaching a nadir at 39.4 $ton.ha^{-1}$ for the control plot.

Total carbon content in the studied sites

Total carbon content of all sites is derived from the soil carbon content and biomass which is represented in ton per hectare. As is implied by table 3, total stored carbon in the sites dominated with *Ko.prostrata* (that is 96.96 $ton.ha^{-1}$) is higher than the remaining sites. The site dominated with *At.verruciferum* with the total stored carbon per hectare at 73.069 $ton.ha^{-1}$ is ranked second and the lowest goes to *Ha.strobilaceum* with the total storesd carbon at 58.46 $ton.ha^{-1}$.

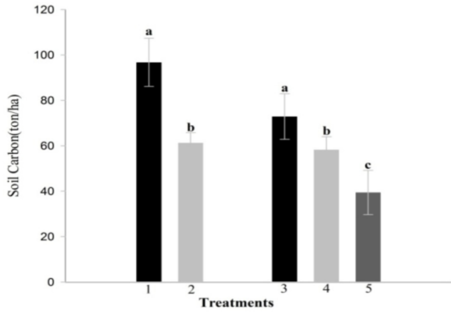

Fig. 3. Comparing total soil carbon for saline site containing At.verruciferum, Ha.strobilaceum and Kochia prostrate respectively and the related control sites (1 and 2 denotes non-saline site containing Kochia prostrate; 3, 4 and 5 denotes saline site containing At.verruciferum, Ha.strobilaceum and control site respectively).

Assessing other physic-chemical characteristics of under study sites

Applying one-way variance analysis on soil texture, nitrogen, lime, electro conductivity, bulk density and acidity in the underlying soil of the sites dominated *At.verruciferum*, *Ko.prostrata* and *Ha.strobilaceum* and saline and none-saline control plots showed that there is a significant difference between chemical and physical characteristics of different soils at the confidence level of 1 percent. Likewise, Duncan test which was used for mean comparisons for treated sites and control plots at the confidence level of 5 percent is brought in table 4.

Conclusions

Findings of the study point out to the differing conversion coefficients for *Atriplex verruciferum*, *Halocnemum strobilaceum* and *Kochia prostrata* for different tissues. Generally the coefficient is higher for woody tissues as against other tissues. Roots hold the greatest conversion coefficient while this is lowest for leaves. Fang *et al.*, 2006 argued the same. Birdseyet *et al.*, 2000 provided the same analysis therein different conversion coefficients for plant tissues were separately identified and it was pointed out that there could be a relationship between carbon coefficients of different parts of a plant and the level of woodiness. The more woody a part of a plant is, the higher the conversion coefficient gets and the higher the capacity of that part reaches for carbon sequestering. Bordbar and Jahromi, 2006 suggest the high level of minerals as the driver of lower organic carbon coefficient in leaves. The conversion coefficients of studied species are different likewise in such an order that *Halocnemum strobilaceum* and *Kochia prostrata* stands at the top (highest) and the bottom (lowest) of the order respectively. The reason why the coefficient of the former is high could be traced back to its woodiness of its tissues. Lamlom and Savidge, 2003 believe that higher lignin indicates higher carbon and any differences in lignin content could spark differing levels of carbon in the woody tissues.

Stored carbon of different tissues (as leaves, stems and roots) carried out individually for different treatments followed by generalization of the carbon coefficients to their biomass content led to the conclusion that there are significant differences among studied species. All three species has stored the highest possible level of carbon so that stems of *At.verruciferum* with 55 percent (that equals 110.82 $kg.ha^{-1}$), stems of *Ha.strobilaceum* with 55 percent (that equals 110.82 $kg.ha^{-1}$) and stems of *Ko.prostrata* gaining 46 percent (that equals 96.40 $kg.ha^{-1}$) have stored far higher carbon compared to the other tissues. Results indicate that canopy cover quota of total biomass is higher than underground tissues. The investigation carried out by Houghton *et al.*, 1999 centers on the point that more than 50 percent of total carbon of a plant is stored in the woody tissues like stems. This corroborates the finding of the current research in which case stems of *At.verruciferum* with 56 percent (that is to say 215.10 stems of *Ha.strobilaceum* with 54 percent (that is to say 193.42 $kg.ha^{-1}$) and finally stems of *Ko.prostrata* with 46 percent (that means 206.41 $kg.ha^{-1}$) have stored the maximum level of carbon of the total biomass feasible in the form of dry matter well compared to those of leaves and roots. Given what is concluded, while *Ha.strobilaceum* compared to those other species has gained higher dry matter (that is 51 percent) and at the same time *At.verruciferum* has gained the lowest level (say 17 percent), however astonishingly enough, *Ko.prostrata* with 35 percent (equaling 211.05 $kg.ha^{-1}$) compared to *At.verruciferum* and *Ha.strobilaceum*(respectively with 35 percent (211.05 $kg.ha^{-1}$) and 32 percent (192.82 $kg.ha^{-1}$)) has stored the highest level of carbon in its total biomass. Of the major causes of this is the high density of *Ko.prostrata* in the area (1750 plants per hectare) regarding the simultaneous levels of *At.verruciferum* (1210 plants per hectare) and *Ha.strobilaceum*(980 plants per hectare). In presence of high solutes in the underlying soil of *At.verruciferum* and *Ha.strobilaceum* stress is undoubtedly underway and as the results, there are lower densities possible for these species. In such instances, total sequestrated carbon is affected (Lal, 2009). Thus factors like biomass content, canopy cover and plant density is likely to alter carbon stored per hectare because with the increase of leaf area index, the photosynthesis could escalate and in result higher carbon could be taken in and sequestrated (Ranjbari Karimian, 2011).

Results obtained from the soil carbon content gives indication of obvious differences between under study sites regarding their capacity to sequester carbon. In non-saline site, comparing soil carbon contents of *Kochia prostrate* (with 96.75 $ton.ha^{-1}$) and control plot (with 61.26 $ton.ha^{-1}$) at the depth range of upper 40 centimeters show principle differences at the confidence level of one percent. In saline sites results also show that the ordering is as follow: *At.verruciferum*, *Ha.strobilaceum* and saline control plot possessing 72.87, 58.27 and 39.4 ton per hectare carbon. Study of Sing *et al.*, 2003 demonstrate a positive link between soil organic carbon and canopy cover and root masses. Abdi *et al.*, 2007 also concluded a direct relationship between total carbon sequestering per area and vegetation cover, biomass and its components, litter matters and soil organic carbon. The main stream of soil organic carbon is plant tissues. Under natural circumstances, canopy cover and roots of trees, scrubs and other ephemerals provide a great deal of litter (Brady and Weil, 2007). Moreover, soil lacking in organic carbon has barer surfaces and this accelerates desertification (Lal, 2002).

As is implied by the results, soil carbon is higher in saline sites juxtaposing with none-saline sites. In none-saline site owing to the lack of tensions like salinity and regarding high density of dominant species (*Kochia prostrata*), diversity and frequency of accompanying species and short intra space between plants, there is expected to have high canopy cover biomass per area which has direct impact on the escalation of soil stored carbon and could facilitate root expansion in wider depth ranges which lessen the level of competition over water and nutrients. A good example in this case is provided by Moghaddam, 2007 as saying that longer intra distances between plants and fewer plants per hectare as a results of water deficiency, are able to lessen underground biomass which is explainable through interpretation of the roots expansion and volume provision depending on soil moisture, soil type and the plant species. Rui and Zhang, 2010 ascertained the same about the importance of roots and litter roles in boost carbon content. Further analysis showed that build up of litter and roots excretion in the soil could raise annual soil carbon content up to 0.41 $ton.ha^{-1}$. Soil acts as the principle sink of carbon in rangeland ecosystems, and what's more, soil organic matter is the only sink of carbon in arid and semi-arid environments. For this reason, recognition of influential factors in carbon sequestration in soil is worthwhile. According to the results obtained, understanding important factors in carbon sequestration in soil is inevitable. Bruce *et al.*, 1999 also argued that soil organic carbon functions based upon climatic, vegetation, topographic, soil texture and structure, bulk density, lime content and soil salinity factors.

The current findings add to a growing body of literature on the substantial role of soil clay content on the stored level of carbon. Soils with fine particles compared with the same soil with coarse particles, has a stronger tendency toward carbon sequestering. Hassink, 1997 insists on the solid relationship between the stability of soil organic carbon and soil clay content. The author advocate the idea that the highest possible storable organic matter in a certain soil is controlled by soil silt and clay content. Yong Zhong, 2007 and Demmi *et al.*, 1986 believe that in a certain short period, sandy soils are more capable of storing carbon and nitrogen than clayey soils. But in a long run, clayey soils get over the sandy soils. Bulk density of the three species doesn't show significant differences with an average amount of 1.2 $gr.cm^{-3}$. Mckenzie *et al.*, 2000 pointed out to the deterministic role of soil bulk density in soil capacity of carbon sequestering. In order to approximate the soil carbon content in a defined soil volume, soil organic carbon percentage must be multiplied by soil bulk density. When it comes to comparing two predetermined soil samples, both with the same level of organic carbon but different bulk densities, the sample with higher bulk density will have higher amount of organic carbon. Yet Mohseni Fashmi *et al.*, 2009 speak about a mutual relationship between soil bulk density and soil organic carbon in such a way that addition of organic matter could improve soil porous media and its capacity to infiltrate water which in turn lessens the runoff and erosion potential. This process decrease wasting of carbon through erosion. Therefore, there could be a firm correlation between soil bulk density and carbon content.

The results of this study indicate that soil of all vegetation types is alkaline and the closer we get to the sea, the higher goes the soil alkalinity and thereby *Halocnemum strobilaceum* make its way through the other species to reach the dominancy. However, pH of the saline and control sites has decreased remarkably. It has conclusively been shown by Hoseinzadeh *et al.*, 2008 that pH tapers off as a result of organic matter, organic acids and minerals mount up, which in this case carbonic acid as a weak acid, sparks lime solution and leaching the byproducts in the root expansion zone and lowers the pH in this area because there is an ongoing process of acid production in a zone of roots of high density. David *et al.*, 2004 comparative study shows that in terms of pH reduction, factors like dense vegetation cover, accumulation of organic matter, increase of root density and high activity of microorganisms in the soil are inclusive.

In spite of the fact that by comparison, *Kochia prostrata* (with total production of 96.96 $ton.ha^{-1}$) is ranked higher for its total carbon storage, but there couldn't be drawn a rule of thumb that non-saline sites have sequestered higher volumes of carbon than the saline sites. One reason is that carbon sequestering of a given plant depends on the nature of the species and the amount of woody tissues it has developed through time. Another factor that shouldn't be overlooked is the role of adjoined plant species. Salinity of saline sites could have implications on vegetation density and accompanying plants diversity which indirectly could attenuate carbon sequestering in the area. But due to the existence of vast saline sites in Iran, the role of halophyte plants as carbon sequesters couldn't be neglected. As a result, although halophytes are of lower importance for grazing intentions, but regarding status quo of erosion and the role of these species in carbon sequestering, there is a growing demand for in-depth insight into saline sites characteristics and the spatial distribution patterns of species and communities and more particularly endemic ones to rehabilitate and utilized salt lands and salt marshes in a sustainable manner. in these circumstances, halophytes could play the key-role in the recovery process of degraded rangelands.

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