کلمات کلیدی: ترسیب کربن، قرق، مرتع، گمیشان

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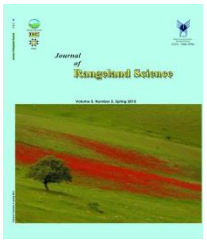

Research and Full Length Article:

Investigation of Carbon Sequestration Potential in Four Species Including *Atriplex canescens*, *Haloxylon persicum*, *Artemisia sieberi* and *Agropyron desertorum* (Case Study: Zarandieh, Saveh, Iran)

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Abstract. Climate changes and global warming are considered as very important challenges of sustainable development. Carbon sequestration is the easiest and cheapest way to reduce the greenhouse gases, especially carbon which constitutes the largest portion of them. In the present study, the potential of carbon sequestration in four plant species of *Atriplex canescens*, *Haloxylon persicum*, *Artemisia sieberi* and *Agropyron desertorum was* studied in the rangeland of Zarandieh, Saveh, Iran. Key areas and study sites were selected and size and number of plots were determined using the minimal area method. Then, aerial and underground organs were cut and litter of species was collected from the soil surface. Also, the soil samples were taken from two depths of 0-30 and 30-70 cm in the same plots. Samples were moved to laboratory and the rates of plant organic carbon and soil organic carbon were determined using combustion and Walky-Black methods, respectively. Data were analyzed and means comparison was made using Duncan method in SPSS software. Results showed that the rates of carbon sequestration in different species, vegetation organs and soil layers were different and increased in wooding species. Also, the rate of soil carbon sequestration in the upper depth was more than the lower one; thus, carbon storage in soil near short trees (*Atriplex canescens, Haloxylon persicum)* was higher than that near shrubs *(Artemisia sieberi)* and herbaceous form *(Agropyron desertorum).*

Key words: Carbon sequestration, Different life form, Zarandieh Saveh

Introduction

Greenhouse gases such as carbon dioxide, methane and nitrogen oxide have increased since the industrial revolution in 19th century (IPCC, 2001). Carbon dioxide concentration in the atmosphere has increased from 280 to 365 parts per million (ppm) since 19th century and it seems that in 21st century, it will reach up to 600 ppm. This leads to an increase in the mean annual temperature of the earth at a rate of 1 to 4.5°C (Houghton *et al.*, 1992). In addition to natural factors, the increase in human population, increased use of fossil fuels, ecosystem disturbance intensification and increased agricultural production have caused the increased greenhouse gases (IPCC, 2001; Vitousek, 1994, Houghton *et al.*, 2001). Climatic changes and increased global warming are of the major challenges in the sustainable development and will have a negative impact on aquatic and terrestrial ecosystems (Huang and Kronard, 2001). Carbon refinement with artificial method such as filter is very costly; for instance, its costs are estimated around 100 to 300 $ for each ton of carbon in the United States (Finer, 1996). Soils hold carbon over three times as much as the atmosphere (Lemma *et al.*, 2006) more than the Earth's vegetation and atmosphere and have the capacity to hold much more carbon (Lal, 2004). In this context, the industrialized countries have predicted long-term plans to reduce the concentration of carbon dioxide. In Kyoto conference, this issue was seriously discussed and in a protocol, countries have been urged to use vegetation for carbon sequestration (Dixon *et al*., 1994). Plants through photosynthesis absorb carbon dioxide and sequester it in the soil and their organs and so they can help a lot to curb the global warming (Brooks, 2000). The difference in the carbon content in different rangelands largely depends upon soil and climatic factors. Carbon sequestration in the plant biomass and soil is the simplest and the most economical practical solution for reducing atmospheric carbon dioxide (Forozeh *et al.*, 2008). Carbon content in the soil is more than that in the biomass or roots (Aradottir *et al.*, 2000). Woomer and Toure (2004) in a context with the amount of carbon storage in the plants and soils in Senegal concluded that 60% of the organic carbon might be stored in the depth of 20 cm in the soil.

Among the studies that have been conducted on the potential carbon sequestration in different species, some of the following can be noted: Ojima (2000) studied the effects of overuse of rangelands and their conversion into farmland on soil carbon storage and concluded that vegetation changes caused by land use changes can be reduced by carbon sequestration. Forozeh *et al*. (2008) investigated the potentials for carbon sequestration in three species including *Helianthemum* sp., *Artemisia sieberi* and *Dendrostellera lessertii* in the arid rangelands in Iran. They found that species of *Artemisia sieberi* had the highest potential for carbon sequestration in the region. Amani and Maddah Arefi (2003) by investigating carbon sequestration in the planting of *Haloxylon* shrub lands in the country expressed that the average rate of carbon sequestration in the aerial biomass of 20 year-old *Haloxylon* is more likely to be 5 ton h^{-1}. Ahmadi *et al.* (2009) by comparing carbon sequestration in *Haloxylon* organs

in southern salt lake showed that the rate of carbon sequestration in different organs of *Haloxylon ammodendron* was significantly different and the highest carbon sequestration was obtained in the sections of leaf, main stem, root and lateral branch, respectively. Gholami (2009) with the evaluation and carbon in soil, respectively. Hassan Nejad *et al.* (2014) by investigating carbon sequestration in *Astragalus gossypinus* and *Dactylis glomerata* in the mountainous regions of Hezarjarib in Behshahr concluded that there was a significant difference between carbon sequestrations in different organs in the enclosure rangeland species with the same organs in the same species in the rangelands under grazing. Carbon storage in two soil depths showed that at both depths in the enclosure, the carbon sequestration was greater than that in the grazing area. Also, soil had stored more carbon than plant biomass. Tamertash *et al.* (2012) evaluated the effects of different vegetation types on carbon sequestration in the plains of Miankaleh rangeland and concluded that the rate of carbon sequestration was different in plant species and organs and increases with the woody cover percent and its increase. Results on the investigation of carbon storage potentials in three species of *Artemisia aucheri*, *Stipa barbata* and *Agropyron elongatum* in Peshert Kiasar, Ran showed that the rates of carbon sequestration in three species were significant ($P<0.05$) and *Artemisia aucheri* had the highest rate of carbon sequestration in the region. Also, the soil of *Artemisia aucheri* had stored more carbon in comparison with the other species (Jafarian *et al.*, 2012). Gholami *et al.* (2012) in a survey estimated the capacity of carbon sequestration by *Atriplex* in Novdehak, Qazvin, Iran and concluded that almost 36.2 and 5.4 ton h^{-1} carbon in the soil and *Atriplex*'s organs were sequestered. Contribution of the soil in carbon sequestration in the studied comparison of the rate of carbon sequestration in two species of *Atriplex canescens* and *Hulthemia persica* in Qazvin Novdehak region, Iran showed that total carbon sequestration in *Atriplex canescens* was 1.27 times higher than that in *Hulthemia persica* and the two species had stored more than 98 and 87% of region was 87%. Thus, it was concluded that soil of rangeland ecosystems was the most important source of organic carbon. Due to the importance of carbon sequestration at the global level and considering that the rangeland constitutes a wide area of the country surface, it is essential to study the amount of carbon sequestration in different rangeland species, investigate the herbaceous species because of much distribution in the rangeland areas and compare them with shrub species and short tree. So, this research aims to examine carbon sequestration potentials of four species involving *Atriplex canescens*, *Haloxylon persicum*, *Artemisia sieberi*, *Agropyron desertorum* in the rangelands of Zarandieh, Saveh, Iran.

Materials and Methods

Study area

Zarand city is located at a distance of 30 km from Saveh in southwest of Tehran, Iran at of 30°48'46" Northern longitude and 56°33'50" Eastern latitude. Zarandieh Saveh is a steppe region in Iran. Mean annual rainfall is 239 mm and the mean annual temperature is 25°C with a semi-arid climate. Its altitude is 1256 m above sea level.

Research methods

In order to study the carbon sequestration after the identification of the sites, studies were performed on vegetation types based on the life form and dominant species. Appropriate number of plots per the vegetation types was calculated using a statistical method (Mesdaghi, 2003) (Equation 1).

$$N = \frac{t^2 s^2}{p^2 x^2} \qquad \text{(Equation 1)}$$

Where

N= the number of samples required
t= t student, x=primary average
p=range of error (-0.1 and + 0.1)
s=variance the initial samples
Also, appropriate plot size for each type was determined with the minimal area method (Mueller and Ellenberg, 1974). On this basis, optimum plot size with 4 m^2 and 40 plots for sampling were selected. To estimate the moisture percent and carbon content in the shoots of dominant species, the cutting and weighing method was used. For this reason, 10 plants from the dominant species as a combination of young and old stands were selected and then, sampled and litter of any species was collected from the soil surface. Underground organs were sampled from rooting zone. In addition, in the same plots, soil samples were taken from two depths of 0-30 and 30-70 cm. Vegetation and soil samples were transported to the laboratory and in order to determine the conversion ratio of carbon sequestration in various organs of species to organic carbon, the method of combustion in an electric furnace with a temperature of 400°C for 24 h (McDicken, 1997) was used. The weight loss resulting from the combustion indicates the amount of organic matter and 56% of that would be the organic carbon (Birdesy, 1996). Then, organic carbon ratio of plant aerial and root biomass was obtained by dividing the weight of organic carbon (g) on the weight of dry sample used in an Electric furnace. Finally, the amount of stored organic carbon in the plant aerial and root biomass was obtained by multiplying the organic carbon ratio of plant parts in their total dry weight. Soil samples were dried out in the open air and passed through 2 mm sieve. The soil organic carbon was measured using the Walkley-Black method and to estimate the total carbon percent, the bulk density of the soil samples was obtained by clog (Walkley, 1947). To determine the rate of carbon sequestration in the plant organs, the conversion ratio of organic carbon in the plant biomass was multiplied by the total weight of carbon sequestration in each plot at each hectare from vegetation area. Also, the rate of carbon sequestration was calculated in soil (C) by bulk density (B_d) and depth of soil (e) per hectare using (Equation 2), (Lemma *et al.*, 2006).

$$Cc = 1000 \times C\% \times B_d \times e \qquad \text{(Equation 2)}$$

Where
(C%) = carbon % in soil, B_d=bulk density
e= depth of soil
Finally, to determine significant differences in vegetation and soil data, one way ANOVA was used. Means comparison was made using Duncan's method. Data were analyzed using the statistical software $SPSS_{16}$.

Results

Carbon sequestration in species organs

The results of one-way ANOVA of plant organs showed significant differences of carbon sequestration between the plant organs of *Haloxylon persicum* ($P<0.05$) and the other three species ($P<0.01$) (Table 1). Means comparison of carbon sequestration in the aerial, underground and litter of individual species was made using Duncan's test (Fig. 1). Results showed that *Atriplex canescens* with the average value of 411.1 kg/h^{-1} had the highest carbon storage in its aerial organ followed by *Haloxylon persicum* with the average value of 241 kg/h^{-1}. The carbon storage rates of underground organs of *Haloxylon persicum* and *Atriplex canescens* were 234.85 and 161.1 kg h^{-1}, respectively (Fig. 1). The highest and lowest carbon storage rates of litters with the average values of 120 and 14.3 kg h^{-1} were obtained in *Haloxylon persicum* and *Agropyron desertorum*, respectively (Fig. 1). In general, the lower values of 36.4, 21.3, 14.3 kg h^{-1} and 54.6, 30.8, 19.8 kg h^{-1} were obtained for the aerial and underground organs and litter in *Agropyron desertorum* and *Artemisia sieberi*, respectively (Fig. 1).

Table 1. Analysis of variance of carbon sequestration in different organs of each species

Source of variation	df	MS			
		Haloxylon persicum	*Atriplex canescens*	*Artemisia sieberi*	*Agropyron desertorum*
Between organs	2	42747.4*	351166.4**	3166.3**	1285.4**
Error	27	8653.21	19319.5	128.42	57.51

*, **= Significant at the probability levels of %5 and %1, respectively

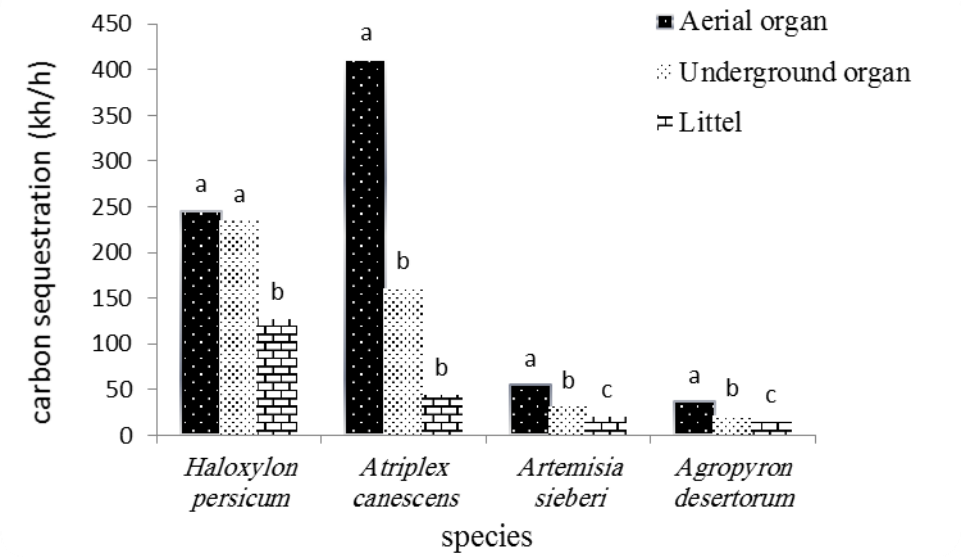

Fig. 1. Aerial, underground organs and litter carbon sequestration in each species
Means of plant organs with the same letters are not significantly different (ρ<0.01)

Soil carbon storage of species

The results of ANOVA of carbon sequestration by species in two soil depths (upper and lower layers) are shown in Table 2. There were significant differences between plant species for each depth (P<0.01). According to Duncan test, carbon storage amounts in soil upper depth near *Haloxylon persicum* and *Atriplex canescens* were 583.67 and 555.46 ton h^{-1}, respectively. Both species had significant differences with two other species. In the lower depth, the rates of carbon sequestration in *Atriplex canescens, Artemisia sieberi* and *Haloxylon persicum* were 239.2, 202.4 and 240.6 ton h^{-1}, respectively while the lower value of 176 $tonh^{-1}$ carbon storage was obtained from *Agropyron desertorum* (Fig. 2).

Total carbon storage of species

Total amounts of carbon sequestered in four species were tested and the results of analysis of variance are presented in Table 2. There were significant differences between the species for total carbon sequestration (P<0.01) (Table 2). *Haloxylon persicum* and *Atriplex canescens* with the average values of 610 and 600 kgh^{-1} had the highest rate of total carbon sequestration. However, there was no significant difference between them. The least amount of total carbon sequestration with the average value of 72.11 ton h^{-1} was observed in *Agropyron desertorum* (Fig. 3).

Table 2. Analysis of variance of carbon sequestration in soil under species in two depths 0-30 and 30-70 cm and total carbon sequestration of the four species

Source of Variation	df	MS		
		0-30 cm	30-70 cm	Total Carbon Sequestration
Between species	3	633055 **	112940.2**	913922.6**
Error	36	18713	4524.9	37621.1

**= Significant at the probability levels %1

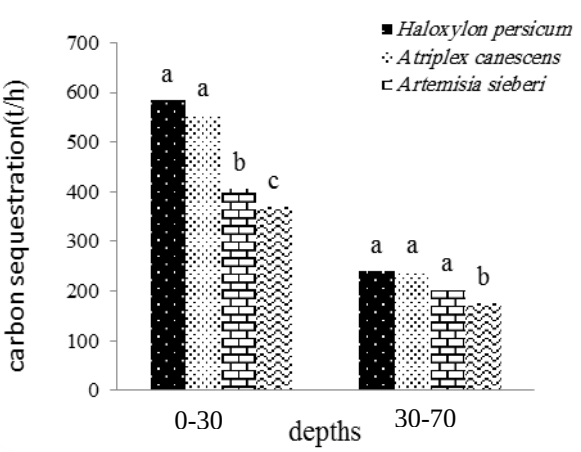

Fig. 2. Carbon sequestration in soil at two depths 0-30 and 70-30 cm in four species
Means of species with the same letters are not significantly different (ρ<0.01)

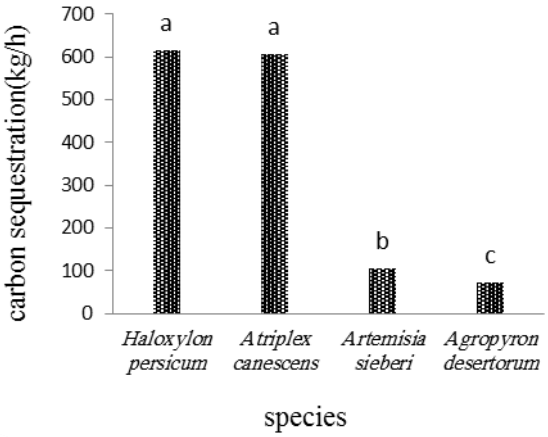

Fig. 3. Total carbon sequestration in each species
Means of species with the same letters are not significantly different (ρ<0.01)

Discussion

The results of this study showed that in all the studied species, carbon sequestration rate in the aerial organs was greater than the underground ones. This is because of different capabilities of life forms and the effects of their aerial extent of organs, especially leaves on carbon absorption. In the case of stems, it is because woody tissue has a greater capability to sequester carbon and in fact, the more wooden organs in the plant, the greater capability in carbon sequestration (Cannell, 2003; Indufor, 2002). Also, because of having higher weight of aeria lorgans, they had the highest organic carbon. Among plant species, shrub and short tree species of *Haloxylon persicum* and *Atriplex canescens* had greater capabilities in carbon sequestration than *Artemisia sieberi* and *Agropyron desertorum*. Short trees and shrubs having broad leaves can have more absorption. According to the results, it can be expressed that leaves on the plant species owing to more surface area have more capability to absorb carbon. It is partly due to higher mineral of leaves (Bordbar and Mortazavi Jahromi, 2006). These results were in agreement with those obtained by Temrtash *et al.* (2012); Hasan Nejad *et al.* (2014) and Jafarian *et al.* (2012). This shows various abilities of different plant species in the absorption and carbon sequestration. Accordingly, various studies for different plant species have been conducted and different coefficients have been proposed for carbon sequestration (Frank *et al.*, 2003; Kilbride *et al.*, 1999). According to the results, organic carbon content is more at upper depth rather than lower one. These results corresponded with those reported by Rice (2000) who observed that there was an indirect relationship between carbon sequestration and soil depth. These results also corresponded with the ones found by Schuman *et al.* (2002).

This is because litter decomposition into humus that begins from soil surface is a gradual process. Also, a comparison of carbon sequestration in soil near species in two different depths showed that *Haloxylon persicum* and *Atriplex canescens* had more carbon storage capacities around their roots as compared to *Artemisia sieberi* and *Agropyron* to soil are more and herbaceous species due to high degradability of litter have entered smaller amounts of organic matter into the soil. Also, results showed that carbon was stored in the soil in all life forms more than vegetative organs. Considering the important roles that soil plays in carbon sequestration, it can be considered as one of the known valuable natural ecosystems.

Conclusion

Carbon sequestration potential varies with respect to the plant species, location and management practices; therefore, finding the species that has more capability for carbon sequestration and using it for correcting and restoring vegetation in the region, it is possible to improve carbon sequestration in the desired region. Regarding higher aerial and underground biomass production in the species for the improvement and rehabilitation of rangeland, the more carbon is stored in the body of plants, litter and soil and more effective steps may be taken to reduce the greenhouse gases.

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بررسی پتانسیل ترسیب کربن در چهارگونه *Haloxylon persicum*، *Atriplex canescens*، *Artemisia sieberi* و *Agropyron desertorum* (مطالعه مـوردی: منطقه زرندیه ساوه)

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چکیده. تغییر اقلیم و افزایش گرمای جهانی یکی از مهم‌ترین چالش‌ها در توسعه پایدار محسوب می‌گردند. ترسیب کربن ساده‌ترین و ارزان‌ترین راهکار برای کاهش گازهای گلخانه‌ای به‌خصوص کربن که عمده‌ترین آنهاست، می‌باشد. در بررسی حاضر به منظور ارزیابی توان ترسیب کربن در مراتع زرندیه ساوه، چهار گونه آتریپلکس کانیسنس (*Atriplex canescens*)، تاغ (*Haloxylon persicum*)، درمنه (*Artemisia sieberi*) و آگروپایرون دزرتروم (*Agropyron desertorum*) انتخاب شدند. پس از تعیین منطقه معرف و انتخاب سایت‌های مورد مطالعه، تعداد پلات با استفاده از روش آماری و اندازه پلات به روش حداقل سطح تعیین شد. سپس اندام هوایی، زیرزمینی و لاشبرگ گونه‌ها قطع و به آزمایشگاه منتقل و نمونه‌برداری از خاک نیز صورت گرفت. در آزمایشگاه مقدار کربن آلی اندام‌های گیاهی به روش احتراق و کربن آلی خاک به روش والکی بلاک تعیین شد. تجزیه تحلیل واریانس و مقایسه میانگین‌ها به روش دانکن توسط نرم افزار SPSS انجام شد. نتایج آماری نشان داد که مقدار ترسیب کربن در گونه-های مختلف، اندام‌های گیاهی و خاک متفاوت بوده و با افزایش سطح چوبی شدن در گونه‌ها افزایش یافت. همچنین مقدار ترسیب کربن خاک در عمق اول بیشتر از عمق دوم بوده ضمن اینکه ذخیره کربن در خاک پای فرم رویشی درختچه ای (تاغ و آتریپلکس) بیشتر از فرم بوته ای (درمنه) و علفی (آگروپایرون) بوده است.

کلمات کلیدی: ترسیب کربن، فرم رویشی مختلف، زرندیه ساوه