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Carbon sequestration potential in soil and stand of *Nitraria schoberi* L.

H.R. Naseri*

Desert Management Department, International Desert Research Center (IDRC), University of Tehran, Tehran, Iran

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Abstract

Arid and semi-arid lands cover around one-third of the world's terrestrial expanse and their widespread plant distributions provide these areas with a high potential for sequestering carbon. Vegetation management for developing shrub or tree species in arid and semi-arid regions is one inexpensive and multi-purpose approach for decreasing CO_2. This study assessed the potential of carbon sequestration in the soil and biomass of a *Nitraria schoberi* L. stand in central Iran. Samples were taken from in *N. schoberi* L. stand and the adjacent native vegetation (*Halocnemum strobilaceum* M. B. and *Seidlitzia rosmarinus* (Ehrh.) Bge.) as control area at Hoze Soltan desert region. In both areas, the amounts of aboveground and underground biomass of plant samples were calculated by cutting and weighing the aerial parts (leaves, stem) and roots. The ash method was used to determine the carbon sequestration coefficients of all samples and soil organic carbon (SOC) was measured using Walkley and Black's methods. A comparison between the SOC of planted and control areas showed no difference regarding the ability of carbon sequestration between the two areas. The results indicated that the total carbon sequestration of the *N. schoberi* L. stand (28.06 Mg/ha) was significantly higher ($p<0.01$) than the control area (18.64 Mg/ha) in the Hoze Soltan region.

Keywords: Carbon sequestration; *Nitraria schoberi* L.; Hoze Soltan; Iran

1. Introduction

One of the biggest challenges of the 21^{st}**,** century is reducing the impact of climate change by developing effective ways of natural resources management adaptation (Mendelsohn and Dinar, 2009). Widespread concern about global climate change has led to an interest in reducing carbon dioxide (CO_2) emissions and in certain circumstances, measuring the additional carbon absorbed within soils and vegetation as part of the approach toward emissions reduction. Scientists believe the main factor for increasing the temperature of earth to be CO_2 (Korner *et al.*, 2003). Land use changes and increasing fossil fuel use have contributed to increased atmospheric CO_2 concentrations (Watson *et al*., 1996). Climate changes and global warming are generated by the density of greenhouse gases found in the atmosphere of Earth (Brooks, 1998) and carbon, in turn, is one of the major causes of these greenhouse gases (Lal, 2004).

It has been estimated that in the 21^{st} century, carbon dioxide will be reached to 600 section in million at atmosphere causing an increasing median annual temperature on Earth at a rate of 1Cº to 4Cº (Korner *et al.*, 2003). However, the largest amounts of carbon is absorbed by oceans where it kept as a reserve; nonetheless, studies have shown that this type of source doesn't have more capacity for observation of additional carbon

* Corresponding author. Tel.: +98 21 88971717,
Fax: +98 21 88971717.
E-mail address: hrnaseri@ut.ac.ir

in themselves and its residue should be reserved in land (Kenneth *et al.*, 2000).

In terrestrial ecosystems, plants are the main resources for reserving carbon and forests therefore play a particular role in this process. Worldwide, forest ecosystem activity can hold about 2.3 gigatonnes of carbon annually (Thompson and Matthews, 1989). Refining carbon through artificial methods such as filtration includes a variety of different charges; its expense in America has been measured at about \$100 to \$300 \$ per tonne of carbon (Finer, 1996). Many environmental conferences have highlighted this problem and countries have been obliged to reserve carbon by planting particularly shrubs and trees in a range of ecological conditions, including arid and semi-arid areas. Over time, shrubs can grow on land that had previously had other uses (e.g., croplands) and vice versa.

Shrub planting is the conversion of shrubs to other landscapes that have few or no shrubs. Deserts and semi-deserts occupy approximately 22 per cent of the planet's land surface (Janzen, 2004) and are generally assumed to be relatively minor players in the global carbon cycle. However, shrub planting is an important method for carbon sequestration in desert areas and this practice can help to improve the contribution of these areas to this process.

Nitraria schoberi L. (*Ghar-e-Dagh* in Persian) is an important shrub from the family *Zygophyllaceae* that grows in arid and semi-arid areas of Iran. Many shrubs have adapted to the dry conditions of desert areas and can remove carbon dioxide from the atmosphere through the natural process of photosynthesis, and store carbon (C) in their leaves, branches, stems, bark and roots. On the other hand, oxygen (O) diffuses in the opposite direction, from the plant's leaves into the air. Approximately half the dry weight of a shrub's biomass is carbon; this means there is strong opportunities for carbon sequestration in desert shrub lands. *Nitraria schoberi* L. requires sandy soil with a shallow saline water table for an optimum growth rate; as such, it is a suitable plant for the reclamation of playa area (Naseri, 2008). This study aims to determine the carbon sequestration potential of this valuable plant in a desert region in central Iran.

2. Material and methods

The Hoze Soltan region is a playa with a temporal saline lake located in the north of Qom (Figure 1). The average elevation of Hoze Soltan is roughly 850 metres above sea level. Much of study area is covered with saline soil, which is occupied by native halophytes, e.g., *Halocnemum strobilaceum* M.B. and *Seidlitzia rosmarinus* (Ehrh.) Bge. During a 25-year-period, mean annual precipitation is 147 mm in the plain and about 70% to 80% of the annual precipitation is concentrated in the months from September to March, while less than 5% occurs in the summer months (Naseri, 2008). The average annual temperature is 17.6°C, but significant variations nonetheless occur. Temperatures are extremely high in summer, the hottest month being July. The study area is located four kilometres east of the Tehran-Qom highway (latitude 34º 52′ 22.17″ N, longitude 50º 53′ 9.8″ E).

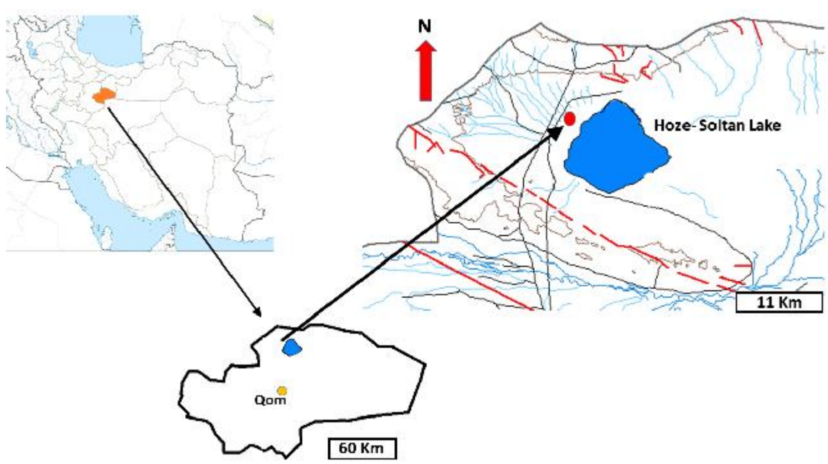

Fig. 1. Study area in Hoze Soltan region, northern Qom, Iran

For soil and plant sampling, study sites were established in the Hoze Soltan rangelands in an area planted with *N. schoberi* L., as well as adjacent native vegetation (control area) (Fig. 2). The age of the *N. schoberi* L. stand in the Hoze Soltan region is about 15 years; this stand is grazed by local livestock (goats and sheep) from April to September; the same applies to native vegetation types.

Fig. 2. *Nitraria schoberi* L. stand (left) and control area (right)

Forty-five 4m × 2m quadrants in the *N. schoberi* L. stand and 60 1 × 1m quadrants in control area were established along seven 1000m transects (three in planted area and four in the control area), which were selected randomly. All plant and soil samples were collected within these plots in July 2012. The leaves, branches, stems and roots of plants were sampled from randomly selected samples in each plot for measuring carbon concentrations. For both sites, the amounts of aboveground and underground biomass of the species were calculated by cutting and weighing the aerial parts (leaves, stem) and roots with 30 repetitions. Litter sampling was conducted at a distance of one-half the canopy radius from the centre of the shrubs. Regarding the goal of the study, effective depth for root sampling in *Nitraria schoberi* L. stand and control area was 30 cm. Leaves were manually separated from stems and roots were washed and weighed. All roots, alive and dead, were included in the sample.

The plant samples (leaves, stems, branches, roots and litter) were oven-dried to a constant mass at approximately 65°C for 48h and then stored in desiccators until use. Following Rayment and Higginson (1992), the ash method was used to determine the carbon sequestration coefficient of the studied species. Soil sampling was conducted randomly at each site. For each of the selected sites representing vegetation type, 30 sampling ditches were dug. Soil bulk density was determined using a soil corer (stainless steel cylinder, 100 cm^3 in volume) and soil samples were collected from a 0.0 to 30 cm depth. Gao et al. (2007) argued that changes in soil's organic carbon content at depths greater than 30 cm are quite small. Thirty soil samples at each site (60 soil samples in total) were taken and moved to the laboratory where they were dried out in the open air and sifted using a sieve consisting of 2 mm mesh. Soil organic carbon (SOC) was measured using Walkley and Black's $K_2Cr_2O_7$–H_2SO_4 oxidation method (Nelson and Sommers, 1982).

In order to determine the amount of sequestrated carbon by the gram per square metre, Formula (1) was employed:

$$Cc = 1000.C\ (\%).Bd.e. \qquad (1)$$

In this formula, Cc refers to the amount of sequestrated carbon weight per square metre. C signifies the percentage of the accumulated carbon in the calculated depth of soil. Bd represents the bulk density of the soil and e denotes the thickness of the soil depth by the centimetre.

For more details about soil pH and EC in a 1:1(w/w) soil/water slurry, particle size according to the hydrometer method (Bouyoucos, 1962) was also determined in the laboratory. Total system carbon was defined as the sum of the woody biomass, herbaceous biomass, root and litter and soil carbon. All data were analysed using the MSTAT-C for Windows software package. Means of carbon stock in different parts were conducted by paired-samples T test.

3. Results

Planted vegetation had patchy distribution, with *N. schoberi* L. dominating patches 0.5 to 2.5m in diameter. Intervening patches were dominated by soil crusts and native annual and perennial shrubs and forbs. The data were analysed for calculating plant and soil carbon in the control area and the *N. schoberi* L. stand at Hoze Soltan rangeland. The basic soil properties analysis between the *N. schoberi* L. stand and control area are shown in Table 1.

Table 1. Basic soil properties measured at Hoze Soltan

Location	Soil density (gr/Cm^3)	EC(ds/m)	pH	Clay%	Silt%	Sand%	Texture
N. schoberi L. stand	1.51± 0.07	28.2± 3.7	8.2± 0.04	36± 0.9	42.6± 1.6	21.4± 0.9	Clay loam
Control area	1.48± 0. 90	34.40± 5.2	8.0± 0.10	31.9± 2.1	42.7± 4.8	25.5± 2.7	Clay loam

The results of the paired student's t-test analysis and the amount of carbon stocks are shown in Table 2. The comparisons among the means of carbon stock in different parts of plants and soil showed that average soil organic carbon displayed no significant differences between the *N. schoberi* L. stand and the control area, but that the average total carbon and carbon stocks in different part of plants at the *N. schoberi* L. stand differed from the control area. According to the results, the *N. schoberi* L. stand presented significantly higher carbon storage compared to the adjacent control area; meanwhile, leaf and litter carbon stocks in the control area were higher than in the planted *N. schoberi* L stand area.

Table 2. Comparison of carbon distribution (Mg/ha) between the *N. schoberi* L. stand and the control area

Parts of C storage	*N. schoberi* stands areas	Control area	T test
	Mean ± S.E	Mean ± S.E	
Leaves	1.25±0.32	2.21±0.27	2.21⋆
Stem	8.41±1.07	2.34±0.98	2.65⋆
Litter	0.68±0.05	1.09±0.34	2.07⋆
Roots	10.66±3.05	6.32±1.95	2.52⋆
SOC	7.06±1.25	6.68±0.23	2.38ns
Total carbon	28.06±3.21	18.64±1.52	2.55⋆

⋆: significant: <0.01 ns: not significant

Figure 3 shows the percentage of total organic carbon distribution in soil and plants. The results indicated that the roots in the *N. schoberi* L. stand had allocated 38% of the total carbon to itself; however, in the adjacent native vegetation, this amount was taken up by soil. Based on the results yielded by these steps, it appears that in the planted area, the largest percentage of total carbon had been reserved in the live parts of plants. Fifteen years after the *N. schoberi* L. shrubs had been planted, plant stands had added 50% more carbon to the initial ecosystem carbon pool, with an annual sequestration rate 0.625 Mg/ha/year.

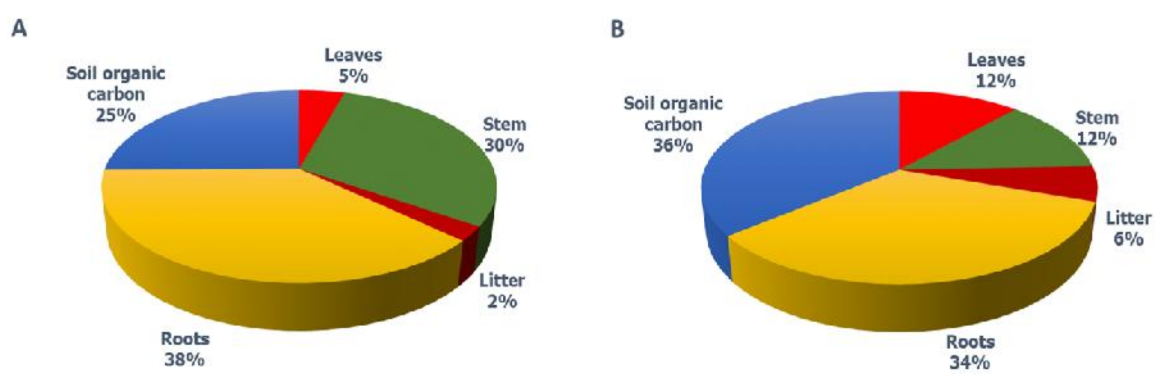

Fig. 3. Carbon distribution in different parts of the *N. schoberi* L. stand areas (A) and the adjacent control area (B)

4. Conclusions

This study clearly demonstrated that shrub planting in the study area showed potential for sequestering atmospheric carbon. The establishment of *N. schoberi* L. in the Hoze Soltan clay loam soils increased the total ecosystem carbon stocks, primarily as a result of plants' carbon components, particularly the stems and roots. Hu et al. (2008) reported the same results from the afforestation of semi-arid sandy soil in southeast Keerqin. However, there were differences in total organic carbon distribution in soil and plants between the control and planted area. Nonetheless, plants were the main facilitators of carbon storage. Schlesinger and Lichter (2001) argued that living wood is the dominant sink for atmospheric CO_2 within regrowth forests; consequently, in arid and semi-arid rangelands, this function belongs to shrubs plants that have sufficient woody stems and roots for reserving carbon. Thompson *et al*. (2006) stated that vegetation distribution within arid and semi-arid shrub lands is often described as ‘‘patchy’’, with macrophytic areas dominated by one or more woody perennial plants. Furthermore, microphytic patches are claimed as the domain of ephemeral plants. Within such ecosystems ‘‘fertile islands’’ are usually centred in macrophytic patches and the soils beneath tend to be enriched with C, N and P, compared to microphytic patches (Schlesinger *et al*., 1990; Whitford, 2002). This means *N. schoberi* L. shrubs can improve the amount of carbon in soil; however, our results could not confirm this problem due to the age of *N. schoberi* L. not having been high enough for effective carbon exchange to have taken place between soil and vegetation. However, remarkable carbon storage in plants' biomass should not be ignored. The sequestration rate that we estimated was based on young the *N. schoberi* L. stand (15 years of age), which was characterized by high initial growth rates. Considering that plantations are clear cut 35 to 40 years after planting (Laclau *et al*., 1999), growth and C sequestration rate decay as plantations got older was to be expected (Binkley *et al*., 2002). Changes in carbon pools following the planting of shrubs were mainly due to plant biomass and litter increases.

The average carbon sequestration rate among shrub planting that we observed (28.06 Mg/ha) matched observations from other afforested systems in semi-arid regions (Grunzweig *et al*., 2003) and evidenced the potential of vegetation development by woody and shrubby plants for carbon sequestration programmes in strongly water-limited ecosystems. A 50% increase in C to the initial ecosystem carbon pool in our study was similar to other studies conducted by Nosetto et al. (2006) in a *Pinus ponderosa* stand in northwest Patagonia. The effects of vegetation development on soil C stocks can be influenced by other factors such as the amount of rainfall (Jackson *et al*., 2002), the plant species involved, stand age, soil texture and site management (Paul *et al*., 2002; Thuille and Schulze, 2006). Worldwide, improved rangeland management strategies and practices can greatly increase soil C sequestration, while also greatly improving their production potential and other environmental benefits (Schuman *et al*., 2002).

Finally, the results of this paper showed that in spite of a rain shortage and harsh conditions in the central deserts of Iran, these areas can support atmospheric carbon as remarkable reserve. As such, efforts applied to vegetation improvement can potentially be useful for carbon sequestration projects.

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