



Effects of Planting *Haloxylon* and *Atriplex* on Soil Carbon Sequestration in Desertified Land Reclamation (Case Study: Kerman Province)

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Abstract

Reclamation of sandy land in arid and semi-arid areas has a high potential in increasing carbon sequestration and improving soil quality. The objective of this study was to assess the amount of soil carbon sequestration and enhancement of soil properties under plantation of two well-adapted species to desert environment, i.e. *Atriplex* and *Haloxylon*. This study was conducted in Shahid Zenderuh Research Station in Jupar city of Kerman Province. In this region *Atriplex canescens* and *Haloxylon ammodendron* species have been planted for wind erosion control. According to the research objectives, 24 soil samples were taken from each depth (under canopy cover and control sites) through systematic-random method. Soil carbon sequestration was determined using Walkley-Black method. The results showed that the reclamation of severe sandy desertified land with these plants significantly increased soil organic carbon (SOC). SOC concentration in areas planted with *Haloxylon* and *Atriplex* species increased by 16.2 and 18.1 ton/ha respectively as compared to control. However, this amount in *Atriplex* plantation site was more than that observed in *Haloxylon* plantation area. Therefore, it is concluded that *A.canescens* has better performance in soil carbon sequestration in the sandy study area compared to that of *H.ammodendron*.

Keywords: *Atriplex*, *Haloxylon*, Soil carbon sequestration, Land degradation

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1. Introduction

Desertification is defined as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities (UNEP, 1991a). Desertification affects more than 100 developed and developing countries in all continents (UNEP, 1997). Some 200 million people are believed to be affected directly by desertification and more than one billion people at risk (FAO, 2004).

Land desertification degrades soil structure and aggregation and in turn, leads to reduction in the total soil carbon pool and increase in carbon dioxide (CO₂) emission from soil and vegetation to the atmosphere (UNEP, 1992). Concentration of CO₂ in the atmosphere has increased about 28 percent during the past 200 years. Human activities are shown by atmospheric scientists to be responsible for increasing the amount of carbon dioxide CO₂ in the atmosphere (IPCC, 2001).

Desertification can be prevented through proper management practices to ensure sustainable development of land resources. Strategies and policies for desertification control include: establishment and protection of vegetation cover to protect soils from erosion, controlled overgrazing; improved water conservation; supplemental irrigation; soil fertility management which enhances biomass productivity; increased water use efficiency; and improved soil quality; improved farming systems and grazing management (Lal, 2001b). The importance of these activities is that any action taken to sequester carbon (C) in biomass and soil will generally increase the organic matter content of soils. Most of the drylands are on degraded soils, soils that have lost huge amounts of carbon. Dryland environments are characterized by a set of features that affect their capacity to sequester C. The main characteristics of drylands are lack of water and high temperature. These constrain plant productivity severely and thus affect C accumulation into soils. Therefore, proper management of the water resources shortage is essential (Lal, 2002a). Hence, the potential for C sequestration (CS) through drylands rehabilitation is substantial (FAO, 2001b).

With 2.1% of the world's arid area and 4.2% of desert landscape, Iran occupies 6.3% of the world's desert regions. Arid and semi-arid areas consist 61% of the total area of the country (FRWO, 2012)¹.

Combatting Desertification has been considered as a principal policy to maintain ecological security in Iran. In the past decades, some effective measures of desertification control have been widely applied in desertified regions from the centre to south of Iran. Successful measures included the establishment of protective tree belts and sand-fixing shrub groves (Jabbari, 2000).

Accurate estimates for soil carbon sequestration potential via desertified lands rehabilitation needs to be supported by a series of researches in various regions of

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Iran. Especially, researches from long-term observation sites in typical areas of desertification control are very important for evaluating soil carbon sequestration influence on desertified land rehabilitation. The main objective of this study was to assess the carbon sequestration brought about by planting *Haloxylon* and *Atriplex* species in the sandy desertified lands of Kerman Province, southern Iran.

2. Materials and Methods

2.1. Site description

The study was conducted in the Shahid Zenderuh Research Station in Jupar city (between $30^{\circ} 07' 21''$ - $30^{\circ} 07' 32''$ N, and $57^{\circ} 03' 39''$ - $57^{\circ} 03' 51''$ E). The area has a relatively temperate desert climate: dry and hot in summer, cold in winter, very little precipitation, strong winds, and frequent drifting sands (Fig. 1).

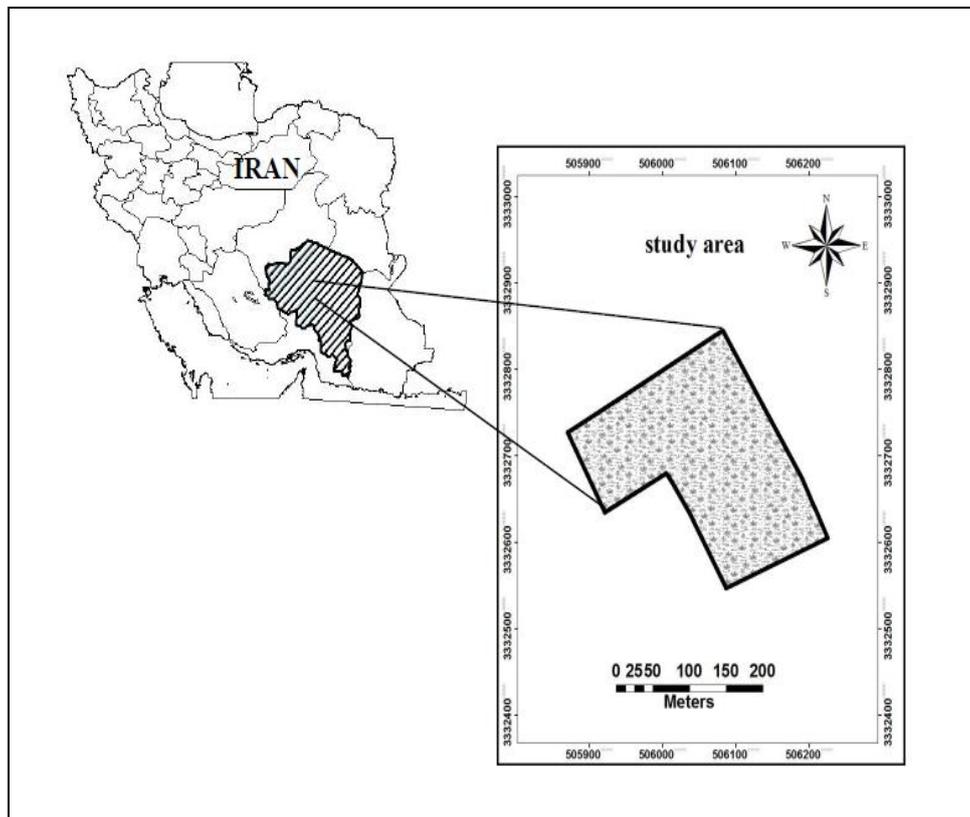


Figure 1. Location of the study area on Iran map

Twenty years ago, IFRWO conducted a desertification control project to develop effective techniques to rehabilitate desertified land. Plantation of drought-tolerant desert shrubs on shifting sand is one of those techniques. In the study area *Haloxylon ammodendron* and *Atriplex canescens* have been planted for this purpose.

2.2. Measurements

To collect soil samples, three transects 100 m long and 50 meters from each other was considered. Eight points were selected on each transect, randomly. Twenty four soil samples were taken from the three areas including: 1) control plots (untreated shifting sand); 2) 20- year-old *H. ammodendron* shrub land; and 3) 20-year-old *A. canescens* shrub land. Soil bulk density was determined using a soil core (100 cm³) taken in each sampling location. To measure lime content, acidity was measured using a pH Meter. Electrical Conductivity Meter (Waterproof Ectestr, 11) was used for measuring Electrical conductivity (EC). SOC was measured using the Walkley-Black method and converted to organic matter through multiplying it by 1.724. To estimate the percentage of total carbon, the carbon accumulation and bulk density of soil were specified as the variables. In order to determine the amount of the sequestered carbon in gram per square meter, Equation 1 was employed:

$$\text{Equation 1:} \quad C_c = 1000 \times C (\%) \times B_d \times e$$

In this equation, C_c refers to the amount of the sequestered carbon weight per square meter, C signifies the percentage of the accumulated carbon in the calculated depth of soil, B_d represents the bulk density of the soil, and e denotes the thickness of the soil depth by the centimeter (Mahdavi *et al.*, 2011).

3. Results

3.1. Soil chemical and physical properties as influenced by *A. canescens*

After revegetation with *A. canescens* some soil chemical and physical properties were changed as shown in Tab. (1). pH was equal to 7.82 and EC was 3.38 dS/m. Soil texture with 8% clay, 3.9% silt and 88 % sand, was categorized as sandy and sandy loam classes. Organic carbon (OC) and SOM values were 0.41 and 0.71%, respectively. Average soil lime was 15.39%. The average bulk density was 1.85 g/cm³. Soil samples were lacking in gypsum, and soil structure in this area is sub angular and angular blocky.

3.2 Soil chemical and physical properties as affected by *H. ammodendron*

H. ammodendron afforestation caused some chemical and physical alterations in soil of the study area. Average pH was 8.34; EC was 1.93 dS/m and soil texture with 6.5% clay, 4.54% silt and 88.9% sand was sandy and sandy loam. Organic carbon and SOM were 0.36 and 0.62%, respectively. Soil lime was 16.56% and

average bulk density was 1.87 g/cm³. Soil samples were lacking in gypsum, and soil structure in this region is sub-angular and angular blocky. Moreover, a significant difference was observed in OC at two depths (0-20 and 20-50 cm). Results in Tab. 1 and Tab. 2, show the properties of the surface soil in different sites.

Table 1. Properties of the surface soil (0-20 cm) at different sites

Location	Bulk density (g/cm ³)	Gypsum (%)	pH	EC (dS/m)	Lime (%)	SOM (%)	OC (%)	Silt (%)	Clay (%)	Sand (%)
<i>Atriplex</i>	1.85 c	-	7.82 c	3.38 a	15.39 c	0.71 a	0.41 a	3.91 b	8.02 a	88.06 a
<i>Haloxylon</i>	1.87 b	-	8.34 a	1.93 b	16.56 a	0.62 b	0.36 b	4.54ab	6.57 b	88.89 a
Control	1/89 a	-	8.25 b	1.31 c	16.11 b	0.14 c	0.08 c	5.33 a	6.87 b	87.8 a

(Different letters indicate difference in significance)

Table 2. Soil bulk density and Organic carbon values in two depths

Location (sites)	Depth (cm)	Bulk density (g/cm ³)	Organic Carbon (%)
<i>Atriplex</i>	0-20	1.81 a	0.52 a
	20-50	1.88 b	0.3 b
<i>Haloxylon</i>	0-20	1.86 a	0.43 a
	20-50	1.88 b	0.28 b
Control	0-20	1.89 a	0.09 a
	20-50	1.89 a	0.07 b

(Different letters indicate difference in significance)

The amount of soil organic carbon was significantly different in two depths (surface versus subsurface layer), and three locations (artificial plantation of *Atriplex* and *Haloxylon* and control area) (Fig. 2, 3 and 4).

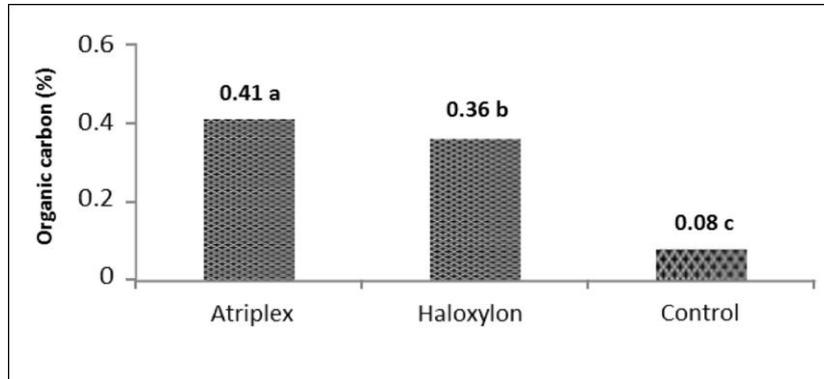


Figure 2. Soil organic carbon values in different sites (Different letters indicate the significant difference at 1% confidence level)

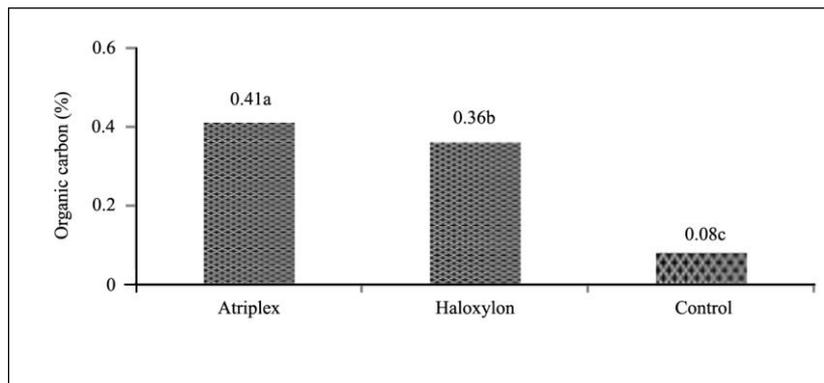


Figure 3. Soil carbon values in different soil sample depths (Different letters indicate the significant difference at 1% confidence level)

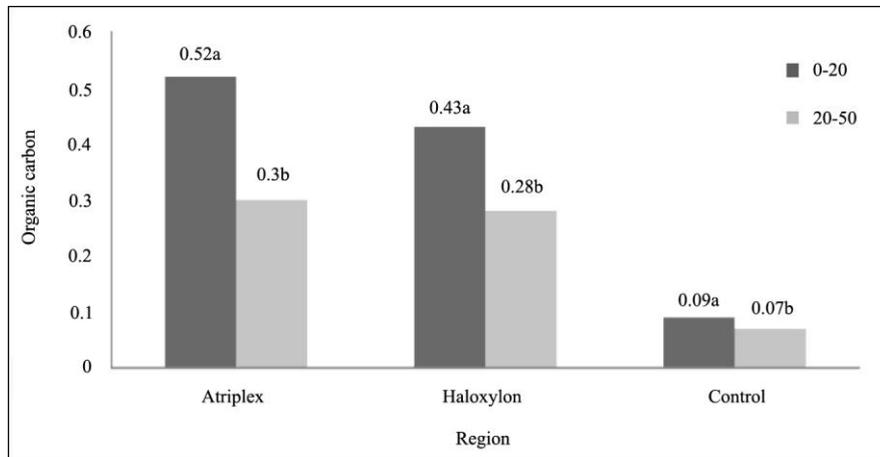


Figure 4. Soil carbon values in different sites and depths

3.3. Estimation of soil carbon sequestration per unit area (ton/ha)

Regarding SOC and bulk density values, and soil depth (equation 1), soil carbon sequestration per unit area was estimated in all sites. According to Fig. 5, significant differences in soil carbon sequestration were observed in plantation sites in comparison to control. Furthermore, carbon sequestration rate in *Atriplex* area was significantly higher than that of *Haloxylon* area (Fig. 5). Similarly, soil carbon sequestration rates were significantly different in both soil sampling depths (Fig. 6).

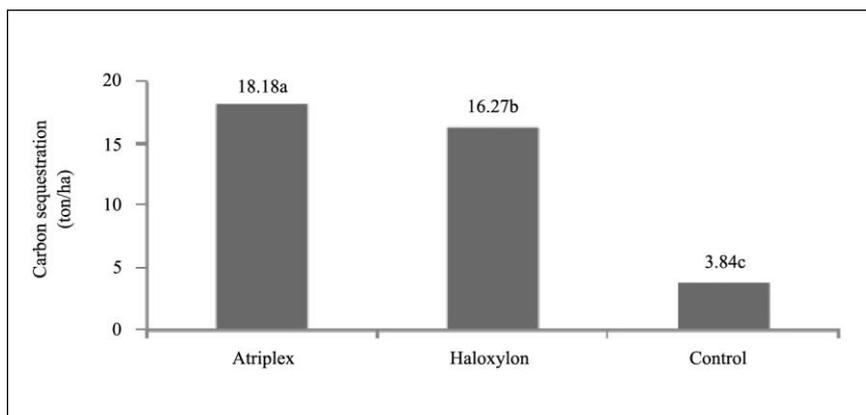


Figure 5. Soil carbon sequestration (ton/ha) at different locations (per unit area)

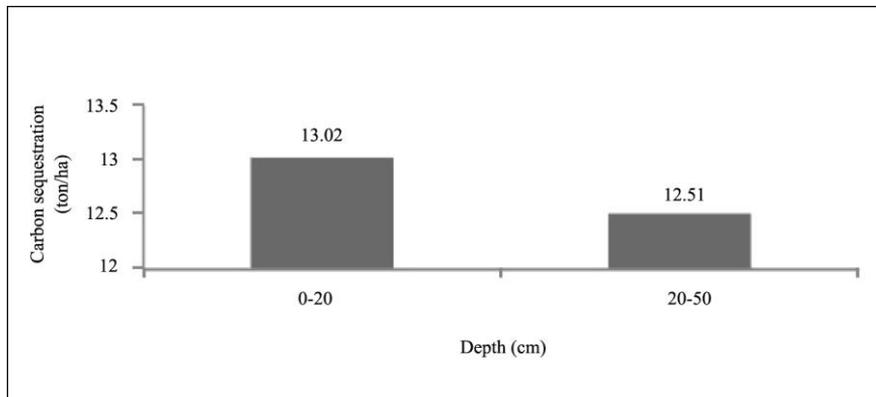


Figure 6. Soil carbon sequestration (ton/ha) values in two depths (per unit area)

4. Discussion

Decreasing risks of soil degradation is important to minimizing losses of terrestrial C from the ecosystem. The distribution of SOC with depth and the total SOC density (kg/m^2) are influenced by vegetation, soil texture, landscape position, soil truncation, and the effect of water and wind erosion (Lal, 2004). The results expressed a significant increase in SOC concentration and pool following the revegetation of the desertified land, which is in accordance with Lal (2005) who suggested that the reclamation of desertified land and the adoption of recommended management practices had a significant soil carbon sequestration effect.

The results of this study showed that planting *H. ammodendron* and *A. canescens* on shifting sand dune resulted in the accumulation of carbon in the topsoil. The amount of soil carbon sequestration in *Atriplex* and *Haloxylon* plantation areas and control region were 18.2, 16.27 and 3.8 ton/ha, respectively. This represents a significant increase in carbon sequestration rate per unit area in the *Atriplex* region as compared with *Haloxylon* plantation site and between the soils in the two depths. These results indicate that the rate of carbon sequestration depends on type of vegetation cover.

Moreover, the top soil layer had larger carbon sequestration values in comparison with subsurface layer. Compared to *Haloxylon* plantation area, the *Atriplex* area received greater amounts of litter fall inputs which in turn showed higher carbon sequestration rates in this area. Similarly, Abdi (2009) concluded that the soil carbon sequestration had high positive correlation with plant diversity and biomass density. Also in eastern Spain, Ruecker *et al.* (1998) suggested that

cultivation of trees or shrubs on degraded lands led to significantly increasing SOC concentration in 0–10 cm layer after 30 years of plantation.

Desertification leads to decrease in the ecosystem C pool and attendant reduction in SOC. Opportunities for improved land management as well as increasing CS should be developed in dryland areas. The potential for global benefits, as well as local benefits, to be obtained from increased CS in drylands should be an additional incentive for stronger support for reforestation in drylands (FAO, 2004). Increasing biomass production in dryland ecosystems is very difficult and must first be approached through reclamation of degraded soils. Accordingly, reclamation of land degradation is recommended as a way to increasing soil carbon. In this study, soil carbon sequestration amount in the *Atriplex* area was significantly higher than *Haloxylon* area. Therefore, it can be introduced as an effective species in order to mitigate carbon flux from soil to air.

Acknowledgements

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