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Effects of Biological Practices on Soil Stability in a Desertified Area of Iran

M. Solaimani Sardo[1], H. R. Asgari[1*], F. Kiani[2], Gh.A. Heshmati[3]
[1]Department of Arid Zone Management, Gorgan University of Agricultural Sciences and Natural Resources, Iran.
[2]Department of Soil Science, Gorgan University of Agricultural Sciences and Natural Resources, Iran.
[3]Department of Range Land Management, Gorgan University of Agricultural Sciences and Natural Resources, Iran.

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Abstract

The rehabilitation of sandy desertified land in various dryland ecosystems by different management practices has a great potential to increase aggregate stability and improve soil quality. However, plants in general may have a different ability to sustain soil. The objective of this study was to determine the effects of practices including *Haloxylon ammodendron* and *Atriplex canescens* plantation on some soil properties, soil erodibility and the relationships between soil properties and erodibility index in desertified land of Jupar in Kerman Province, South East of Iran. According to the research objectives, 24 soil samples from 0-20 cm depth were taken from each area, i.e. reclamation sites and control area (untreated land) using a systematic – random method. Soil properties such as soil texture, structure, pH, EC, $CaCO_3$, gypsum, bulk density, organic carbon and soil organic matter were measured. The mean weight diameter (MWD) and geometric mean diameter (GMD) were used as soil erodibility indices. The results of our study showed that MWD had positive correlation with organic carbon, $CaCO_3$ and soil acidity values. Furthermore, according to the effect of *Haloxylon* on aggregate stability and its positive role in modifying soil physical and chemical properties, and also the height of this species, which can contribute to wind erosion control in this area, we conclude that *Haloxylon ammodendron* has better performance in desert rehabilitation and sandy land stabilization in Jupar area than *Atriplex canescens.*

***Keywords*: *Atriplex*; *Haloxylon*; Soil erodibility; Mean weight diameter; Geometric mean diameter; Biological practices**

[*] Corresponding author: hras2010@gmail.com

1. Introduction

In the Convention to Combat Desertification (CCD) ratified in 1994, desertification has been described as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variability and human activities" (Chen and Tang, 2005).

The most important results of land degradation are the chemical degradation of the soil; reduction of vegetation and soil organic matter (SOM); reduction in soil water storage and topsoil infiltration capacity; decreasing water table (Kassas, 1999), and decline in soil aggregation which in turn, lead to reduction in the total soil carbon pool and CO_2 emission from soil and vegetation cover to the atmosphere, and therefore, thus impacting the global C cycle (Su et al., 2010).

Soil erodibility is directly linked to the aggregation quality in the soil surface. Soil aggregation usually implies the presence of large and linked macro-pores and largely controls movement of water, particularly near the soil surface, where crust formation and compaction can seal the surface (Celik, 2005).

Most of the drylands are on degraded soils, soils that have lost significant amounts of C. Therefore, the potential for sequestering C through the rehabilitation of dryland is substantial (Lal, 2004).

Atriplex canescens and *Haloxylon ammodendron* have been cultivated extensively in Iran. In addition to soil conservation, these plants also serve as forage for livestock and wildlife. *A. canescens*is a shrub with 1 to 2 m height and 1 m diameter, diocious or rarely monoecious, with linear or spoon leaves, no petiole or short petiole. The fruit is achene with 4 wings, the time of flowering is at the end of summer and the fruits ripen in autumn (Asadi, 2001). Among the non-native species, this genus is planted extensively and primarily in dry regions. It is highly resistant to high and low temperatures and has the ability of water absorption, maintenance and storage. *H. ammodendron* is also a shrub or short tree, with about 4 m height; the leaves are very small and flaky, sometimes absolutely consumptive, with single flowers. In steppes of Iran-Turanian region this plant is usually seen on sandy hills and has been cultivated in desert regions (Asadi, 2001).

Establishment of large-scale short-rotation woody crop plantations has been advocated as an effective method for sequestering CO2 and mitigating increased atmospheric CO2 levels, through increasing long-term C storage in woody biomass and in the soil, and by providing an alternative source of biomass for bioenergy (Arevalo *et al.,* 2009). The increased soil C pool can enhance the soil aggregation (Bronickand *et al.,* 2005) and therefore stabilize shifting sand (Su et al., 2010). However, the performance of different vegetation restoration types would be varying (Fu *et al.,* 2010).

The objective of this study was to evaluate the effects of the establishment of vegetation and decertified land rehabilitation on some soil properties and aggregation in a desert region in south east of Iran.

2. Materials and methods

2.1. Site description

The study was conducted in 2011 in the Shahid Zenderuh Research Station in Kerman City (situated between 30° 07' 21" - 30° 07' 32" N, and 57° 03' 39"- 57° 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 (Plan and Budget Organization, 1995) (Figure 1).

Plantation of drought-tolerant desert shrubs on mobile sand is one of the techniques used for the area. In the study area Haloxylon ammodendron and Atriplex canescens have been planted for this purpose.

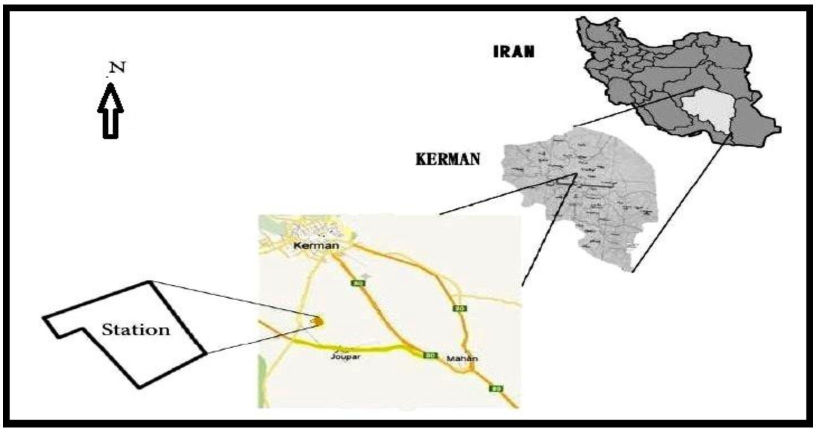

Figure 1. Location of the study area (Shahid Zenderuh Research Station) on Iran map

2.2. Measurements

For taking soil samples, three transects 100 m long and 50 meters apart from each other were considered. Eight points were selected on each transect, randomly. According to the research objectives, 24 soil samples were taken from the three areas including: 1) control plots (untreated shifting sand land); 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 cm^3) taken in each sampling location. After air drying, soil organic carbon (OC) was measured by the Walkley–Black wet dichromate oxidation method (Nelson and Somers, 1982) and converted to organic matter through multiplying it by 1.724. To determine lime amount, the total neutralizing value (TNV) on the basis of calcium carbonate was measured using acid acetic volume consumed to neutralizing carbonates. Acidity was measured using a pH Meter (Ritvo et al., 2003). Electrical Conductivity Meter (Waterproof Ectestr 11) is used for measuring EC. The aggregate stability was determined using the wet-sieving method based on the mean weight diameter (MWD) as proposed by Kemper and Rosenau (1986). Fifty gram of air-dried soil sample (<8 mm) was placed onto the top of the five sieves (5, 2, 1, 0.5 and 0.25 mm), and gently moistened to avoid a sudden rupture of aggregates. After the soil was moistened, the set was sieved 10 min in distilled water at 30 oscillations per minute, and the soil remaining on each sieve was dried. The mean weight diameter (MWD) (mm) was calculated as follows:

$$MWD = \sum_{i=1}^{n} xiwi$$

Where: *wi* is the mass percentage of aggregate remaining on sieve; *xi* is the average diameter of the two adjacent size classes. Geometric mean diameter was calculated as follows:

$$GMD = \exp\left\{\frac{\sum wi.Ln\ xi}{\sum wi}\right\}$$

Where *wi* is the weight of the aggregates of each size class (g) and *Ln xi* the natural logarithm of the mean diameter of size classes (Gardner, 1956).

2.3. Statistical analysis

Statistical analysis (LSD test and regression analysis) was implemented using SAS 9.1 at a $P<0.05$ significance level. For relationships between soil properties and MWD stepwise regression was completed.

3. Results

Soil chemical and physical properties differed among the different treatments. After rehabilitation measures via *A. canescens* and *H.ammodendron* chemical and physical characterization of soil were changed as shown in Table 1. For example, in *Atriplex canscens* plantation area, pH is equal to 7.6 and Electrical Conductivity (EC) is 4.37 dS/m. Soil texture with the 8.25% clay, 3.41 % silt and 88.3% sand is categorized as sandy and sandy loam classes. Organic carbon (OC) and SOM were 0.53 and 0.9% respectively. Average soil lime is 15.1% and bulk density is equal to 1.81 g/cm^3. Soil samples were lacking in gypsum, and soil structure in this area is sub angular and angular blocky.

Similarly, *Haloxylon ammodendron* afforestation caused chemical and physical alterations in the soil of study area (Table 1). pH is equal to 8.5; EC is 2.42 dS/m and soil texture with the 7.7% clay, 3.6% silt and 88.2% sand is sandy and sandy loam. OC and SOM were 0.44 and 0.75%, respectively. Soil lime is 16.9% and average of bulk density is equal to 1.86 g/cm3. Soil samples were lacking in gypsum, and soil structure in this region is sub angular and angular blocky.

No significant differences were observed in sand and clay proportion among the three study areas. There were significant differences in soil organic carbon (SOC) concentration at the two different rehabilitation sites. Organic carbon (OC) and SOM values increased significantly in the reclamation areas as compared to the control. Moreover, soil in *Atriplex* plantation site had significantly higher OC and SOM values than that observed in *Haloxylon* plantation. EC had a significant increase in the rehabilitation sites (*Atriplex* and *Haloxylon* plantation sites). Furthermore, *Atriplex* resulted in higher soil EC as compared to other treatments (*Haloxylon* plantation and control). Significant reduction in soil pH was observed under *Atriplex* plantation as compared to other treatments. Also, bulk density had significantly decreased after reclamation practices. However, this value was significantly higher in *Haloxylon* plantation as compared to *Atriplex* region.

Table 1. Results of the physical and chemical characteristics of soils in the study areas (different letters in columns show significant difference)

Sand (%)	Clay (%)	Silt (%)	OC (%)	SOM (%)	Lime (%)	EC (dS/m)	pH	Gypsum (%)	Bulk density (g/cm3)	Location
88.2	7.7	3.65 ab	0.44b	0.75b	16.9a	2.42b	8.5a	_	1.86 b	Haloxylon
88.3	8.2	3.41 a	0.53a	0.9a	15.1b	4.37a	7.6c	_	1.82 c	Atriplex
87.7	7.41	4.83 b	0.9c	0.16c	16.07a	1.39c	8.1b	_	1.89 a	Control
ns	ns	*	**	**	**	**	**	_	**	significant

Significantly different at P< 0.05: *, significantly different at P< 0.01: **,
Not-significant: ns

Results showed significant differences in MWD and GMD values among the three areas. In *Haloxylon* area, GMD and MWD were equal to 1 and 0.76 mm, also in *Atriplex* plantation site GMD and MWD were 0.99 and 0.67 mm. Therefore, in *Haloxylon* site, MWD and GMD were significantly higher than that observed in *Atriplex* area and also in comparison with control site Figure (2) and Figure (3).

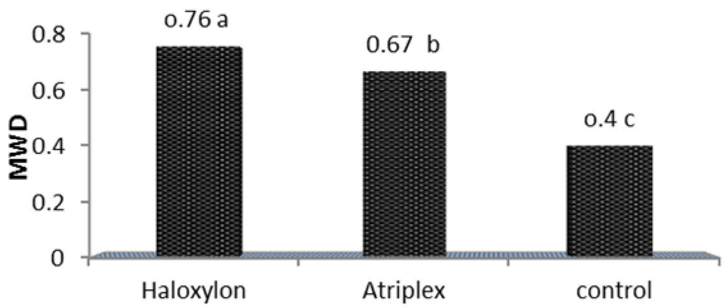

Figure 2. Soil mean weight diameter (mm) values in each location (different letters indicated the meaningful difference at 1% confidence level)

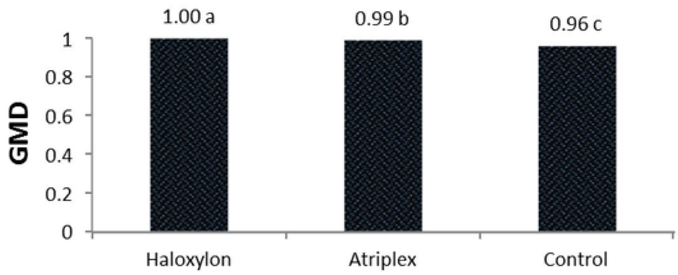

Figure 3. Soil geometric mean diameter (mm) values in each location (different letters indicated the meaningful difference at 1% confidence level)

3.1. Relationship between MWD and chemical properties of soil

Relationship between MWD and some soil physico-chemical properties were explained by following equation:

Equation 2:

$$MWD = -0.978 + 0.831\ (Soil\ carbon\ sequestration) + 0.128\ (pH) + 0.017\ (Lime)$$

The relationship between mean weight diameters and soil organic matter levels showed a positive correlation. With increasing soil organic matter, mean weight diameter was increased. Also MWD had positive correlation with pH and lime. The R^2 values (0.81 and 0.63) showed that there was significant linear relationship between SOC and MWD and GMD. It indicated that aggregate stability increased with an increasing soil organic carbon (Figures 4 and 5).

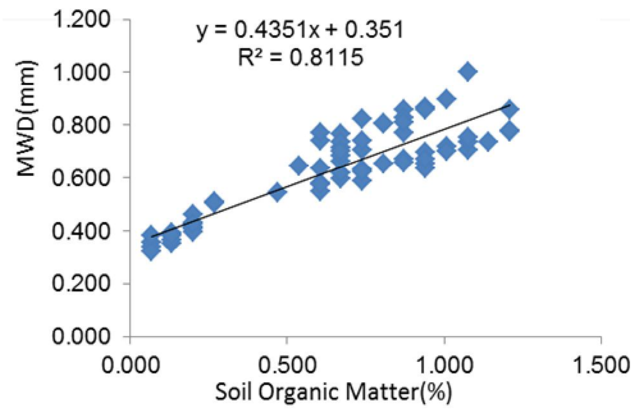

Figure 4. Linear relationship of soil organic matter with Mean Weight Diameter

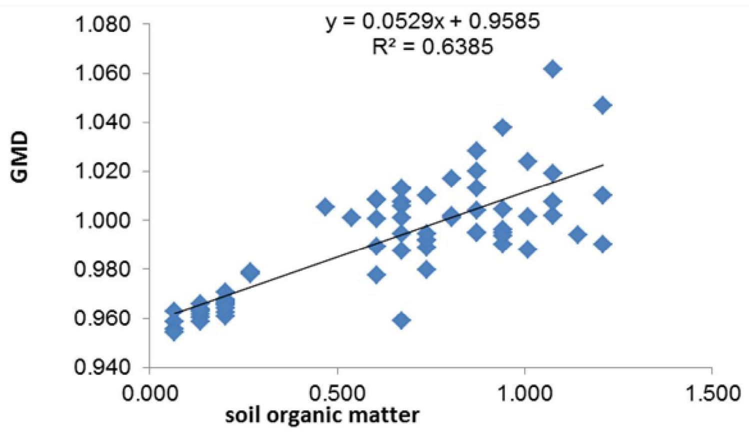

Figure 5. Linear relationship of soil organic matter with Geometric Mean Diameter

4. Discussions and Conclusions

The results of this study showed that *Atriplex* plantation on shifting sand land caused significantly higher accumulation of clay particles in the topsoil. The result was in agreement with the results of Su et al., 2010 who reported that planting *H. ammodendron* resulted in the accumulation of fine particles on the surface soil. Moreover, Fearnehough *et al.,* (1998) and Li *et al.,* (2006) stated that straw checkerboard establishment and revegetation enhanced the aeolian dust entrapment. Soil C accumulation for the shrub land had similar results reported in most research studies in the desertification areas. For example, Li *et al.,* (2007) and Sartori *et al.,* (2007) concluded that SOC exponentially increased via rehabilitation measures in desertified land. The results indicated a significant increase in SOC concentration following the revegetation of desertified land, which is in agreement with Lal, (2004) results who suggested that the rehabilitation of desertified land and the adoption of recommended management practices had positive and significant effects on soil carbon sequestration effect.

In this study, SOC accumulation in afforestation sites was significantly higher than that observed in control site, also SOC values varied under different revegatation treatments. However, this amount was significantly higher in *Atriplex* plantation site as compared to *Haloxylon* site. *Haloxylon* plantation resulted in significantly higher MWD and GMD values than two other treatments (*Atriplex* plantation and control). In addition, significantly higher calcium carbonate was observed under *Haloxylon* afforestation as compared to *Atriplex* plantation site. This matter has effective role in aggregate stability. As it is shown in Equation (2), Mean Weight Diameter had positive correlation with SOC and $CaCO_3$ percentage. Similarly, Tayel *et al.,* (2010) stated that aggregation is mediated by SOC, biota, clay and carbonates which act as binding agents and as a nucleus in the formation of aggregates. Also Su et al., (2010) concluded that MWD has a positive correlation with $CaCO_3$. Moreover, they observed that $CaCO_3$ plays an important role in soil stability. Therefore, the result of our study corresponds well with these results.

According to the effect of *Haloxylon* on aggregate stability and its positive role in modifying soil physical and chemical properties, it is concluded that *Haloxylon ammodendron* has better performance in desert rehabilitation project andsandy land stabilization in Jupar area than *Atriplex canescens*. Therefore, this plant can be introduced as an effective species in order to increase soil stability. However, more investigations are needed for the area to examine other soil erodibility indices in future (e.g. CR index, MCR index).

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