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Investigation on biological activities for combating desertification in the western shores of Lake Urmia, Northwest Iran

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Abstract: Lake Urmia, Northwest Iran, has confronted a drying procedure in recent years with losing 90% of its water body. The authorities concerned about desertification processes and possible dust events throughout the region. In this regard, the Iranian Natural Resources and Watershed Management Organization has taken ecological measures to plant vegetation using salt cedar (*Tamarix ramosissima* Ledeb.) shrubs to combat desertification. This study aimed to investigate the vegetation and soil characteristics of natural and plantation stands of salt cedar on the western shores of Lake Urmia. To this end, 7 transects were randomly selected with 15 shrubs in natural stands, and 7 transects were randomly selected with 15 shrubs in the plantation parts along the planting rows. Then, vegetative characteristics were examined. Also, soil samples were taken from the vicinity of the shrubs. The results indicated that there was no significant difference between the mean diameter at breast height (DBH) of salt cedar in natural sites. There was a significant difference between the mean number of sprouts per sprout-clumps, mean crown diameter, collar diameter, total height, and also between mean crown diameter and freshness of shrubs among different sites ($P<0.05$). It was also found that soil variables, such as clay content, organic matter, electrical conductivity (EC), Na^+, specific absorption rate (SAR), Cl^-, SO_4^{2-}, Na^+, K^+, and PO_4^{2-} are the most significant variable parameters between studied sites. As the results shown, the values of EC, SAR, Na^+, and Cl^- are 6 times higher in the planted stands than in the natural stands of *T. ramosissima*. Also, the colonization of *T. ramosissima* in the planted stands is unsuccessful by dramatic drop in the total height and average diameter. Considering the role of soil characteristics in explaining the variance of data and site separation, it seems that these indicators can be applied in executive plans as important indicators to identify suitable planting sites for combating desertification.

Keywords: salinity resistance; soil; vegetative characteristics; *Tamarix*; Lake Urmia

1   Introduction

Desertification control is a crucial way to maintain the sustainable development and rehabilitation of arid and desert lands. But, the amount of running water is declining in several arid and semi-arid regions of the world because of prolonged drought (Sebghati et al., 2016) and overexploitation by humans, especially in the agricultural lands. This declining trend can be exacerbated by drought, dust storms, desertification processes, and climate change (MacDonald, 2010; Ahmady-Birgani et al., 2017, 2019a; Neira et al., 2022). As a result, the water flow of many rivers such as Colorado (USA) (Rajagopalan et al., 2009) and Nile (Africa) (Yactayo et al., 2017), and the volume of water reaching downstream lakes and wetlands has been severely reduced, and has resulted in severe environmental, social, and economic consequences (Stewart et al., 2020). Hence, water scarcity in the environment leads to problems such as salinity, disease outbreaks, wetland destruction, biodiversity loss, desertification, soil salinity, dust storms, and sometimes salty storms (Ahmady-Birgani et al., 2016; Harati et al., 2021). Dust storms are significant environmental problems on a regional scale (Yang and Qu, 2022). One of the most important effects and consequences of dust storms can be the intensification of soil erosion, ecosystem change, reducing agricultural production, salinization, reducing herbaceous growth, plant diversity, etc. (Goudarzi et al., 2014; Ahmady-Birgani et al., 2015; Katebi et al., 2021; Neira et al., 2022).

   Lake Urmia is the second largest saline lake in the world, the largest natural habitat of *Artemia* (for example, *Artemia urmiana* Günther), and the largest inland lake in Iran. It was declared a protected area by UNESCO (United Nations Educational, Scientific and Cultural Organization) in 1967, a national park in 1970, and then as one of the biosphere reserves of Iran. This lake has been a natural reserve and genetic reservoir for its unique characteristics such as having 102 islands and fresh water in some of these islands, being a safe haven for the migratory birds that some are in danger of extinction, and the absence of threatening factors from its inception (Alipour and Olya, 2015). This basin is one of the divisions of the Centers of Plant Diversity (CPD) project completed by the International Union for Conservation of Nature (IUCN) and the World-Wide Fund for Nature (WWF) (Stöhr et al., 2013). The predominant vegetation of this region includes halophytic, xerophytic, pseammaphytic, and hydrophtic species (Djamali et al., 2008). The process of reducing the level of this lake began in 1995, and during twenty years, the level of the lake has decreased by more than 8 m. Lake Urmia has lost more than 30×10^9 m^3 of water compared with its high-water periods, and this lake has reached below the level of 1272 m in the summer of 2020 (Tudryn et al., 2017; Kong et al., 2022). It is currently given that the drying and receding water of Lake Urmia has not created susceptible lands to dust storms in the lake bed and its margins (Ahmady-Birgani et al., 2021). The FRWO (Forests, Range and Watershed Management Organization, Iran) has launched biological measures to resist this phenomenon by planting indigenous vegetation such as *Tamarix* (Rostami et al., 2021) in western Azerbaijan Province and Urmia City since 2013. Similarly, Feng et al. (2018) revealved that planting *Tamarix chinensis* Lour. on highly saline coastal soils in northern China led to a decrease in the soil water content and an increase in the soil salinity to 0.49 g/kg from 2014 to 2016. Meanwhile, the amount of Na$^+$ and Cl$^-$ in the soil had increased, and the average soil pH had also increased. Tatian and Zabihi (2011) attempted to select the plant species that adapt to the soil in the dry steppe of Qom salt dome in Qom Province, Iran. The results indicated that salinity and soil texture were the main factors limiting the growth of plant species in these areas and only two species of *Stipagrostis plumosa* (L.) Munro ex T. Anderson and *Tamarix aphylla* L. responded positively to sandy and saline soils, respectively. Amiri et al. (2011) studied the effect of planting *Tamarix aphylla* (L.) H. Karst. on the physical and chemical properties of soil in Esfandaqeh rural district, Kerman Province, Iran. The results showed that *T. aphylla* increased SOM (soil organic matter) in the soil surface and improved soil structure in the long term, and soil nutrients such as potassium, phosphorus, and nitrogen also increased. Allahgholi and Asri (2014) reported that the most important factors in the distribution of plants were EC (electrical conductivity), pH, soil

texture, lime, and Na^+ uptake ratio, and plant communities are strongly affected by salinity in the southeastern shore of Lake Urmia.

Understanding the relationship between plant communities and soil characteristics can help to recognize ecosystem processes, prevent the destruction of natural resources, and preserve biodiversity (Dale et al., 2000). Thus, the restoration of Lake Urmia has been important issue in the next step. Several measures have been taken to rehabilitate the lake and prevent the occurrence of salty, dust storms, and sand dune movements, such as afforestation with *Tamarix* shrubs on the western shore of the lake (Ravan et al., 2019). So far, the success of these projects and the quantitative, qualitative, and freshness of these vegetation have not been studied. Due to the great importance of soil in the diversity and distribution of vegetation, the present study was conducted to examine the vegetative characteristics of natural and planted stands of *Tamarix* as well as to explore the relationships between these plants and soil properties on the shore of the lake. Particularly, this study aims to answer these questions: (1) what is the status of vegetative characteristics and freshness of planted *Tamarix* stands on the shore of Lake Urmia compared with its natural stands? And (2) have the soil physical and chemical properties of the planted stands affected the vegetative characteristics of *Tamarix*?

2　Materials and methods

2.1　Study area

Lake Urmia is located in northwestern Iran, 17 km east of Urmia City. In this study, two stands of *T. ramosissima* on the outskirts of Osalu (37°41′35″N, 45°13′03″E) and Goltapeh (37°53′44″N, 45°24′40″E) villages were selected as the natural habitats. Moreover, plantations on the outskirts of Seporghan (37°45′20″N, 45°14′01″E) and Jabalkandi (37°51′25″N, 45°45′02″E) villages were selected as the plantation stands of *T. ramosissima* (Fig. 1). The planted stands were afforested in 2013 with 10 m×10 m planting distance with an area of about 400 hm². Considering the plant community structure and species composition, Ahmadi (2018) reported that the vegetation communities are mostly bushes and grasses including *Atriplex verrucifera* M.Bieb., *Halanthium rarifolium* K.Koch, *Halocnemum strobilaceum* M.Bieb., *Phragmites stenophyllus* Rouy, *Salicornia europaea* L., *Suaeda altissima* Pall., *Tamarix meyeri* Boiss., *Tamarix octandra* Bunge, *Puccinellia bulbosa* Grossh.-*Polypogon monspeliensis* (L.) Desf., and *Puccinellia bulbosa* Grossh.-*Aeluropus littoralis* (Gouan) Parl. Because rapid loss in water volume of Lake Urmia is associated with increased water retreatment and dried-up bare lands (Ravan et al., 2022), new ecological succession in vegetation communities simultaneously appeared in the region.

2.2　Data collection

In each natural stands, 7 transects each containing 15 shrubs were identified. Sampling in the planted stands was similar to the natural parts (containing 15 shrubs) along the planting rows. In each transect, the characteristics of shrubs including total height, collar diameter, diameter at breast height (DBH), large and small crown diameter, frequency and number of sprouts, freshness (good, moderate, poor, and dried classes) and survival (live and dried shrubs) were measured. To figure out the freshness degree, we used the rules of Iranian High-Council for Natural Resources and Watershed Management Organization (http://www.fwr.ir), which classified it into three categories. Freshness degree 1 means not having dry branches and pests, and being green and alive. Freshness degree 2 means having dried new branches and pests at a moderate rate. Freshness degree 3 means having dried main branches and heavy blight with wilting. Also, freshness degree 4 means completely dried of mother plant or main stem. Also, in order to sample the soil in each site, simultaneously with the transect sampling from the vicinity of the first, last, and eighth shrub located in each transect, we took 3 soil samples from a depth of 0–20 cm, and mixed them into a single sample. In each site, 7 soil samples were collected. In the laboratory,
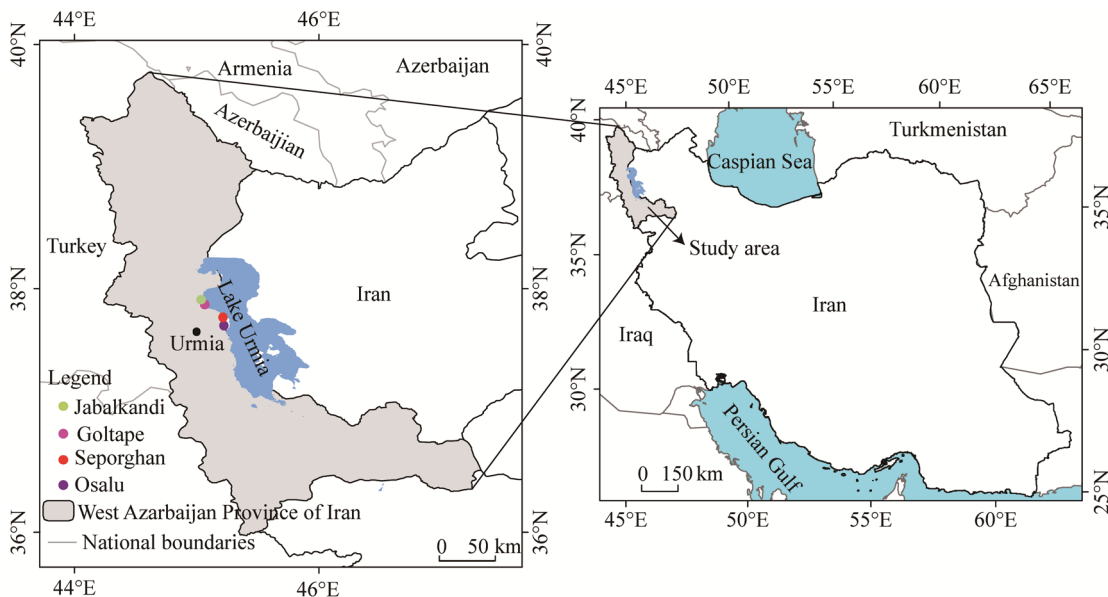
Fig. 1   Geographical location of studied area and sampling stands of *T. ramosissima*

after passing through a 2-mm sieve, the physical-chemical properties of the soil including soil pH, SOC, EC, soil texture, concentration of carbonate and bicarbonate ions, Na^+ uptake ratio, soluble cations (Na^+, Ca^{2+}, Mg^{2+}, and K^+) and soluble anions (Cl^-, SO_4^{2-}, PO_4^{2-}, and NO_3^-) were determined.

2.3   Data analysis

Due to the normal distribution of data, independent *t*-test and one-way analysis of variance (ANOVA) were used for quantitative characteristics of DBH and number of sprouts. Kruskal-Wallis test was used for quantitative characteristics of total height, collar diameter, and average crown diameter because of the non-normal distribution of data. Chi-square test was used to compare the qualitative characteristics, i.e., freshness. ANOVA and Duncan's comparison test was used for soil characteristics. Principal component analysis (PCA) was applied utilizing the PCORD software v.5.0 to determine the most important physical and chemical factors affecting the soil in natural and plantation stands of *T. ramosissima*. Pearson correlation between factors and axes obtained from PCA analysis was used to determine the main gradient of changes in soil physical and chemical characteristics. Considering that the Broken-stick statistics of the first and second axes were smaller than the eigenvalues of these two axes, two axes were selected to present the results.

3   Results

3.1   Growth characteristics of *T. ramosissima*

Totally 420 shrubs of *T. ramosissima* (105 in each stand) were measured in the four stands. According to Figure 2, it was observed that there was no significant difference between the mean DBH of *T. ramosissima* in the two natural stands of Osalu and Goltapeh (α=0.05). In contrary, the mean collar diameter of *T. ramosissima* in the two natural stands of Osalu and Goltapeh was significantly different (α=0.05). Regarding planted *T. ramosissima* shrubs in Seporghan and Jabalkandi, the values of DBH of these two shrubs are not measured due to their limited growth.

The results of ANOVA revealed that there was a significant difference between the mean number of sprouts in the sprout-groups (α=0.05; Table 1). The highest average number of sprouts was observed in Osalu natural stand and the lowest value was observed in Jabalkandi and Seporghan planted stands (Fig. 3). However, the mean number of sprouts of *T. ramosissima* in the two natural stands of Osalu and Goltapeh was significantly different (α=0.05).
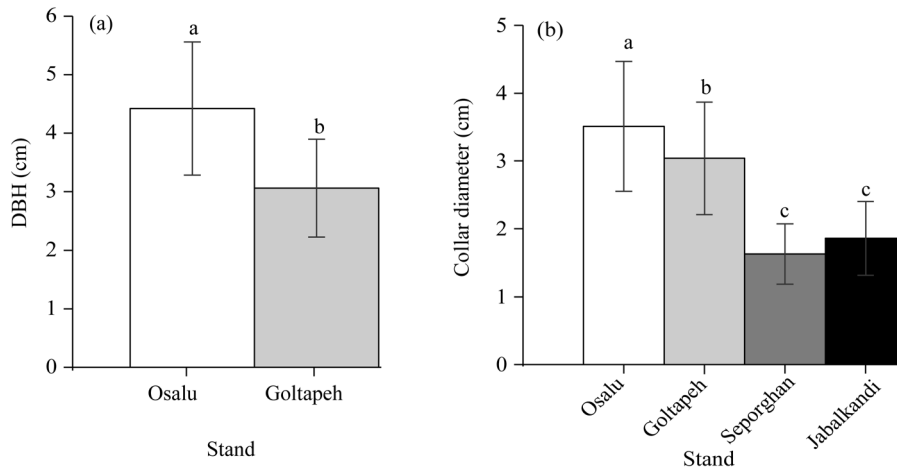
Fig. 2 DBH (diameter at breast height; a) and collar diameter (b) of *T. ramosissima* in natural and planted stands. Different lowercase letters above the bars indicate significant difference among different stands at $\alpha=0.05$ level. Bars are standard errors.

Table 1 ANOVA analysis of number of sprouts in studied stands

Indicator	Sum of square	*df*	Mean square	*F*	Sig.
Between stands	6395.45	3	2131.81	66.25	0.00
Within stands	12,131.05	377	32.17		
Error	18,526.50	380			
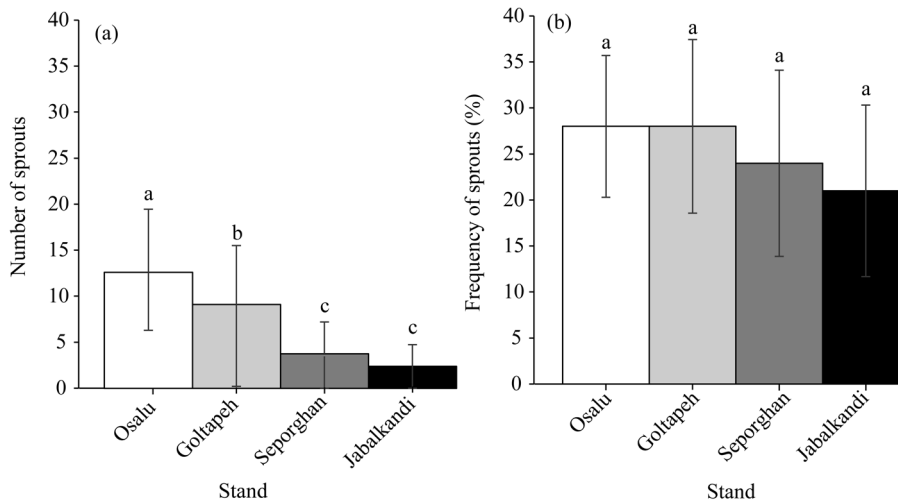
Fig. 3 Comparison the mean number of sprouts (a) and its frequency (b) of *T. ramosissima* in natural and planted stands. Different lowercase letters above the bars indicate significant difference among different stands at $\alpha=0.05$ level. Bars are standard errors.

The results of the Kruskal-Wallis test for other quantitative characteristics showed a significant difference ($\alpha=0.05$; Table 2). According to the results of the Mann-Whitney test, a significant difference was observed between the mean total height and the mean crown diameter of the studied *T. ramosissima* shrubs in Osalu and Goltapeh natural stands ($\alpha=0.05$). Also, a significant difference was observed between the mean crown diameter and the total height of in Seporghan and Jablakandi planted stands ($\alpha=0.05$; Table 3; Fig. 4).

Table 2   Result of the Kruskal-Wallis test for studied quantitative characteristics

Indicator	Kruskal-Wallis	*df*	Significance
Mean crown diameter	139.56	3	0.00
Collar diameter	79.04	3	0.00
Total height	147.45	3	0.00

Table 3   Comparison of the mean quantitative characteristics of natural and planted stands

| Indicator	Stand	Region	Frequency (Dimensionless)	Mean±SE (m or cm)	Mann-Whitney (Dimensionless)
Total height	Natural	Osalu	105	2.03±0.08[a]	4185.50
		Goltapeh	105	1.64±0.06[b]	
	Planted	Seporghan	90	1.04±0.02[c]	3143.50
		Jabalkandi	81	1.00±0.03[c]	
Collar diameter	Natural	Osalu	105	3.51±0.21[a]	4715.50
		Goltapeh	105	3.04±0.18[a]	
	Planted	Seporghan	90	1.63±0.05[a]	3204.50
		Jabalkandi	81	1.86±0.10[a]	
Mean crown diameter	Natural	Osalu	105	204.00±10.86[a]	4253.50
		Goltapeh	105	162.80±8.75[b]	
	Planted	Seporghan	90	84.20±2.99[c]	1487.00
		Jabalkandi	24	74.42±4.25[c]	

Note: Different lowercase letters within the same indicator indicate significant differences among different stands at α=0.05 level. The unit for total height is m, and the unit for collar diameter and mean crown diameter is cm.
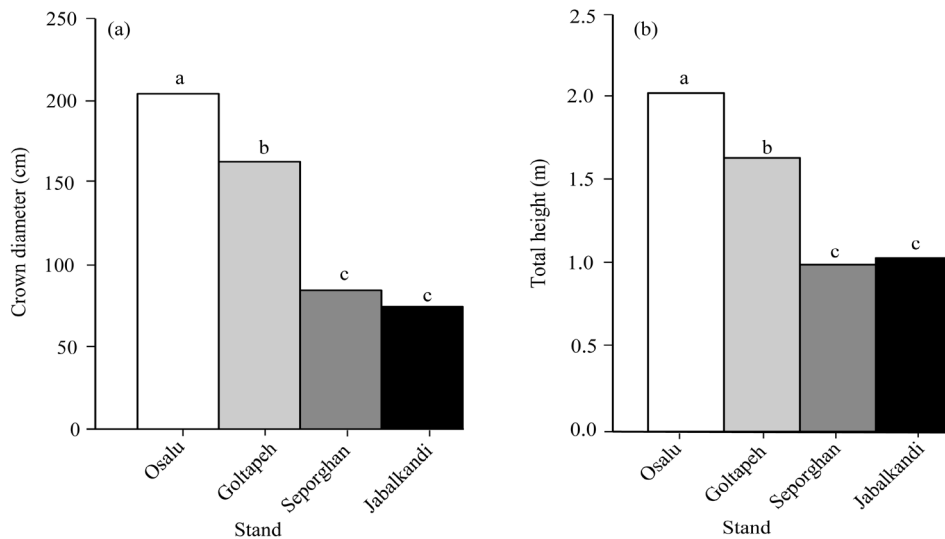
Fig. 4 Crown diameter (a) and total height (b) of *T. ramosissima* in natural and planted stands. Different lowercase letters above the bars indicate significant difference among different stands at α=0.05 level.

3.2   Freshness of *T. ramosissima*

According to Figure 5, natural stands of Osalu and Goltapeh had the highest percentage of freshness, 58.1% and 44.8%, respectively, however, in Jabalkandi and Seporghan planted stands, the percentages of *T. ramosissima* shrubs with poor freshness were 50.5% and 47.6%, respectively. Likewise, the dried shrubs in Jabalkandi and Seporghan planted stands were 22.9% and 14.3%, respectively. The chi-square test showed a significant difference between the freshness of *Tamarix* shrubs in different stands (α=0.05).
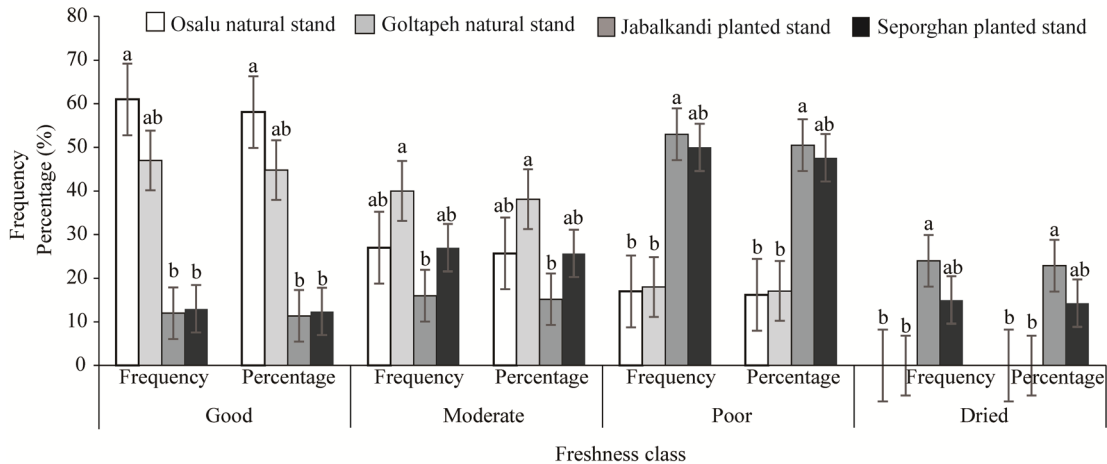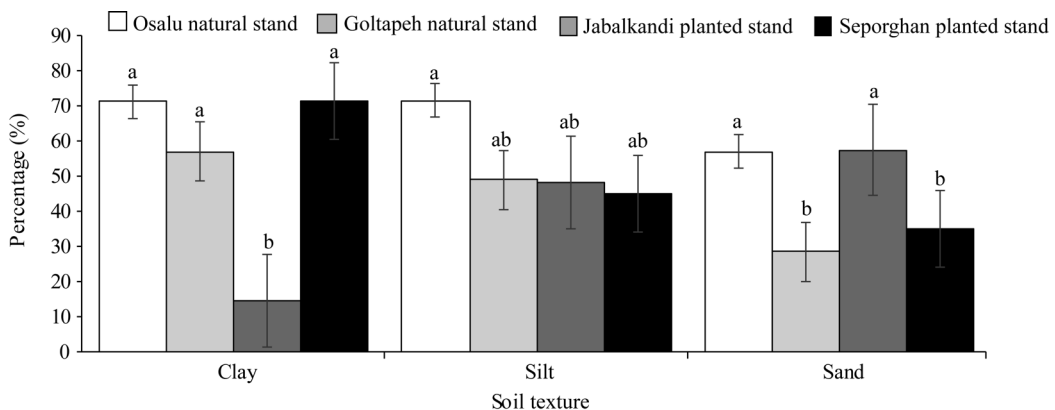
Fig. 5 Freshness class of *T. rmosissima* in natural and planted stands. Different lowercase letters above the bars indicate significant difference among different stands at *α*=0.05 level. Bars are standard errors.

3.3   Soil property

3.3.1   Soil physical property

The highest amount of clay particles is related to Seporghan planted stand, and the lowest is related to Goltapeh natural stand. For the silt, the highest and lowest amounts are related to Osalu natural stand and Jabalkandi planted stand, respectively. The highest amount of sand particles was observed in Goltapeh natural stand and the lowest belonged to Seporghan planted stand (Fig. 6). Also, the results of the soil texture indicate that Osalu natural stand soil has silty clay loam to silty loam, and clay textures. For Seporghan planted stand, silty clay, silty clay loam, and silty loam are dominant textures. Goltapeh natural stand has sandy loam to silty loam textures, and Jabalkandi planted stand has just loam texture.

Fig. 6 Soil texture of *T. rmosissima* in natural and planted stands. Different lowercase letters within the same soil particle indicate significant differences among different stands at *α*=0.05 level. Bars are standard errors.

3.3.2   Soil chemical property

According to Table 4, the highest EC, SAR, Cl^-, SO_4^{2-}, Na^+, K^+, Ca^{2+}, and Mg^{2+} were found in Seporghan planted stand and the lowest were found in Goltapeh natural stand. The highest values of pH and PO_4^{2-} were found in Goltapeh natural stand. The lowest values of pH, organic carbon, and PO_4^{2-} were found in Seporghan planted stand. The highest values of bicarbonate and NO_3^- were found in Osalu natural stand and Jabalkandi planted stand, respectively. The lowest values of NO_3^- and Ca^{2+} were found in Osalu natural stand and the lowest bicarbonate was found in Jabalkandi planted stand.

Table 4 Soil chemical properties of the studied stands

Indicator	Osalu natural stand	Seporghan planted stand	Goltapeh natural stand	Jabalkandi planted stand
EC (µS/cm)	37,157.70±6759.92[b]	92,214.78±7795.73[a]	12,317.14±1352.32[c]	52,307.54+5421.14[b]
pH	7.00[b]	7.00[b]	7.00[a]	7.00[a]
SAR	57.30±3.73[b]	114.90±9.61[a]	10.85±1.51[c]	58.71±4.86[b]
SOC	0.70±0.15[b]	0.64±0.11[b]	8.46±0.88[a]	1.39±0.07[b]
Bicarbonate (meq/L)	25.71±2.97[a]	24.28±2.02 [a]	13.85±0.67[b]	11.42±1.32[b]
Cl^- (mmol/L)	272.52±52.22[c]	634.47±47.60[a]	73.92±10.94[d]	457.46±46.50[b]
SO_4^{2-} (mmol/L)	66.10± 10.70[b]	93.87±7.92[a]	40.75±4.28[c]	72.10±10.18[ab]
NO_3^- (mmol/L)	0.20±0.02[b]	0.35±0.07[b]	0.65±0.19[b]	1.41±0.24[a]
PO_4^{2-} (mmol/L)	0.07±0.01[b]	0.02±0.00[c]	0.12±0.01[a]	0.08±0.01[ab]
Na^+ (mmol/L)	308.40±44.45[b]	804.78±78.82[a]	58.90±9.64[c]	379.33±33.54[b]
K^+ (mmol/L)	3.40±2.12[b]	12.94±0.74 [a]	3.00±0.20[b]	6.15±0.58[b]
Ca^{2+} (mmol/L)	25.71±5.28[b]	41.42±4.59[a]	29.00±1.79[ab]	30.00±4.87[ab]
Mg^{2+} (mmol/L)	40.00±12.34[ab]	62.85±13.92[a]	28.00±2.15[b]	59.28±10.76[ab]

Note: Different lowercase letters within the same row indicate significant differences among different stands at α=0.05 level. EC, electrical conductivity; SAR, specific absorption rate; SOC, soil organic carbon. Mean±SD.

The results of PCA analysis of soil parameters in the studied stands are presented in Figure 7. It is obvious that based on the degree of significance and the values of Broken-stick eigenvalue, the first and second two main components for soil parameters can be extracted between stands (Table 5). The first component represents about 48.64% of the total variance, and the second component represents 17.49% of the total variance. The two components together account for 66.14% of the total variance. Based on the analysis of the main components, the distribution of stands, and parameters in the space of the two main components, we found that the four stands can be separated by two main components.

We determined the parameters on the first component extraction based on the factor loads. The parameters clay, SOC, EC, SAR, Cl^-, SO_4^{2-}, Na^+, K^+, and PO_4^{2-} have significant factor loads. Thus, they are significant in extracting the first component and separating Jabalkandi planted stand from Goltapeh natural stand. In other words, the most important variable parameters between these stands are clay, SAR, K^+, Cl^-, and EC. The more movements from Goltapeh natural stand to Seporghan planted stand happens, the more SAR, SO_4^{2-}, Na^+, and K^+ increase. By inverse movement, the values of these parameters decrease. Moreover, moving from Seporghan planted stand to Goltapeh natural stand, SOC, and PO_4^{2-} values increase, and moving in the opposite direction reduces the amount of these parameters. According to the factor loads, the parameters on the extraction of the second component are determined. The three parameters NO_3^-, HCO_3^-, and sand have significant factor loads. Consequently, they play an important role in the extraction of the second component and the separation of Osalu natural stand from Jabalkandi planted stand. In other words, they are considered the most significant variable parameters between these stands, i.e., the more movement from Jabalkandi planted stand to Osalu natural stand happens, the more the HCO_3^- values increase and the less NO_3^- and sand values become, and vice versa (Table 6).

4 Discussion

Generally, average crown diameter and crown cover of trees provide important information about the quantitative and qualitative characteristics of vegetation cover. The average diameter of crowns (204.0 cm) of *Tamarix* shrubs in Osalu natural stand was significantly higher than that in Goltapeh natural stand (162.7 cm) (α=0.05; Table 3). The low diameter of the crown and consequently the crown area of *Tamarix* shrubs in Goltapeh natural stand may be due to the exploitation of the villagers for various household purposes.

The average number of sprouts is higher in Osalu natural stand than in Goltapeh and planted
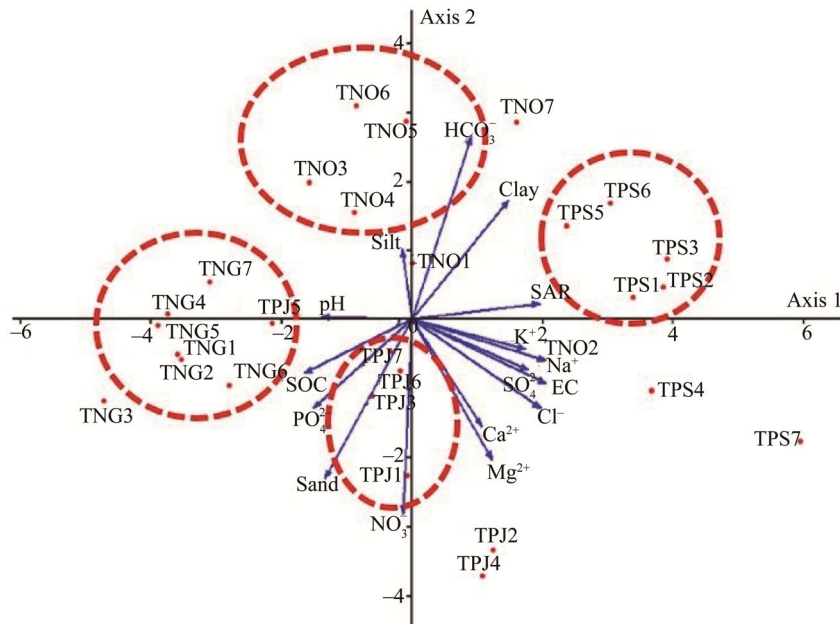
Fig. 7 PCA (principal component analysis) of soil parameters in the studied stands. TPJ, Jabalkandi planted stand; TPS, Seporghan planted stand; TNO, Osalu natural stand; TNG, Goltapeh natural stand. EC, electrical conductivity; SAR, specific absorption rate; SOC, soil organic carbon.

Table 5 Result of principal component analysis (PCA)

Axis	Eigenvalue	Percentage of variance (%)	Percentage of cumulative variance (%)	Broken-stick eigenvalue	P
1	7.783	48.60	48.64	3.381	0.001
2	2.799	17.49	66.14	2.381	0.001
3	1.547	9.67	75.80	1.881	1.000
4	0.910	5.67	81.49	1.547	1.000
5	0.773	4.83	86.32	1.297	1.000
6	0.541	3.38	89.71	1.097	1.000
7	0.446	2.77	92.49	0.931	1.000
8	0.378	2.36	94.85	0.788	1.000
9	0.328	2.05	96.90	0.663	1.000
10	0.231	1.44	98.34	0.552	1.000

stands (Seporghan and Jabalkandi) (Fig. 3). *Tamarix* is one of the fast-growing trees, and with having a suitable environmental conditions, the growth of these species will increase (Ghasempour et al., 2016). Due to less destruction in Osalu stand than in Goltapeh stand, the growth of *T. ramosissima* has increased. The natural reproduction of *T. ramosissima* species is mostly asexual and occurs through the sprouts. The high freshness of *Tamarix* stands in Osalu stand compared with other stands has increased the growth capacity of this species (Fig. 5). Other studies (Moradi et al., 2007) have shown that in addition to habitat conditions, the value of the average crown diameter also depends on the height of the trees. The average height of trees was 19.21% higher in Osalu stand than in Goltapeh stand.

Mohammadi et al. (2017) and Rouhi Moghaddam et al. (2018) studied the soil texture of *Tamarix* species and found that the sandy loam, silt loam, loam-sand, and loam are suitable for the

Table 6 Pearson correlation coefficients between PCA ordination axes and soil parameters

Parameter	Axis 1	Axis 2
Clay	0.460[*]	0.230
Silt	0.004	0.080
Sand	0.370	0.410[*]
SOC	0.570[**]	0.050
EC	0.890[**]	0.070
pH	0.410	0.000
SAR	0.810[**]	0.004
HCO_3^-	0.180	0.530[**]
Cl^-	0.820[**]	0.130
SO_4^{2-}	0.680[**]	0.040
Ca^{2+}	0.250	0.180
Mg^{2+}	0.320	0.320
Na^+	0.890[**]	0.030
K^+	0.640[**]	0.020
NO_3^-	0.004	0.610[**]
PO_4^{2-}	0.406[*]	0.130

Note: SOC, soil organic carbon; EC, electrical conductivity; SAR, specific absorption rate. [*], α=0.05 level; [**], α=0.01 level.

growth of the species. *Tamarix* is better established in soils with medium (loamy texture) to semi-heavy texture (clay loam texture) than heavy soil texture (clay texture), which is consistent with the results of this study. Sargezi (2013) found that the content of clay was not significantly related to the distribution of *Tamarix*, but the content of silt was significant with its distribution, which is also confirmed by Matinkhah and Kaveh Sedehi (2017). Similarly, Ahmady-Birgani and Ravan (2019b) reported that the distribution of the vegetation communities on the western shores of Lake Urmia is mostly related to the various landforms and geomorphic features. The study of physical properties and soil texture in the two natural *Tamarix* stands also showed a significant difference (α=0.05).

The study of soil chemical properties in two planted stands of *T. ramosissima* indicated high levels of Na^+ and K^+ and high salinity of soil in Seporghan stand compared with Jabalkandi stand (Table 4). One of the important issues in the physiology of nutrient uptake is the relationship between K^+ and Na^+ under stress conditions. K^+ is significant in reducing the osmotic potential of root cells and maintaining the water balance of the whole plant in saline soil, but high Na^+ in the root environment reduces the absorption of K^+ and lowers the ratio of K^+ to Na^+. Salinity also reduces the uptake of phosphorus, K^+, Ca^{2+}, and Mg^{2+} in root (Ilahi et al., 1994). EC, as one of the most important factors, is directly related to the amount of Na^+ and Cl^- in the soil. In addition to impairing the absorption of elements and disturbing the ionic balance, increasing salinity affects the osmotic pressure of the soil directly, and increasing the concentration of salt in the plant tissue and causing toxicity leads to lack of establishment and optimal growth of *Tamarix*. High concentrations of Na^+ cause tuber formation and weaken aggregates, thereby reducing soil permeability. Also, the high concentrations of Na^+ and Cl^- can have direct toxic effects on membranes and enzyme systems. Accordingly, Na^+ and Cl^- are two important ions with ion-specific effects that significantly reduce plant growth and function. Salinity increases the amount of energy to maintain the natural condition of the plant, so less energy remains for growth needs. Consequently, plants are generally weaker in saline conditions and have smaller leaves than plants in non-saline and normal conditions. In most studies, such as Wang et al. (2016) and

Li et al. (2019), desert salinity has reduced the EC of the soil; nonetheless, the results of the present study do not indicate this issue and are consistent with the results of studies by Rouhi Moghaddam et al. (2018), Ladenburger (2006) and Feng et al. (2018). The increase in salinity is mainly due to the increase in Na^+ and Cl^- in the soil (Feng et al., 2018). Ghorbanian et al. (2012) in their research on the effects of salinity stress on growth, accumulation of ions, and phytobiochemical indices in *Nitraria schoberi* L. plant, revealed that high salinity concentration reduces the production of *N. schoberi* plant; however, this plant shows relatively high resistance to medium salinity concentration.

In the analysis of the key component, it was observed that parameters such as EC play an important role in the extraction of the first factor, where sampling areas are saline soils. So, as expected, salinity changes are significant in explaining the data and the most important limiting factor. Furthermore, soil fertility parameters such as SOC, PO_4^{2-}, and K^+ in the first component play an important role in site separation. Just as soil nutrients are necessary for plant growth, the results also confirm the need to pay attention to the number of soil nutrients when implementing planting plans. Other researchers (Mehdifar et al., 2015) regarding the relationship between the vegetative characteristics of *Tamarix* and soil parameters represented that the parameters of SOC, EC, moisture, absorbable phosphorus, and silt percentage are significant factors in plant communities establishment, particularly in arid and semi-arid regions. Nevertheless, Rezaipoor-baghedar et al. (2012) reported that the physical characteristics and soil texture play an effective role in determining the habitats of *Tamarix*. Also, Mahmoudi et al. (2013) also revealed that fertility characteristics (such as SOC, total nitrogen, and soil moisture) are the most important effective factors in the freshness of *Haloxlylon* and *Tamarix* species.

Considering the roles of clay, SOC, EC, SAR, Cl^-, SO_4^{2-}, Na^+, K^+, and PO_4^{2-} parameters selected on the first component compared with the second axis parameters including NO_3^-, HCO_3^-, and sand, it seems that these essential soil parameters can be applied in executive plans for combating desertification in order to identify suitable planting sites. In general, according to the results, it is clear that in saline ecosystems, soil fertility parameters are the most important indicators in the success and establishment of planting, so soil fertility should be considered when choosing planting sites.

5   Conclusions

In Iran, the efforts for combating desertification through planting resistant vegetation are in progress. For example, planting *T. ramosissima* in the desertified lands of Iran is widespread. However, investigation on these ecological measures for combating desertification is limited. In the present study, the results showed that due to the ecological characteristics of *T. ramosissima* in the natural habitats and the existence of high amounts of EC, SAR, Na^+, Cl^-, etc. compared with the planted stands, many of these soil parameters are 6 times higher than natural stands of *T. ramosissima*. Hence, the establishment of *T. ramosissima* in the planted stands has very little chance of success for combating desertification. As the results presented, increasing salinity decreased the total height and average diameter of *T. ramosissima* in the study areas. Based on field observations, we found that planting *T. ramosissima* in all sites have faced many challenges and high costs. Conversely, inhibition of livestock in these sites becomes effective in restoring annual and perennial herbaceous vegetation.

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