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Determination of Ecological Thresholds in Saline Habitats on Western Shore of Lake Urmia, Iran

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Abstract:

In temporal and spatial patterns, the critical (ecological) thresholds have rapid changes in ecological gradient. Determination of thresholds along the environmental gradients can help to control destructive factors and therefore, the success in restoration projects can be guaranteed. This study was conducted to evaluate the trend of changes in functional and structural indices along soil salinity gradient and to determine the ecological thresholds in saline habitats of Uremia Lake, Iran, in the growing season of 2019 and 2020. Landscape Function Analyses (LFA) guideline was used to evaluate the sites. The values of the indices were fitted with the pattern diagrams (S-shaped curves). The habitat restoration process after five years of range management and development projects was evaluated and ecological thresholds were determined. The results showed that the values of the functional and structural indices decrease along the salinity gradient and the lowest values were observed at the end points of the gradient. As a result, the success of range development projects was lower at salinity center. The results of the S-shaped curve models showed that the regression relationship between landscape organization index and nutrient cycle with eleven soil indices along the salinity gradient was not significant and their determinant coefficients were less than 50%. On the other hand, there was a strong relationship between the index of stability and permeability with the salinity gradient, with determinant coefficients of 83 and 63%, respectively so that the values of these two indices decreased significantly when approaching the salinity center. Regarding the PCA analysis, the first component justified 39% of the changes in the properties, and the values of Sand, Mg, and Ca increased as they approached the salinity center, and on the other hand, as they moved away from the salinity center, the values of Clay, N, OM, CEC, p, and Silt increased. The participation of the most soil parameters in the extraction of the first component of the decomposition of the physical and chemical characteristics of the soil along the salinity gradient and the separation of the sites from each other indicate the good ability of the LFA method in showing the ecological processes of nature. In this regard, to fit the data by the S-shaped curve, the distance of 1000 m far from the salinity hotspot was defined as an ecological threshold, through which sudden changes occur. At these thresholds, the functional differences of the habitat were more than the surrounding areas, so for controlling the dust centers, different projects such as drainage, windbreaks or planting dense vegetation cover are suggested to stabilize the thresholds. In such a case, the soil seed bank in the distance between the two thresholds could be regenerated and prevent the soil surface from eroding if grazing is prevented. Identifying thresholds as a transition zone and surrounding zones as state zones in this study will be a scientific and appropriate alternative to the conventional guidelines in executive organizations and will help them to zoning ecosystems according to nature and selection and prioritization of restoration sites in saline rangelands.

Keywords: Saline lands, Rangeland planting, Habitat functional characteristics, Landscape organization index

1. Introduction

At present, in a large area of saline lands around Urmia Lake, Iran, due to the regression of the lake as the result of groundwater decline and reduced input water, centers for the production of fine dust and sand have been established and over the past few years, planting projects have taken place in the area. Usually in such habitats, vegetation cover distribution has a heterogeneous and stain pattern, and accordingly, the concepts of ecological patch and inter-patch are defined (Ludwig and Tongway, 2000; Miller, 2005). Depending on the landscape, the size, frequency and spatial distribution of patches vary. Typically, in arid and semi-arid regions, fertile patches (ecological patches) spread in small areas of the landscape. The scale of the patches and inter-patches change in response to rainfall and other environmental factors. As in the dry season, the size of the patches decreases because there is no enough moisture to maintain them (Ludwig et al., 2004; Ghodsi et al., 2010).

Structural and functional characteristics of plant patches are changed, due to turbulence and distance from crisis centers such as intensity of livestock grazing, distance from livestock placement and water sources and environmental gradients such as salinity, slope, altitude, climate, soil surface moisture, etc. (Heshmati et al., 2018; Azimi et al., 2018; Sharafatmand-Rad and Khosravi Mashizi, 2019). In the stages of changes in the structural and functional characteristics of plant patches, there are boundaries called ”thresholds” (Groffman et al., 2006). These thresholds describe rapid changes in ecological characteristics in time intervals and spatial patterns (Beisner et al., 2003; Hille et al., 2018). Determination of degradation or changes of thresholds onset can be helpful in rangeland management and controlling destructive factors (Hobbs and Harris, 2001). Therefore, range management and development field are looking for a model that can recognize ecological thresholds as a start point for landscape controlling (Stringham et al., 2003).

Determination of ecological thresholds has so far been based on various theories such as ”succession” and ”state and transition”. According to the theory of state and transition, ecosystem changes occur from one state to another state through processes or interventions. These changes occur at points called thresholds (Samhouri et al., 2010; Furniss, 2010). Walker and Meyers (2004) believe that the ecological threshold is the point between two consecutive states and when a system passes through it, a sudden change occurs. Friedel (1991) introduces the threshold as spatial and temporal boundaries between the two states. Wiens et al. (2002) identify thresholds as transition zones in changing systems. Bennett and Radford (2003) identify thresholds as areas where rapid changes from one ecological state to another occur. Also, Wiens et al. (2002) believe that thresholds are the areas where the rate of change has intensified.

To determine the change of thresholds in an ecosystem, it is important to understand the structural and functional response of the ecosystem to intruders (Adel et al., 2014). So far, studies have been conducted to determine the trend of structural and functional changes in the ecosystem along grazing gradients or in response to natural and anthropogenic interventions. Graetz and Ludwig (1987) studied the effect of grazing gradients on some plant and soil characteristics and reported that the relationship between watering place distance and ecosystem reaction was sigmoidal. Bastin et al. (1993) also reported that the relationship between grazing gradient and plant response was sigmoidal. Toms and Lesperance (2003) introduced a piece-wise regression model for threshold determination. Ahmadi et al. (2009) determined the critical threshold in rangeland ecosystems using this method. In this regard, to determine ecological thresholds, three functional features include Stability, permeability and nutrient cycle and a structural feature including vegetation canopy amount per hectare were used. For this purpose, the performance and structure of the ecosystem were measured at distances of 1000, 2000, 3000, 4000, and 5000 m from three villages in the Maravah Tappeh desert habitats in the north of Iran. The results showed that there was a significant difference between three functional features and a structural feature at the beginning and end of the three villages. So, the rangelands near the village had much less functional and structural values than the rangelands far from village. At the end of the 4,000 m distance, structural and functional differences between start and end of the distance revealed an ecological threshold.

Fakhimi and Motamedi (2020) conducted a study to evaluate the effect of copper extraction on the structure and function of rangeland ecosystem around the mine area in Dareh Zereshk, Yazd province, Iran. They selected three study sites were considered at the specified intervals of the mine (0-200, 200-500 and 500-1000 m). The structural characteristics were measured for ecological patches and inter patches space along each transect and the landscape organization indices for each ecological unit (distance from the mine) were calculated. Based on the results, there were significant differences between the nearest (0-200 m) and far (500-1000 m) ones from the mine for indicator and functional traits ($P < 0.05$). But, there was no significant difference between the mid distance of the mine (200-500m) and two other sites, near and far from the mine ($P > 0.05$). Their results demonstrate the efficiency of the landscape function analysis method to assess the post mining damages and any subsequent reconstruction of rangeland in the around area. Motamedi and Sheidai-Karkaj (2022) conducted a research in the Separghan region in Urmia, Iran, as a pilot study area and a representative of saline habitats of the western shore of Urmia Lake. About 24 transects were established in three ecological areas to measure the structural and functional characteristics of the habitats. Moreover, the number, length, and width of ecological patches, the percentage of patches' lengths, and the landscape organization indices were calculated for each area using the established linear transects in each ecological unit. The study results indicated that the indices' mean varied along the salinity gradient, being significantly different in various ecological areas. Fakhimi and Naderi (2020) evaluated the structure and function of Yazd steppe rangelands of Iran at different levels of grazing. For this purpose, 9 sites were selected in light, medium and severe grazing levels. In each transect, types of echogenic spots were identified and the length and width of the space between the spots were recorded. During each transect, 5 samples were randomly selected from each type of ecological spot and 11 indices of surface soil condition were determined according to the instructions of the LFA method and surface soil performance criteria in these areas. Based on the results, most of the structural (patch

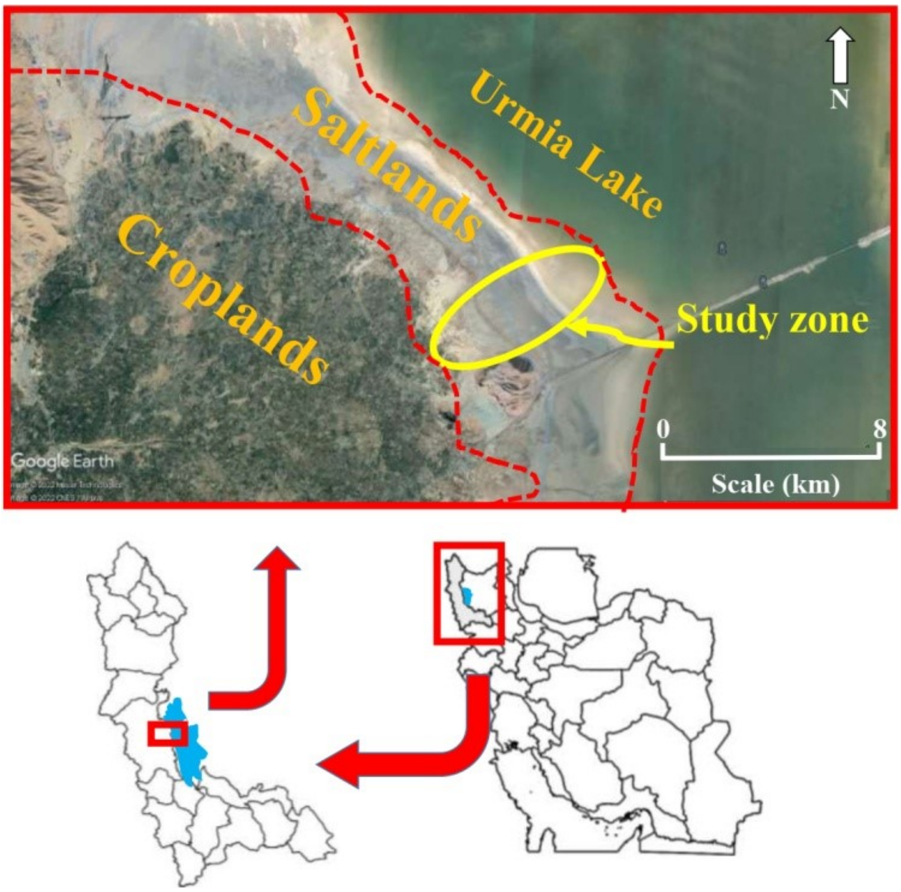

Figure 1. Location of the study area.

length, number of patch, patch surface index and landscape structure index) and functional characteristics (permeability, stability and cycle elements) had a significant difference between light and severe levels, but between moderate grazing level and two other ones, no significant differences were observed. According to the results of the study, in order to better manage and increase the functional characteristics of rangelands, it is necessary to increase vegetation, especially with plant structure, herbaceous leaf and grass. Heshmati (1997) used landscape analysis in a study to identify distinct zones around watering place in South Australian shrublands. The results showed that the indices of permeability, stability and nutrient cycle clearly reflect the effect of grazing around the watering place and have a positive correlation with the natural zone and a negative correlation with the degraded zone.

To determine the ecological thresholds along the salinity gradient at salt land of west shores in Urmia Lake, this study used the structural and functional characteristics of the habitat and aimed to distinguish the sites where the structural and functional characteristics have sharp breaks as critical thresholds for management purposes.

2. Materials and methods

2.1 Study area

In this study, the saline habitat of Separghan region with a geographical position of 37° 45′ 14″ N and 45°14′ 19″ E is located at 30 km northeast of Urmia city and on the western areas of Urmia Lake, (Fig. 1) and was selected as the study area because it is representative of saline habitats in west of Urmia Lake, Iran. The average long-term rainfall and annual temperature of the region are 326 mm and 12 °C, respectively. The climate of the region is cold and semi-arid based on the Emberger classification method. The lands of the region are flat and saline and the texture of the soil is loamy clay. The soil of the region has an electrical conductivity (salinity) of about 28.7 to 62.9 ds/m (Motamedi et al., 2018).

Separghan region, in 2014, was recognized as one of the centers of salt dust and it was in the priority of conservation and management projects, and it was named as a reference site and research pilot to generalize the results to similar habitats. Therefore, rangeland planting operations with different species were carried out on a large scale along the salinity gradient and livestock grazing in the area was prevented.

Index species of Separghan region include the following species:
Halocnemum strobilaceum, Atriplex verrucifera, Camphorosma monspeliaca, Kochia lana, Aeluropus littoralis, Aeluropus lagopoides, Puccinella distans and Alhagi pesudalhagi.

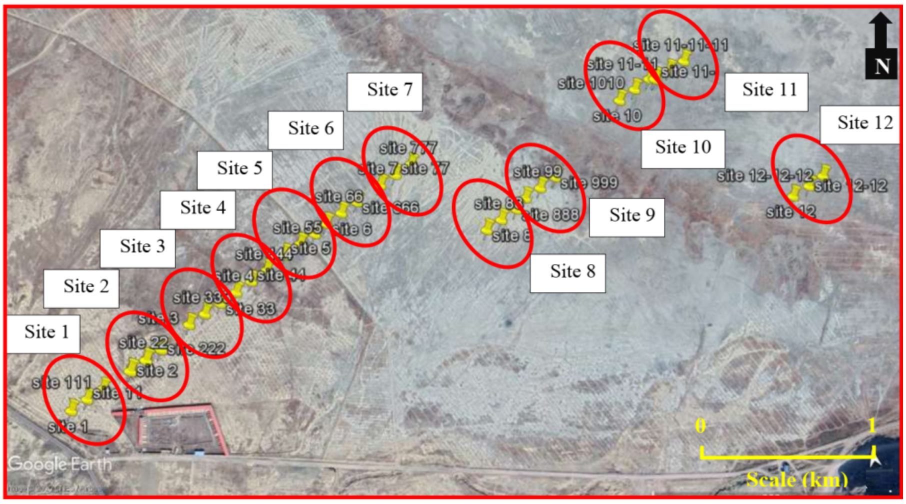

Figure 2. Establishment of ecological sites (areas) along the salinity gradient.

2.2 Research methodology

2.2.1 Measurement of landscape organization index and habitat performance indices

For this purpose, by establishing 24 transects of 50 m, along 1200 m, the salinity gradient (Fig. 2), the number of ecological patches, the length and width of ecological patches and the percentage of patches length were measured and the landscape organization index was calculated for each ecological unit. In this regard, in each ecological unit located along the salinity gradient, 5 transects with the length of 100-m were used along the salinity gradient. Then, for each of the patches and the inter-patches along each transect; five measurement zones were considered and according to the guidelines of soil surface assessment indicators (Tongway and Hindly, 1995), 11 soil surface indicators were evaluated and categorized. Finally, the functional characteristics of the habitat were calculated for each ecological unit according to the instructions of soil surface evaluation indicators. The resulting number reflects the situation of the area under the influence of rangeland planting operations. The details of the structural and functional characteristics are explained by Motamedi and Sheidai-Karkaj (2022).

2.2.2 Determination of functional and regenerative process of the studied habitats

For this purpose, the value of each of the structural and functional characteristics was adjusted with the pattern diagrams in scientific reports (S-shaped curve), and the ecosystem regeneration process was evaluated after five years of planting operations. Ecological thresholds for management purposes were also determined by drawing S-shaped (Sigmoid) curves at different distances of the environmental gradient (Tongway and Hindly, 1995).

2.2.3 Measurement of physical and chemical properties of habitat soil

For this purpose, a soil sample from 0-30 cm depth was taken from each of the established transects and then from the total of three consecutive transects, a composite soil sample was extracted by mixing them and transferred to the laboratory. Thus, the samples were first sieved using a 2 mm sieve (physical tests) and a half mm (chemical tests). Then, percentage of sand, clay, silt and soil texture, percentage of Soil Saturation Percent (SP), bulk density, acidity (pH) in saturated mud, Electrical Conductivity (EC) (salinity) in saturated extract, percentage of Nitrogen (N), percentage of carbon (OM), amount of Magnesium (Mg), Calcium (Ca), available Phosphorus (P), sodium (Na), Cation Exchange Capacity (CEC), Chloride (Cl), bicarbonate (HCO_3^-), sulfate (SO_4), Sodium Adsorption Ratio (SAR), and Exchangeable Sodium Percentage (ESP) for each soil sample were measured according to the guideline No. 467 of the National Soil and Water Research Institute, Tehran, Iran.

2.3 Data analysis

Data of 11 valued indices were analyzed to determine the performance characteristics using the Landscape Function Analysis (LFA) software designed in Excel (Ludwig and Tongway, 2002). Also, using LFA software, three soil performance indicators including stability, permeability and nutrient cycle were obtained for each patch and each interpatch in the ecological units located along the salinity gradient. In order to compare the mean values of functional and structural indices as well as physical and chemical properties of soil in different ecological units located along the salinity gradient, one-way analysis of variance test was used by Motamedi and Sheidai-Karkaj (2022). Due to the significant difference between ecological units, in order to predict the trend of changes in structural and functional properties along the salinity gradient, a four-parameter sigmoid regression model (Fig. 3) was performed, and Sigma Plot software version 12 was used to draw and fit the model. In the equation

$$y = y_0 + \frac{a}{1 + e^{-\frac{x - x_0}{b}}}$$

there are different components that represent different parameters of the ecosystem.

$(y_0 + a)$ is the maximum possible value of the evaluated index for the ecosystem, which is controlled by climate, bedrock or other influential environmental and managerial

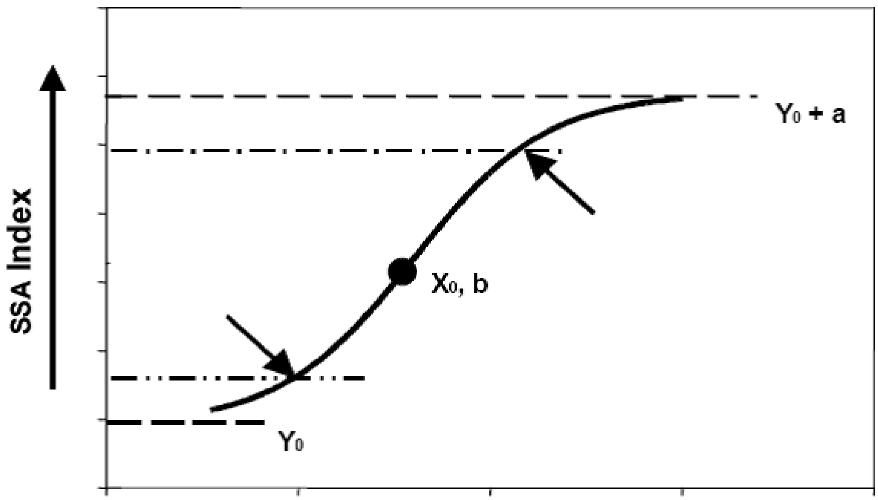

Figure 3. Four-parameter sigmoid model (Tongway and Hindley, 2004a).

factors, and can be named as "biochemical potential".

y_0 is the lowest value available for considered index of the ecosystem under turbulent and intervening conditions.

x_0 indicates the turning point of the curve on the x axis, and b is the slope of the turning point, which indicates the rate of increase of the measured index over time or distance. In fact, this curve is for landscapes where resources are limited.

In order to evaluate the compatibility of LFA guideline indices with classic indices in soil science, Principal Component Analysis (PCA) was performed using PC-ORD software. In this regard, due to the distribution of sites in the space of soil parameters, it is possible to decide about the confirmation of outcomes of LFA indices.

3. Results

3.1 Structural and functional indices values along the salinity gradient

Results of landscape organization index and habitat performance indices (soil stability, permeability and nutrient cycle) showed that the mean values of the indices vary along the salinity gradient and there is a significant difference between the ecological areas. The highest value of the landscape organization index (0.32) belonged to the further away from the salinity hotspot, and the lowest values (0.10 and 0.06) belonged to closer sites to the salinity hotspot. The average values of the stability indices (44.40, 37.01 and 20.70), permeability (21.50 and 24.90, 13.20), and the values of the nutrient cycle (11.19, 11.80 and 7.90) were obtained in the first, second, and third ecological zones, respectively (Motamedi and Sheidai-Karkaj, 2022). In general, the values of structural and functional indices decrease along the salinity gradient.

3.2 Sigmoid regression model

3.2.1 A. Fitting the landscape organization index along with the salinity gradient

Fitting between the landscape organization index and the distance from the salinity center was significant ($P < 0.01$) indicating Sigmoid model as an efficient method of describing the data trends (Table 1). Accordingly, the value of the landscape organization index can be modeled with distance from the salinity center. The adjusted S shape equation was as follows;

$$f = \frac{a}{1+\exp(-\frac{(x-x_0)}{b})}$$

$$y = \frac{0.546}{1+\exp(-\frac{(x-0.89)}{0.15})}$$

Where:

y is the landscape organization index,

a is the constant value,

x is the distance from the salinity center,

x_0 is the location of the turning point on the x-axis, and

b is the slope of the turning point.

The f value was significant in the regression model ($P < 0.01$). The results showed that parameters a and x_0 were significant at ($P < 0.05$ and $P < 0.01$) probability levels, respectively (Table 2). In this regard, the amounts of explanation coefficient (R^2) and adjusted-R^2 and standard error of the model estimation are 0.53%, 0.48% and 0.13, respectively.

3.2.2 B. Fitting the data of soil stability index along the salinity gradientds

Adjustment stability index data with distance from salinity center based on signed model showed that the data, significantly fitted Sigmoid regression ($P < 0.01$), indicating S-shaped curve are efficient for the explanation of data trends (Table 1). Since in statistical point of view, both of total regression and coefficients are done by various statistical tests and are not necessarily dependent on each other; therefore, each of tests may present different results. Therefore, overall results imply significant relationships between variables but it is suggested to conduct more observations in the similar studies.

Accordingly, the value of the stability index can be modeled in relation to the distance from salinity center. The

Table 1. Analysis of variance of sigmoid regression between distance from salinity center and functional indices.

functional indices	**SOV.**	**DF**	**SS**	**MS**	**F**	**R^2**	**Adjusted-R^2**
landscape organization index	regression	2	0.45	0.22	11.88**	53%	48%
	residual	21	0.39	0.01	-		
	total	23	0.03	-	-		
stability index	regression	2	2761.2	1380.6	58.84**	0.84%	0.83%
	residual	21	492.7	23.4	-		
	total	23	3254	-	-		
permeability index	regression	2	592.2	296.1	20.9**	0.66%	0.63%
	residual	21	296.6	14.1	-		
	total	23	888.9	-	-		
nutrient cycle index	regression	2	152.7	76.3 7.5**	0.41%	0.36%	
	residual	21	212.6	10.1	-		
	total	23	365.3	-	-		

**= significance 1% probability levels.

adjusted S shape equation between two variables was as follows;

$$f = \frac{a}{1+\exp(-\frac{(x-x_0)}{b})}$$

$$y = \frac{42.43}{1+\exp(-\frac{(x-0.19)}{0.09})}$$

Where:
y = stability index,
a is the constant value,
x is the distance from the center of salinity,
x_0 is the curve turning point on the x-axis, and
b is the slope of the turning point.

The f value was significant for the regression model ($P < 0.01$). The result showed that the parameters a, b and x_0 were also significant ($P < 0.01$) (Table 2). In this regard, the amounts of explanation coefficient (R^2) and adjusted-$R^2$and standard error of the model are 0.84, 0.83 and 4.8, respectively. The Sigmoid curve representing the relationship between two data sets related to the stability index and the distance from the salinity center is shown in Fig. 4.

3.2.3 C. Fitting the data of soil permeability index along the salinity gradient

Adjustment of distance from salinity center and permeability index data based on signed model was significant ($P < 0.01$) indicating that Sigmoid model is very efficient in describing the data trends (Table 1).

Accordingly, the value of the permeability index can be modeled in response to distance from the salinity center. The adjusted S shape equation is as follows;

$$f = \frac{a}{1+\exp(-\frac{(x-x_0)}{b})}$$

$$y = \frac{23.05}{1+\exp(-\frac{(x-0.14)}{0.06})}$$

Where:
y = stability index,
a is the constant value of the equation,
x is the distance from the center of salinity,
x_0 is the curve turning point on the x-axis, and
b is the slope of the turning point.

The f value was significant for the regression model ($P < 0.01$). The parameters a, b and x_0 were also significant ($P < 0.01$) (Table 2). In this regard, the amounts of explanation coefficient (R^2) and adjusted-R^2 and standard error of the model are 0.66, 0.63 and 3.7 respectively. The sigmoid curve expressing the relationship between the two data sets is shown in Fig. 4.

3.2.4 D. Fitting the nutrient cycle index along the salinity gradient

Fitting of permeability index and distance data from salinity center was significant ($P < 0.01$) indicating Sigmoid model as an efficient method in describing data trends (Table 1).

Accordingly, the value of the permeability index can be modeled according to distance from the salinity center. The adjusted S shape equation is as follows;

$$f = \frac{a}{1+\exp(-\frac{(x-x_0)}{b})}$$

$$y = \frac{11.58}{1+\exp(-\frac{(x-0.14)}{0.05})}$$

Where: y is the landscape organization index, a is the constant value of the equation, x is the distance from the center of salinity, x_0 is the turning point of the curve on the x-axis, and b is the slope of the turning point. The f value was significant in the regression model ($P < 0.01$). The result showed that the parameters a and x_0 were also significant ($P < 0.01$). (Table 2). In this regard, the amounts of explanation coefficient (R^2) and adjusted-R^2 and standard error of the model are 0.41, 0.36 and 3.1, respectively. The Sigmoid curve expressing the relationship between the two data sets related to the nutrient cycle index and the distance from the salinity center is shown in Fig. 4.

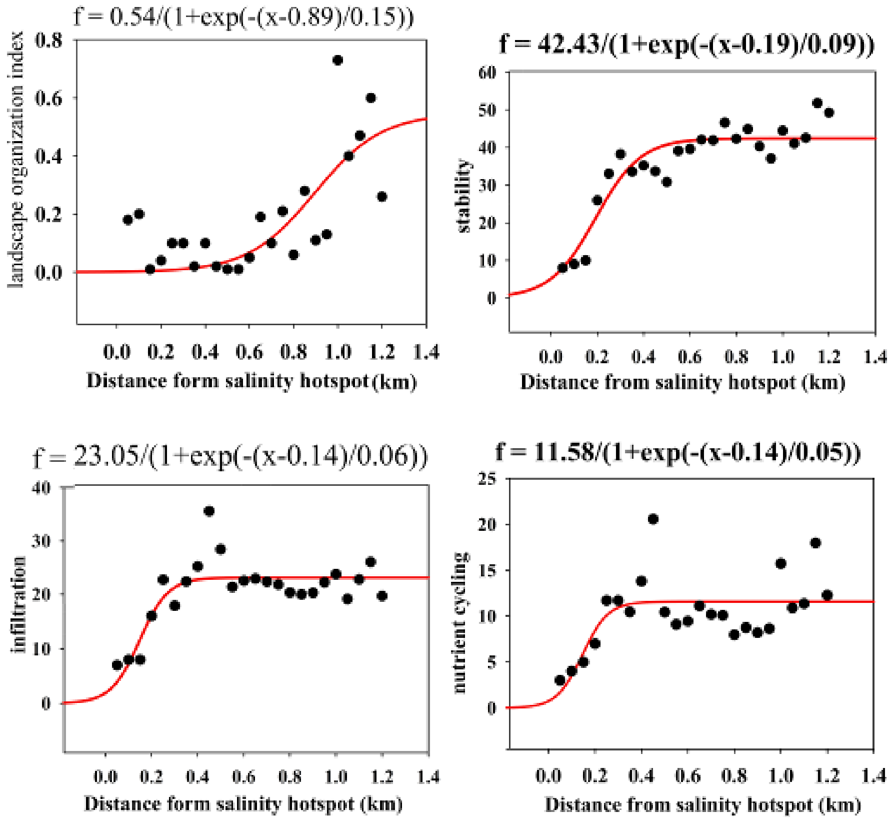

Figure 4. Shaped curve between functional indices and distances from the lake (salinity center).

3.3 Principal components analysis of soil properties along salinity gradient

Regarding Table 3, the two first components explain about 56.55% of variation among the sites. On the other hand, the results of LFA method can present more clear results among the sites. Similar to the ecosystem function, by moving from the spot to the further sites, the amount of soil properties also is changed.

Transects distribution in the space of the soil parameters is shown in Fig. 5. According to the Bi plot obtained from PCA, it is determined that the first transects (sites) that are far from the center of salinity are scattered on the right side of the graph and by moving to the left of the graph, the sites close to salinity are scattered. It is obvious that this analysis was efficient to differentiate the study sites. In this regard, first to sixth transects, which were within 600 m distance from the beginning of the gradient, are well separated from other sites. Also, most of the soil parameters had a significant contribution in separating the sites from each other. As it gets closer to the sites of the salinity center, salinity parameters such as SAR, ESP, CL, Na, EC increase, and as they move farther away from the salinity center, the OM, Silt CEC, N, and P indices increase. In the first component, Sand, Mg, and Ca properties with negative coefficients and Clay, N, OM, CEC, p, and Silt properties with positive coefficients played an important role in explaining this component, and in the second component, SP, ESP, and SAR traits had a significant correlation with the second component. According to the graph, their values were higher in sites 7 and 9.

Additionally in Table 3, the obtained results for PCA show the share of each parameter in extracting the component. Another point that becomes clear is that the participation of most of the soil measured parameters in defining

Table 2. Estimated sigmoid model's parameters between distance from salinity center and functional indices.

functional indices	Sigmoid model $f = a/(1+\exp(-(x-x_0)/b))$	a	T value	b	T value	x_0	T value
landscape organization	$y = 0.546/(1+\exp(-(x-0.89)/0.15))$	0.546	2.29*	0.15	2.56 ns	0.89	4.99**
stability index	$y = 42.43/(1+\exp(-(x-0.19)/0.09))$	42.4	31.7**	0.09	4.3**	0.19	8.7**
permeability index	$y = 23.05/(1+\exp(-(x-0.14)/0.06))$	23.05	25.1**	0.06	2.6**	0.14	6.2**
nutrient cycle index	$y = 11.58/(1+\exp(-(x-0.14)/0.05))$	11.5	15.1**	0.05	1.5 ns	0.14	3.9**

ns, * and **= no significance, significance at 5% and 1% probability levels.
In the Sigmoid model: y is the functional indices, a is the constant, x_0 is the turning point of x-axis.

Table 3. The results of PCA for the soil data Rotated Component Matrix.

characteristics	unit	PCA 1	PCA 2	PCA 3	PCA 4
eigen values		7.45	3.30	2.98	2.71
% of Variance		39.21	17.35	15.68	14.26
cumulative %		39.21	56.55	72.23	86.49
clay	%	0.91	0.03	-0.07	0.06
nitrogen	%	0.92	0.05	0.15	-0.05
organic Matter	%	0.95	-0.04	0.07	-0.09
cation Exchange Capacity	meq $100g^{-1}$	0.73	0.02	0.64	0.18
phosphorus	mg kg^{-1}	0.87	-0.20	-0.02	-0.30
silt	%	0.89	-0.22	0.23	0.15
sand	%	-0.94	0.15	-0.12	-0.11
magnesium	meq l^{-1}	-0.85	0.23	-0.20	0.19
calcium	meq l^{-1}	-0.73	-0.03	-0.22	0.49
soil Saturation Percentage	%	0.07	0.90	-0.15	0.11
exchangeable Sodium Percentage	meq l^{-1}	-0.25	0.92	0.01	0.17
sodium Adsorption Ratio	mmols l^{-1}	-0.10	0.94	-0.05	0.17
pH	-	0.35	-0.22	0.86	-0.24
Na	meq l^{-1}	0.28	0.11	0.88	0.13
HCO_3^-	mg l^{-1}	-0.13	-0.14	0.91	-0.14
electrical Conductivity	M Siemens cm^{-1}	-0.48	0.48	0.07	0.70
Cl	mg l^{-1}	-0.33	0.50	0.02	0.75
SO_4	mg l^{-1}	0.07	-0.02	0.04	0.95
bulk density	gr/cm-$^{-3}$	0.09	0.17	-0.16	0.39

first component and the separation of sites from each other indicates the good ability of the LFA method to show the ecological processes in nature. Parameters such as bulk density and bicarbonate did not play a significant role in differentiating the sites from each other.

4. Discussion and conclusion

In saltlands, various plant species such as *Halocnemum strobilaceum, Atriplex verrucifera, Salsola sueada*, are the most important commentnet of vegetation community. These plants can produce relatively high consumable biomass in saline areas where non-halophytic species cannot grow or have low dry matter yields. Therefore, halophytes and some other salt-tolerant plants can provide a drought reserve or a supplementary feed source under arid and semi-arid conditions. On grazing lands, the halophytes can serve as complementary nutrient sources to other conventional foodstuffs such as Atriplex spp. and cereal straws or hays. In addition to biomass production, wide variations in palatability, chemical composition, nutritive value and animal responses to several halophytes and salt-tolerant forages have been reported in the literature (El Shaer, 2010).

Vegetation cover in arid and semi-arid regions is in the form of plant patches and in bare soil of inter-patch areas, this form of vegetation cover can be useful to study plant impact on soil to get applicable knowledge for predicting plants efficiency in restoration projects (Motamedi et al., 2018).

The results of measuring the landscape organization index and performance indices of stability, permeability and soil nutrient cycle along the salinity gradient showed that the values of the indices decrease near the salinity center and the end points of the gradient have the lowest value of the indices. As a result, the success of rangeland management projects is lower near the salinity center. In other words, rangeland development projects did not meet the expected goals of the first step of the performed operations, which aimed to increase vegetation cover and reduce the bare soil between patches in the areas near the lake. The results of studying the soil properties suggest that the soil texture of the habitat is loamy- clay and heavy, which reduces soil permeability. On the other hand, leaching of salts is very difficult. Also, with increasing bulk density of the soil, the soil becomes more compact that results in less empty space and the decreased permeability of the soil. Therefore, *N. schoberi* which has a different ecological nature and grows successfully in sandy habitats with surface water does not have the ability to grow successfully in this area where the soil is heavy. In this regard, it is reported that the finer the soil texture and the greater the amount of clay; the amount of organic carbon as well as saturated moisture increases. In other words, fine-textured soils have a greater potential for carbon sequestration and long-term storage of moisture (Jafari and Panahi, 2011). On the other hand, high levels of soil acidity due to accelerated decomposition of soil carbon have a negative effect on soil carbon content and soil organic carbon content has an inverse relation with soil acidity (Vargas et al., 2018). The low amount of soil organic carbon in ecological areas also confirms this statement.

In the other areas of shore in Urmia Lake, Motamedi et al. (2018) conducted another research to study some soil properties in natural vegetation patches of some halophytes. The results showed that soil EC decreased from10.32 ($mS.cm^{-1}$) in bare soil to 4.92 ($mS.cm^{-1}$) in vegetated areas. Also, significant increase of soil pH and phosphorous content was observed in vegetation patches soil that

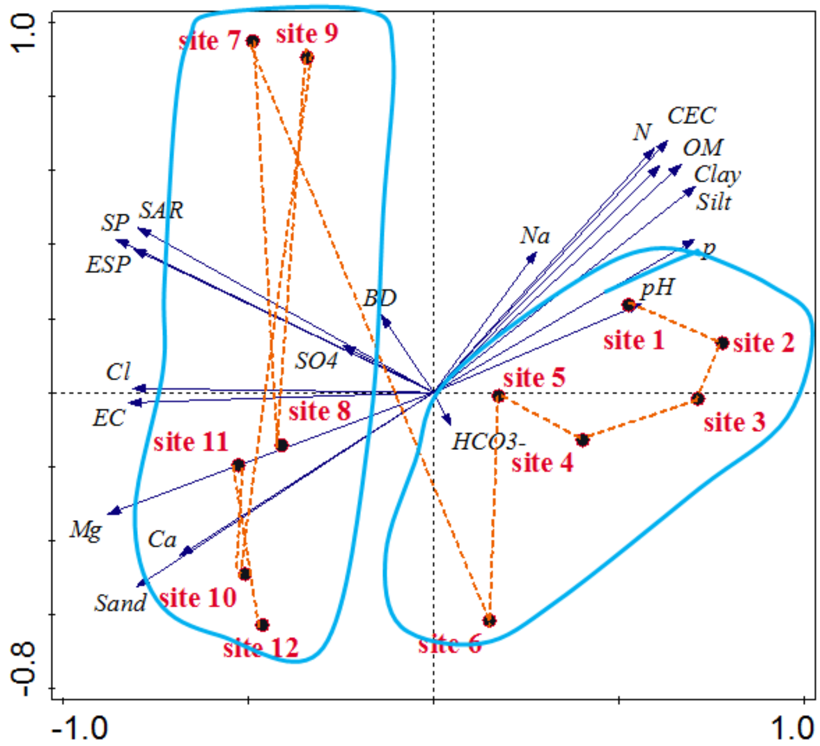

Figure 5. Bi-plot of the distribution of transects in the space of soil parameters by PCA (Soil properties' names have been explained in material and method section. The site numbers are shown in Fig. 2. Site one is the farthest and site 12 is close to the lake and the salinity center).

were 8.73 and 29.61 (ppm), respectively in comparison with bare soil that were 8.51 and 12.81 (ppm). As vegetation patches caused decreases in soil evaluated cations, the main shoot succulent halophytes of *Salsola dendroides, S. nitraria, S.iberica* and *Halocnemum strobilaceum* which can uptake these ions were selected to measure their above ground biomass and root tissue content of these salts; the results showed significant differences between plant species in their salt uptake and accumulating ability. *Halocnemum strobilaceum* had higher amount of sodium and magnesium in shoots that were 9.73 and 2.96 ($mg.kg^{-1}$), respectively, so they had the most ability to absorb these salts by roots and transporting them to shoots. In overall, these plants can improve soil nutrients and chemical condition in their rhizosphere.

Saturation Percent (SP) is an important index in hydrological studies. Saturation percent is related to the mechanical components of the soil, which can be considered as a quantity of soil texture, water holding capacity and cation exchange capacity. There is usually a correlation between the clay, silt and sand percentage maps. Therefore, in places with high sand content, soil saturation moisture content is low and in areas with high clay and silt content, soil saturation moisture content is high (Khan and Weber, 2008). This causes suffocation of the roots of rangeland species as the groundwater level rises, causing the plant species death (Barrett-Lennard et al., 2003). Therefore, the construction of drainage at different intervals of salinity gradient is one of the basic requirements to reduce the wetland status of the habitat for the successful growth of plant species.

The participation of most of the measured soil parameters in the extraction of the first component of the decomposition of the physical and chemical characteristics of the soil along the salinity gradient and the separation of the sites from each other also indicates the good ability of the LFA method in showing the ecological processes of nature.

By drawing S-shaped (sigmoid) curves over time and at different distances of the environmental gradient, critical thresholds for managerial goals were identified and the process of improving structural and functional characteristics was evaluated. In the S-shaped curve (Fig. 3), the curvature points can be introduced as thresholds (arrowhead). The high point is considered to be the distinguishing landscapes between self-sustaining and near final goal, and the points below this point are at risk of intensifying erosion (Noymeir, 1973; Tongway and Hindley, 2004b; Bastin, 2005; Rezaei et al., 2006; Shahriary et al., 2018).

In this regard, the distance about 1000 m from the salinity center (lake) can be defined as an ecological threshold through which changes occur suddenly. At these thresholds, the functional differences of the habitat are greater than the areas between the thresholds, and in order to control and stabilize the dust centers, different projects such as drainage, wind-breaks or dense vegetation cover are necessary to stabilize these thresholds. In such a case, the native vegetation cover in intervals between the two thresholds will be able to regenerate by seed bank and prevent the soil surface from wind erosion if the grazing is prevented. In this regard, in a study conducted by Sheidai-Karkaj et al. (2022) to determine changes in deposited dung in various grazing intensity zones as well as to find any possible pattern between accumulated dung and distance from the watering point in plain rangeland of Inche-Shourezar in North of Iran, five zones at distances of 50, 150, 350, 650, and 1050 m from the watering point were selected. A declining trend was found in moving from the center to the further zones; therefore, it is necessary to decrease livestock concentration around socialization points to avoid rangeland degradation. Quadratic regression was the best fitted model for distance and dung number (r^2 = 0.91) while cubic regression was fitted significantly for distance and dung weight (r^2 = 0.90). The finding of that research confirmed that grazing gradient and dung deposition don't necessarily follow a linear way while specifically, the dung number parameter showed a more realistic spatial distribution and more coefficient of determination than dung weight.

It seems that identifying threshold as a transition zone and the interval zones between thresholds as state zones in this study will be a scientific and appropriate alternative to the conventional guidelines in executive agencies and will help to zoning according to nature. It will help to select development sites in saline habitat. According to the results, the structural and functional characteristics of the habitat can be used as a tool in the management of saline habitats and dust centers (Munro et al., 2012). Similar to ecosystem function, by moving from the salt spot to the further sites, the amounts of soil properties are changed. This finding confirms the acceptability of LFA method in studying the variation of ecosystem properties and distinguishing the thresholds in the salt lands.

Ethical Approval
This manuscript does not report on or involve the use of any animal or human data or tissue. So the ethical approval does not applicable.

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