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Spatial and Temporal Zoning of Some Chemical Properties of Orumieh Lake Coastal Soils

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Abstract

In recent years, the effects of microgrids and wind erosion on the salt beds of Lake Urmia have affected its coastal lands. Therefore, the spatial and temporal zonation of some of the chemical properties of the coastal soils of the lake were determined in the Makookandi area, which is located in the WindRose direction of the lake. For this purpose, in September 2016 and June 2017, 36 soil samples were collected from 0 cm to 20 cm and 20 cm to 40 cm depths of the study area and then electrical conductivity of soil saturation extract (ECe), Total Dissolved Solids (TDS), acidity (pH) and Sodium Adsorption Ratio (SAR) all of them were determined. Land zoning maps were prepared based on ECe and SAR values using ArcMap software. The land zoning maps over the past two years have shown that ECe and SAR soils in the area have changed dramatically and their surface coverage has expanded. The highest values of ECe and SAR variations were observed in the proximity of the lake shore (boundary between land and dry lake bed). Six interpolation methods were used in the production of zoning maps and the conventional Kriging method was selected as the most appropriate method with the least amount of error compared to other methods. Also the results showed that the land area with ECe more than 20 dS/m in the layer of 20 cm to 40 cm and with SAR more than 93 mmol/l in the layer of zero to 20 cm of soil in 2017 compared to 2016 increased by 35.31% and 23.77%, respectively. Therefore, changes in the percentage of land area based on salinity and alkalinity of different soil layers in terms of temporal increase and spatial distribution were significant, which is a major threat to agricultural and environmental production.

Keywords: Zonalization; Soil saturated extract; Kriging; MakooKandi; Sodium adsorption ratio; Electrical conductivity

Introduction

Soil salinization is a global issue, especially in arid and semiarid regions with low rainfall and high evaporation. Soil salinity monitoring is of great importance from an agricultural point of view in arid and semi-arid regions. Salinity and its detrimental effects on some soil physical properties can be recognized as a major agricultural and environmental concern in different areas. An area of more than 930 million hectares, comprising 7% of the earth's surface, suffers from saline soil, which are expanding. In general, soil salinity is significantly influenced by factors such as topography, climatic and hydrological conditions of the area. Therefore, a better understanding of the causes of soil salinity can provide scientific strategies for controlling salinity in the context of sustainable agricultural management [1]. Various researchers have studied the physical and chemical properties of soils in different parts of the world using geostatistical statistics and statistical methods. Various researchers have studied the physical and chemical properties of soils in different regions of the world using geostatistical and different statistical methods. For example, in a region of Zagros in Iran, physical and chemical properties of soils in different management methods were interpolated using geostatistical and statistical methods. Also, in the Amazon basin in Brazil, geostatistical methods were used to determine the soil characteristics of suitable areas for pasture construction. In addition, in Naghadeh region of Iran, variations of ECe, pH and particulate matter such as clay and sand distribution of soil were investigated using geostatistical methods and conventional Kriging interpolation (OK) method was used to estimate the data and the results showed that exponential semivariograms, spherical and Gaussian were the best fit [2].

The continuation of the drying process of Lake Urmia and the transfer of its dried bed solids to the surrounding lands, the process of salinity and the alkalinity of soils have intensified in recent years and can cause irreparable damage to agricultural lands in the region. Therefore, the study of temporal variations of soil chemical properties such as their spatial variability in the coastal soils of Lake Urmia affected by micro grids and wind erosion of salts in its bed in terms of its impact on crop yield and status the future environment of the region is essential. In this regard, mapping of coastal agricultural lands (MakooKandi area, west of the lake) in terms of temporal and spatial variations of some soil chemical properties was the aim of this study, providing accurate and comprehensive information, can be effective in finding suitable solutions to prevent the increase of salinity and alkalinity in the soils of the region [3].

Materials and Methods

Aiming at spatial and temporal zonation of some soil chemical properties of the coastal lands of Urmia lake (the boundary between the land and the dry lake bed), an area that is dominated by the

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prevailing winds from lake to land and affected by salt marsh erosion was accumulated in the lake bed, was selected. This area is part of the coastal lands of Lake Urmia with an area of 352 ha, located in the geographical range of 37° 49′ 22" to 37° 49′ 48" N and 45° 3′ 35" to 45′ 2′ 16" E in West Azerbaijan Province. It has an average elevation of 1300 meters above sea level and has agricultural land and useless land. The rainy season begins in late October and late November and lasts through June. The average rainfall period in the region was about 93 days, with average rainfall in this period and in the long run averaging 360 mm and 283.1 mm, respectively [4]. Soil sampling was carried out on the basis of regular meshing with grid of 400 meter. The location of soil sampling at each node of the mentioned network was determined by GPS and in the first year and second year 36 soil samples were prepared from 0 cm to 20 and 20 cm to 40 cm horizons. Schematic view of the geographical location of the study area (MakooKandi region west of Lake Urmia) on the Iranian map with 18 points schematic view in three rows of soil sampling from shore (boundary between land and dry lake bed) to the land is shown in Figure 1, in which P1, T1 and F1 are the nearest and P6, T6 and F6 are the farthest points from Urmia Lake.

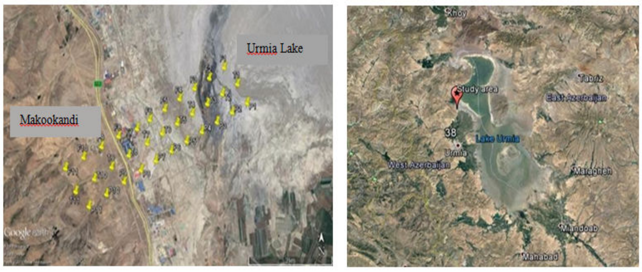

Figure 1: Geological situation of the studied area and sampling points.

The soil samples were transferred to the laboratory after collection, dried in open air, crushed and passed through a 2 mm sieve [5]. Soil texture of all the studied sites was determined by hydrometric method. Measurements showed that points P1, P2, P3, T1, T2 and F1 had heavy texture and the rest had medium texture. The electrical conductivity of the saturation extract (ECe) of soil samples was measured using a conductivity meter and then the soluble solid particles (TDS) in the saturated extract of the soil were determined and their acidity was measured by a pH meter. Soil salinity class was determined by SCS classification method [6]. The amounts of sodium, calcium and magnesium in the samples of soil saturated extract were read by Ion chromatography. Sodium Saturation Ratio (SAR) of soil saturated extract was calculated according to the method described in Esther and Garrison. In this study, geostatistical methods were used for spatial and temporal zonation of some soil chemical properties in a part of the lands adjacent to Urmia Lake (Makookandi region). Determining correlation and spatial variability using geostatistical methods requires calculating spherical, Gaussian, exponential and circular models were considered to evaluate variograms [7]. In this method, by analyzing spatial continuity and temporal variations, variations of the investigated characteristics were analyzed. For this purpose, comparison between Kriging, inverse distance weighted, general polynomials and local polynomials was performed using statistical criteria and the appropriate method was selected [8].

A cross validation technique was used to compare the methods and selected the most suitable geostatistical method. So that at each stage one observation point was eliminated and the rest was estimated using the rest of the points. This was repeated for all observation points until to obtain the estimated number of observation points. Then the statistical indices of Mean Error (ME) and Mean Square Error (RMSE) were calculated according to the following equations, respectively [9,10].

$$ME = 1/n\sum_{i=1}^{N}[Z^*(X_i) - Z(X_i)]$$

$$RMSE = \sqrt{1/n}\sum_{i=1}^{N}(Z - Z^*)^2$$

In these equations, Z^* (xi) is the estimated value at point i and Z (xi) is the observed value for point i.

Results and Discussion

The statistical description of the investigated indices is shown in Table 1. According to the results of this table, the mean soil salinity in the studied lands for the 0 cm to 20 cm layer in 2016 and 2017 were 15.54 and 57.57 and for the 20 cm to 40 cm layer in these years were 11.35 dS/m and 33.17 dS/m, respectively. Since ECe of 4 dS/m and SAR of 13 meq/L are the threshold boundary between saline and non-saline and sodium and non-sodium, respectively, soils of the study area was highly saline and sodium based on the mean values of ECe and SAR at depths of 0 cm to 20 cm and 20 cm to 40 cm. In the studied soils, the pH varied from slightly acidic (6.95) to alkaline (8.54) at two years, which did not restrict crop production.

Properties	Unit	Year (layer)	Minimum	Maximum	Mean	STDEV	CV (%)
ECe	dS/m	2016 (0-20)	0.3	59.25	15.54	21.69	1.39
TDS	mg/L	2016 (0-20)	0.15	34.3	8.97	12.55	1.39
pH	-	2016 (0-20)	7.3	8.47	7.82	0.3	0.03
SAR	meq/L	2016 (0-20)	0.06	141.46	43.18	52.52	1.21
ECe	dS/m	2017 (0-20)	0.75	179.4	57.57	60.45	1.05
TDS	mg/ L	2017 (0-20)	0.48	114.81	36.84	38.68	1.05
pH	-	2017 (0-20)	6.95	8.4	7.61	0.51	0.06

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SAR	meq/L	2017 (0-20)	0.63	302.52	87.51	86.49	0.98
ECe	dS/m	2016 (20-40)	0.28	57.21	11.35	16.81	1.48
TDS	mg/L	2016 (20-40)	0.14	35.1	6.59	9.94	1.5
pH	-	2016 (20-40)	7.39	8.4	7.91	0.27	0.03
SAR	meq/L	2016 (20-40)	0.79	111.1	33.85	38.02	1.12
ECe	dS/m	2017 (20-40)	0.62	78.1	33.17	31.59	0.95
TDS	mg/L	2017 (20-40)	0.39	49.98	21.23	20.21	0.95
pH	-	2017 (20-40)	7.15	8.54	7.8	0.44	0.05
SAR	meq/L	2017 (20-40)	1.11	115.53	57.97	48.74	0.84
Note: ECe: The electrical conductivity of the saturation extract; TDS: Total soluble solids; pH: acidity and SAR: Sodium Adsorption Ratio							

Table 1: The range of changes in some of the chemical properties of the studied soils.

The ECe changes in the rows P, T and F are shown in Figure 2. As seen in the diagrams, the ECe of the coastal soils of the area increased significantly in the year 2017 compared to the year 2016 and this increase was greater in the areas near the shore of the lake than in the remote areas. The increase in salt in the lake shores has been due to the wind erosion of the salts of the dried lake bed [11]. In the surface layer of 0 cm to 20 cm of soil, the ECe was greater than that of the soil layer of 20 cm to 40 cm, due to the presence of an external source of salt (Lake Urmia bed) which was added to the upper part of the soil by the wind erosion. The amount of ECe in the areas further off Lake Urmia (points P5, P6, T5, T6, F5 and F6) was less than 4 dS/m, which was non-saline in accordance with US salinity labratorya staff criteria. Whereas in the nearest lake shores (P1 to P3, T1 to T3 and F1 to F3) the ECe content was higher in both years and in both layers, especially in the 0 cm to 20 cm layer, such that in 2016 and 2017 the averages were 60 dS/m and 180 dS/m, respectively. Thus, in studies, the existence of spatial correlation of soil salinity has been reported [12]. Although decreasing salinity from the seashore to the land had an increasing trend, some variations were observed due to changes in soil texture and as well as could may be depended on topographic status of the soil, coefficient of surface roughness and other effects on the surface.

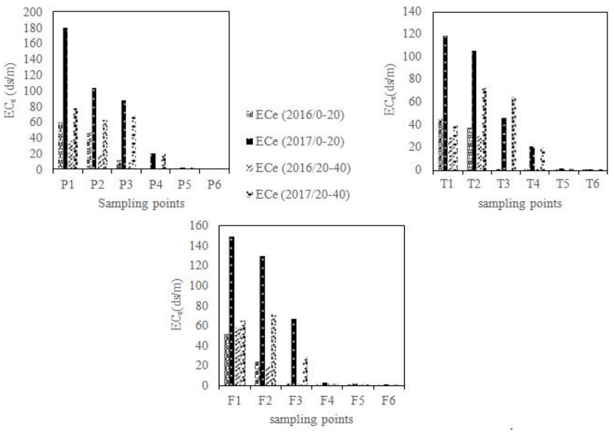

Figure 2: The electrical conductivity of the soil saturated extract (ECe) at the sampling points at depths of 0 cm to 20 cm and 20 cm to 40 cm soil meters for two consecutive years 2016 and 2017.

As shown in Figure 3, soil acidity did not change significantly in the two years sampled and in the two soil layers. In the study area, soil response was less than other variables and was in alkaline range. In region of Urmia, based on soil decomposition before planting, soil pH was reported to be 7.6. Temporal and spatial changes of some soil quality characteristics have been evaluated and it is concluded that soil properties exhibit large variations and the lowest coefficient of variations in soil pH has been observed [13].

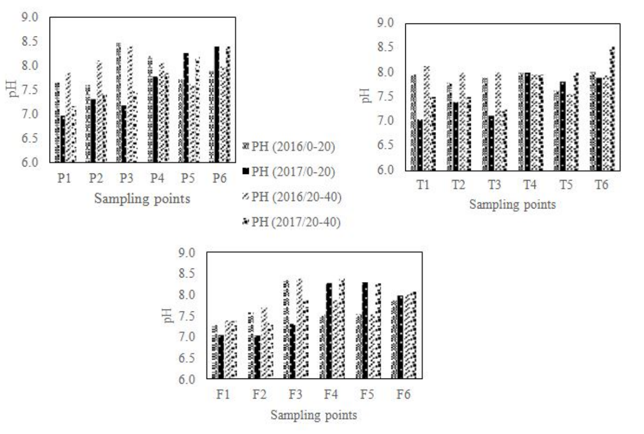

Figure 3: The pH at the sampling points at depths of 0 cm to 20 cm and 20 cm to 40 cm soil meters for two consecutive years 2016 and 2017.

The results of the changes in the SAR of the saturated soil extract are shown in Figure 4. As seen in the figure, the highest amount of sodium adsorption ratio (302.52 meq/L) was at point P1 in the surface layer of 0 cm to 20 cm soil nearest to the lake in the year 2017 and the lowest was at sea level, it was 0.11 meq/L related to the T6 point in the surface layer of 0 cm to 20 cm soil at the farthest point from the seashore. The spatial and temporal variations of SAR were similar to the salinity of soil saturated extracts and increased in 2017 compared to 2016, As the lake shore toward land declined every two years. Since the chemical constituents of Lake Urmia shale are sodium-chloride-sulfate type, the coastal lands of Urmia Lake are exposed to sodium

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[14,15]. Investigation of salinity class of the soils of the study area with respect to ECe, SAR and pH values in both layers of 0 cm to 20 cm and 20 cm to 40 cm using SCS classification method showed that the points near the lake, saline-sodium and farther points were common, this reflects the impact of seagrasses and wind erosion on seafloor salts in coastal crop lands.

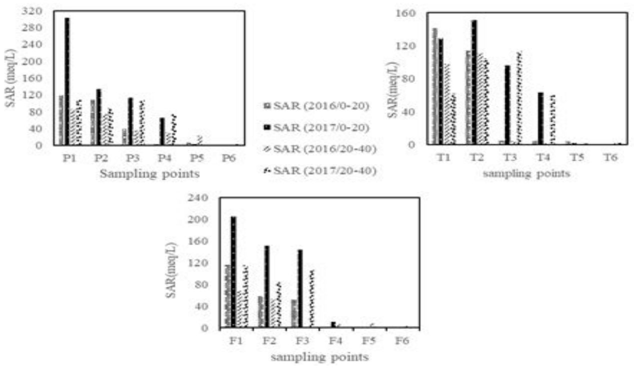

Figure 4: The Sodium Adsorption (SAR) at the sampling points at depths of 0 cm to 20 cm and 20 cm to 40 cm soil meters for two consecutive years 2016 and 2017.

The results of fitting the best semivariogram model for qualitative indices are presented in Table 2. The best fitted semivariogram was identified spherical for most semivariograms. It seems that the high amplitude of the effect on the investigated properties is due to the high dependence between the samples. In the present study, strong spatial dependence of the studied parameters may be due to the effect of eroded salts from the dried bed of Urmia Lake in the region. It may be caused by inherent soil changes and poor spatial dependence by non-inherent soil changes [16]. On the other hand, spatial correlation is strongly affected by the scale in each study and due to the small sampling scale in this study the properties of the study showed strong spatial dependence. In a study in Golestan province, the ECe and pH of soil samples were collected identified by interpolating Kriging with a spherical model semivariogram. Also, a spherical model was selected for surface soil characteristics. A report shows that in Oshnoyeh region located in the south of Lake Urmia, geostatistical methods were used to predict the salinity and sodium distribution of soil and it was concluded that the Kriging method with Gaussian model in places without data is of high accuracy to estimate the soil has salinity and sodium.

Soil properties	(Year/layer)	Model	Nugget effect	Sill	Range (m)	Correlation ratio	ME*	RMSE**
(ECe)	(2016/0-20)	Spherical	0	0.59	1308.08	0	0.001	0.2
(ECe)	(2017/0-20)	Spherical	0	1.2	1411.02	0	-0.001	0.25
(ECe)	(2016/20-40)	Gaussian	0.0006	0.6	2365.91	0	-0.01	0.23
(ECe)	(2017/20-40)	Spherical	0	0.36	2775.98	0	0.0009	0.25
(pH)	(2016/0-20)	Spherical	0.05	0.05	1031.75	0	0.002	0.24
(pH)	(2017/0-20)	Gaussian	0.05	0.53	2775.98	0	0.005	0.3
(pH)	(2016/20-40)	Gaussian	0.03	0.06	822.67	0.5	0.003	0.26
(pH)	(2017/20-40)	Spherical	0.01	1.02	1380.6	0.009	0.002	0.24
(SAR)	(2016/0-20)	Spherical	0	0.47	2775.98	0	-0.002	0.3
(SAR)	(2017/0-20)	Spherical	0	2.02	1443.09	0	-0.001	0.25
(SAR)	(2016/20-40)	Gaussian	0.02	0.336	1305.72	0.0009	-0.002	0.26
(SAR)	(2017/20-40)	Spherical	0	0.36	2775.98	0	0.0009	0.25

Note: ECe: The electrical conductivity of the saturation extract; TDS: Total soluble solids; pH: acidity and SAR: Sodium Adsorption Ratio; *, ** for ECe in dS/m, for pH without unit and for SAR in meq/L

Table 2: Semivariogram parameters for soil properties ECe, pH and SAR.

Table 3 presents the values of the ME and RMSE indices for each of the ECe, pH and SAR components [17]. According to, the results showed that the Kriging method in terms of interpolating the electrical conductivity values of saturated extract, acidity and soil sodium adsorption ratio showed better performance with respect to IDW, LPI and GPI methods according to the mean squared error parameter. Therefore, according to the results of this table, the conventional Kriging (OK) method, a suitable and accurate method for estimating and zoning the measured components, was determined. A number of researchers have suggested that Kriging interpolation is a more appropriate method for estimating components and their zoning. Soil properties in an area of 4 hectares of land of the research center of the university of Pisa in Italy have been spatially analyzed using Kriging method and high variability has been observed in its main characteristics [18]. It is concluded that no method other than geostatistical methods can produce continuous soil properties maps. The zoning maps of the study area based on ECe characteristics for the

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years 2016 and 2017 are shown for the 0 cm, to 20 cm layer in Figure 5 and for the 20 cm to 40 cm soil layer in Figure 6. As seen in these figures, the highest salinity was near the shore (the boundary between the land and the dry lake bed) and in a layer of 0 cm to 20 cm of soil, making these sites more accessible to salts and wind erosion. The salts were from the lake, while the salts were affected by the farther shores and the 20 cm to 40 cm soil layer.

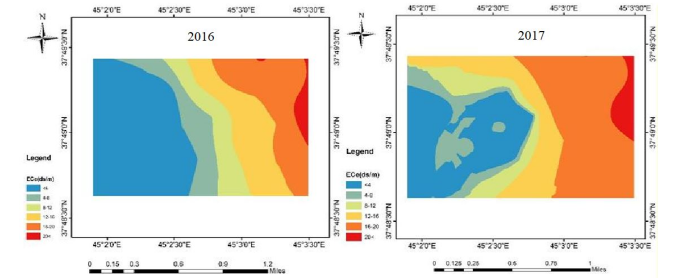

Figure 5: The zoning map of salinity of the saturated extract (ECe) of the 0 cm to 20 cm of soil layer in the 2016.

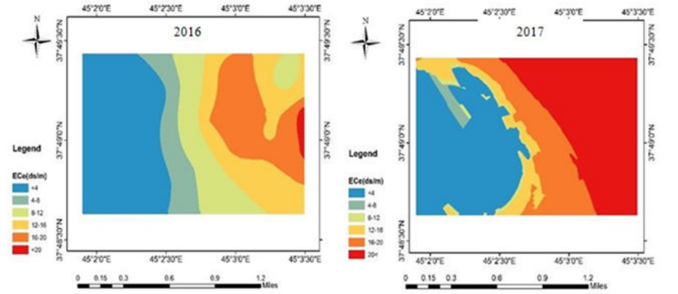

Figure 6: The zoning map of salinity of the saturated extract (ECe) of the 20 cm to 40 cm of soil layer in the 2016 and 2017.

Soil properties	(Year/layer)	Assessment standard	LPI	GPI	IDW Power 2	Kriging		
						Disjunctive	Simple	Ordinary
(ECe)	(2016/0-20)	ME	1.67	-0.69	-1.36	-1.54	-0.26	-0.31
		RMSE	7.58	13.11	9.62	9.2	8.66	6.82
(ECe)	(2017/0-20)	ME	3.59	-1.28	-2.07	-1.88	0.05	-1.53
		RMSE	23.48	26.98	24.88	29.67	29.64	23.84
(ECe)	(2016/20-40)	ME	1.78	-0.5	-0.94	-6.77	8.78	-0.29
		RMSE	9.86	12.23	10.05	60.59	34.46	9.39
(ECe)	(2017/20-40)	ME	-1.86	0.1	0.68	0.63	1.26	-0.07
		RMSE	16.14	17.11	13.87	17.53	17.43	13.04
(pH)	(2016/0-20)	ME	-0.01	0.008	0.01	-0.0003	-0.0003	0.009
		RMSE	0.33	0.32	0.31	0.29	0.29	0.32
(pH)	(2017/0-20)	ME	0.004	-0.002	-0.01	-0.007	-0.003	0.005
		RMSE	0.28	0.3	0.29	0.31	0.3	0.3
(pH)	(2016/20-40)	ME	0.031	0.003	0.006	0.001	0.001	0.003
		RMSE	0.28	0.3	0.27	0.25	0.25	0.26
(pH)	(2017/20-40)	ME	0.01	-0.002	-0.01	0.002	0.002	0.009
		RMSE	0.24	0.23	0.23	0.24	0.24	0.22
(SAR)	(2016/0-20)	ME	4.72	-1.23	-1.86	1.15	3.58	0.21
		RMSE	20.56	28.12	22.67	20.87	19.96	17.77
(SAR)	(2017/0-20)	ME	-0.79	-1.41	-1.68	-6.06	-0.34	-3.52
		RMSE	50.3	46.39	52.02	60.26	59.93	58.34
(SAR)	(2016/20-40)	ME	0.27	-0.64	-1.35	0.28	0.46	1.25
		RMSE	17.37	22.64	18.85	14.6	13.89	19.31
(SAR)	(2017/20-40)	ME	-2.34	0.68	2.59	-0.97	-0.55	-0.23

		RMSE	30.49	31.01	28.08	33.3	33.3	28.68
Note: ECe: The electrical conductivity of the saturation extract; pH: acidity and SAR: Sodium Adsorption Ratio								

Table 3: Results of Kriging, IDW, LPI and GPI methods for estimation of soil properties in the study area.

The zoning maps of the study area based on SAR characteristics for the years 2016 and 2017 are shown for the 0 cm to 20 cm layer in Figure 7 and for the 20 cm to 40 cm soil layer in Figure 8. As seen in these figures, the SAR values indicate the critical state of alkalinity of the soils in the area with the consequences of soil structure degradation [19]. In general, the areas near the shore had high salinity and sodium content, which has been affected by the depletion of Lake Urmia in recent years. In addition to these factors, land use type is also effective in solute accumulation. At points P, T and F with varieties 3 to 6 with winter dryland wheat cultivation, salinity is lower than in other parts of the coast, which has not been due to recent drought in Lake Urmia and sudden increase in crop salinity. To make better use of the area's land, management of the area's leaching needs to be undertaken studied seasonal variations of soil salinity in an area southwest of Lake Urmia and concluded that regular Kriging (OK) has the best fit to predict salinity.

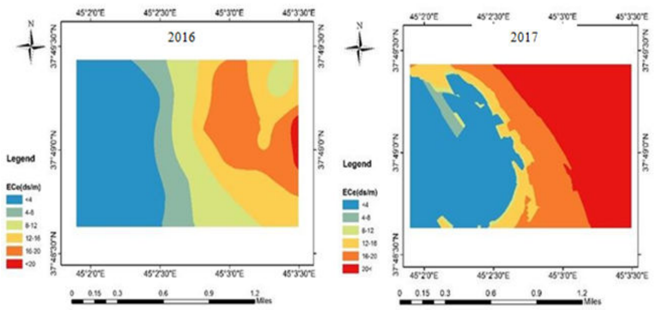

Figure 7: The zoning map of Sodium Adsorption Ratio (SAR) of the 0 cm to 20 cm of soil layer in the 2016 and 2017.

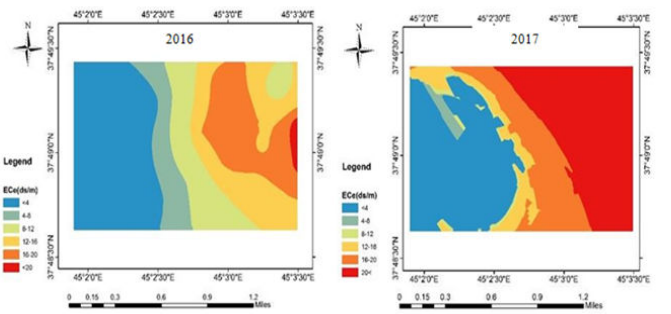

Figure 8: The zoning map of the Sodium Adsorption Ratio (SAR) of the 20 cm to 40 cm of soil layer in the 2016 and 017.

The area (%) corresponding to each of the ranges of the soil saturated extract (ECe) is shown in the zoning maps in Table 4. At the measured distance beyond the boundary between the land and the dried bed of Urmia Lake, land area with salinity less than 4 dS/m in year 2017 compared to year 2016 in layer 0 cm to 20 cm decreased by 10.68% and in range of 16 dS/m to 20 dS/m increased by 13.17%. Also, land area with salinity of more than 20 dS/m in layer 20 cm to 40 cm soil level increased by about 35.31% in the year 2017 compared to 2016. These lands were eroded and propelled by salt salts. The dried beds of Urmia Lake in the region are highly saline and sodic and have been removed from the basement. Increasing the level of saline and sodium fields in this area and transferring the abundant minerals in these areas to the adjacent lands will destroy their physicochemical properties and will cause irreparable damage to the area's agriculture, which will reduce plant yields and even exiting the area from profit lands.

ECe (dS/m)	2016/0-20	2017/0-20	2016/20-40	2017/20-40
<4	38	27.32	36.37	35.49
4-8	10.78	10.9	9.94	1.91
8-12	13.95	9.63	15.95	1.63
12-16	16.5	16.43	19.34	7.36
16-20	18.74	31.91	17.61	17.5
>20	2.02	3.81	0.8	36.11
Note: ECe: The electrical conductivity of the saturation extract				

Table 4: Percentage of land area with different ranges of electrical conductivity of soil saturated extract in the zoning maps based on 0 cm to 20 cm and 20 cm to 40 cm layers in the 2016 and 2017.

The area (%) for each of the SAR ranges is shown in the zoning maps in Table 5. As seen in the table, SAR range of less than 13 and more than 93 meq/L in the 0 cm to 20 cm layer in the year 2017 compared to the year 2016 decreased by 29.16% and increased by 23.77%, respectively. A 20 cm to 40 cm increase was also observed in the percentage of land area with SAR values exceeding critical levels. Changes in the percentage of ECe and SAR area with respect to the threshold level of saline and sodium soils in Table 6 showed that in the 0 cm to 20 cm surface layer, the increase in the level of critical over-ground in the one year under study was greater than in the 20-layer. It was 40 centimeters, probably due to low rainfall, lack of water and lack of attention to the necessary leaching category in the area.

SAR (meq/L)	2016/0-20	2017/0-20	2016/20-40	2017/20-40
<13	42.92	13.76	9.49	5.8
13-33	13.17	16.92	4.22	11.4
33-53	7.14	12.88	11.89	22.3
53-73	13.54	11.1	52.35	17.43
73-93	19.24	17.56	22.06	36.59
>93	4	27.77	0	6.48
Note: SAR: Sodium Adsorption Ratio				

Table 5: Area (%) corresponding to each of the ranges of sodium adsorption ratio of soil saturated extract in SAR zoning maps based on 0 cm to 20 cm and 20 cm to 40 cm layers in the 2016 and 2017.

Parameter	2016/0-20	2017/0-20	2016/20-40	2017/20-40
ECe>4	62.00	72.68	63.63	64.51
SAR>13	57.08	86.24	90.51	94.2
Note: ECe: The electrical conductivity of the saturation extract and SAR: Sodium Adsorption Ratio				

Table 6: Area change (%) for each SAR and ECe domain in zoning maps based on 0 cm to 20 cm and 20 cm to 40 cm layers in the 2016 and 2017.

Conclusion

This study showed that spatial and temporal variations in some of the coastal soils' chemical properties are affected by microgrids and wind erosion in the salt beds of Lake Urmia. Although, the points far away from shore of the lake in terms of the electrical conductivity of soil saturated extract (ECe) had a slight upward trend, but the points near the shore had a strong upward trend, such that in some points the ECe increased from 60 dS/m to 180 ds/m. The results of variogram analysis showed that the best fitted model for ECe and SAR for both soil layers in the both years investigated in geostatistical method for most semicircles was spherical model with the highest accuracy.

In the evaluation and accuracy of interpolation based on the values of ME and RMSE indices, conventional Kriging method with the least values of statistical indices was selected for statistical zoning. The spatial distribution of ECe and SAR showed that most of the statistics were in the vicinity. So having accurate and comprehensive information in this area can be effective in providing appropriate (scientific and practical) solutions to prevent soil salinity, reduce crop yields and even environmental consequences. Lack of attention today to this important regional and even trans-regional challenge will become tomorrow's unresolved issue.

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