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MAPPING THE SALINITY STATUS OF AGRICULTURAL SOILS BETWEEN KIRIKHAN-KUMLU IN THE EASTERN MEDITERRANEAN REGION OF TURKEY WITH GEOGRAPHIC INFORMATION SYSTEMS (GIS)

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Highlights:

- study area soils have alkalization problem towards the lower layers;
- salinity map was created with Kriging method;
- no salinity problem was found in any of the soils;
- soils of the study area vary in terms of soil properties.

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Abstract. In this study, it was aimed to determine the salinity status of agricultural soils between Kırıkhan-Kumlu in the Eastern Mediterranean region of Turkey by mapping with Geographic Information Systems (GIS). For this purpose, a total of 60 soil samples were taken from 0–20 and 20–40 cm depths and from 30 different points to represent the agricultural soils of Kırıkhan-Kumlu region in the Eastern Mediterranean region of Turkey. In the soil samples, pH, cation exchange capacity (CEC) and exchangeable cation (ECC) values were determined to determine some soil properties. Total salt, salinity class, sodium adsorption rate (SAR), exchangeable sodium percentage (ESP) and soluble cations (Na, Ca and Mg) were determined to determine the salinity status of the soils.

According to the results of the research; as a result of the analysis carried out to determine the salinity status of the soils; pH values were determined between 6.91–7.98; total salt content between 0.02–0.13%; SAR values between 0.023–0.044 me/100 gr; ESP values between 0.35–2.96%; soluble Na content between 0.019–0.034 me/100 gr; soluble Ca content between 0.018–0.245 me/100 gr and soluble Mg content between 0.037–0.113 me/100 gr. In addition, by applying the ESP-SAR regression relationship of the soils, it was revealed that the soils tended to alkalize towards the lower layers. The salinity values obtained as a result of the study were transferred to the Geographic Information Systems (GIS) environment and interpolated by Kriging method and a salinity map of the study area was created. In conclusion, as a result of the research conducted in the soils of the study area in the Eastern Mediterranean region, it was determined that all of the agricultural soils of Kırıkhan-Kumlu region were classified as non-saline and that the soils did not have any problems in terms of salinity.

Keywords: Eastern Mediterranean soils, soil salinity, GIS mapping.

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1. Introduction

Soils are known as natural dynamic entities formed by the decomposition and disintegration of rocks, also known as parent materials, and organic materials in different ways over time with the effects of chemical, physical and biological events and environmental factors (Açıkel & Yalçın, 2021). Soil is the product of interacting effects of multiple environmental controls, combined in specific geographical and historical backgrounds to produce highly improbable outcomes (AbdelRahman et al., 2022a). It has become necessary to know the chemical and physical properties of the soils very well and to apply more appropriate management measures in the face of these properties of the soils in order to be able to make production in a sustainable way in areas that are highly decreasing as a result of the use of agricultural areas for non-agricultural purposes and to utilize the soils in agricultural regions at the minimum level (Turan et al., 2010). Salinity is a soil problem caused by the accumulation of salts in the root zone of plants, especially in arid and semi-arid climatic zones and in bottom lands with drainage problems. This accumulation may be on the soil surface or below the surface due to the effect of high temperature (Akgül, 2003). Salts significantly reduce the value and productivity of the areas they affect. Soil salinity and associated problems often occur in arid and semi-arid climates where rainfall is insufficient to wash soluble salts from the soil, or where surface or subsurface drainage is limited (Koç & Kanber, 2020).

Soil salinity is one of the most important problems in limiting the yield obtained as a result of crop production in agricultural areas around the world (Awad-Allah et al., 2020). Soil salinity is a global problem that negatively affects the ecosystem and damages agricultural activities in soils around the world. In order to improve agricultural sustainability in arid and semi-arid areas going forward, it is imperative to monitor soil salinity under control (Wei et al., 2022). Soil salinity is one of the important problems that reduce plant diversity and agricultural productivity in our country as well as all over the world. A very large area in our country is affected by salinity. Insufficient rainfall and high evaporation in arid and semi-arid climate zones, inadequate drainage, agricultural processes and soil properties are the main causes of salinity. Especially in recent years, salinity problem has become more important with the effect of global climate change. Increased salinity in agricultural areas disrupts the structure of the soil and significantly limits the product quality and productivity of plants. Salt stress causes many disruptions at morphological, cellular, physiological and molecular levels as well as various developmental processes in plants (Arslan et al., 2013).

As in the world, salinity problem is observed in the agricultural lands of our country where arid and semi-arid climate is dominant. Although salinity problem is experienced around 2% of the surface area of our country, this figure is approximately 4% in the agricultural lands of the country. Salinity problem is observed in 1.518.746 hectares (ha) of our country's soil and in 837.405 hectares (ha) of land where agricultural production is carried out. In Turkey, 74% of the total wasteland is saline, 25.5% is saline alkaline and 0.5% is alkaline soils (Karaoğlu & Yalçın, 2018). The accumulation of high levels of soluble salts in soil is due to the weathering of primary and secondary minerals, the application of water containing high levels of salts, the decomposition of organic matter and fluctuations in ground water, etc. The tendency of a land to salinity depends on factors such as its location, topography, soil type and rainfall (Özdemir et al., 2019). Diagnosis of soil salinity and its spatial variability is required to establish control measures in irrigated agriculture. Soil salinity can vary temporally and spatially due to dynamic nature of soluble salts (Aboelsoud & AbdelRahman, 2017).

Rapid advances in technology have recently made it inevitable to use new systems and various methods. In line with this technological progress, people can obtain the information they need quickly and effortlessly and use this information very effectively. This has ushered in an era of scientific and technological accessibility. With this new era, people access information very quickly and as a result, new information systems are formed. In this way, innovations and developments in the areas where location-based activities are carried out have enabled the formation of Geographical Information Systems (GIS) (Yomralıoğlu, 2003). Recently, GIS has started to be used in many sectors. One of the main areas of use has been in the field of agriculture. Its use in agriculture provides very important conveniences for those working in this sector. With GIS, many problems encountered in agriculture can be solved to a great extent (Öztürk Çoşar & Engindeniz, 2011). Mapping of soil properties is vital to maintain sustainable management of soils. Using spatial analysis permits producing thematic layers of soil properties, representing a great source of data for the land use planners (Ali et al., 2019).

It is very difficult to obtain data due to the problems that occur in agricultural studies and the problems of keeping records about the work done. Therefore, it is very important to use and follow the newly developing technologies in agricultural studies and the innovations that arise as a result of this, and as a result of this, the emergence of GIS technology is inevitable. The fact that GIS technology, which is generally used in all sectors, has wide usage areas in agricultural studies provides convenience in studies at a very important level. GIS technology plays a very important role in overcoming the problems arising in the evaluation of agricultural immovables, which is one of the most important of these. Because, thanks to GIS technologies, it is very easy to store and protect agricultural data, to keep digital data in the environment and to develop new models with existing data (Karakayacı & Oğuz, 2007). Soil salinity identification is essential for soil management and reclamation projects. Information derived from space data acquisition systems (e.g., Landsat, ASTER) is considered as one of the most rapid techniques in mapping Salt-Affected Soil (AbdelRahman et al., 2022b).

In summary, the scientific significance of this study lies in its detailed investigation of soil salinity in a specific region, its comprehensive analysis of soil properties, the integration of GIS technology, and its practical implications for local agriculture. The findings contribute not only to the understanding of soil salinity in the Eastern Mediterranean but also to the broader scientific discourse on sustainable agricultural practices.

The aim of the study was to determine the salinity status of the agricultural soils of Kırıkhan-Kumlu region, which is located in the Eastern Mediterranean region of Turkey, which is one of the important agricultural problems, and to contribute to the agriculture of the region by mapping the salinity status of the soils with the help of GIS.

2. Material and method

2.1. Material

2.1.1. Location and climate

Hatay Province is located in the south of Turkey, on the eastern shores of Iskenderun Bay. It is surrounded by the Mediterranean Sea from the west, Syria from the south and east, Adana from the northwest, Osmaniye from the north and Gaziantep from the northeast. Hatay consists of the districts of Antakya, Altınözü, Arsuz, Belen, Defne, Dörtyol, Erzin, Hassa, İskenderun, Kırıkhan, Kumlu, Payas, Reyhanlı, Samandağ and Yayladağı. Its surface area is 5,524 km^2 excluding lakes, and 46.1% of the provincial territory is mountains, 33.5% is plains and 20.4% is plateaus (Anonymous, 2020).

Kırıkhan-Kumlu districts of Hatay province, where the study area is located, and its surroundings have Mediterranean climate characteristics (Table 1). The province has a characteristic Mediterranean climate with hot and dry summers and mild and rainy winters. In Hatay, where annual temperature averages vary between 15.1–20.0 °C, monthly temperature averages reach the highest values in summer and the lowest values in winter. The winter season is mild and receives abundant precipitation. The highest annual average temperature values were determined as 44.6 in July, while the lowest temperature was determined as –11.8 in January. The coldest season in Hatay is winter with an average temperature of 4.7 ºC. The hottest season in the research region is summer with an average temperature of 32.0 ºC. The average temperature in the spring season is 17.2 ºC and 20.8 ºC in the fall season (Anonymous, 2021).

Table 1. Climate data of the study area in Kırıkhan-Kumlu region

Months	Max ºC	Min ºC	Average ºC
January	12.3	4.6	8.3
February	12.7	4.9	8.4
March	19.2	9.7	14.2
April	22.2	11.5	16.5
May	28.2	15.4	21.8
June	28.5	19.4	23.6
July	31.5	24.0	27.2
August	33.0	24.4	28.1
September	33.6	23.1	28.0
October	30.6	17.3	23.5
November	20.2	10.4	14.7
December	15.0	7.0	10.7
ANNUAL	28.7	17.1	22.5

2.1.2. Geology and hydrogeology

Hatay province, where the research was conducted, has continued its development on different geomorphologic units since its foundation, where geomorphologically different landforms are found. From the ancient period to the present day, the city area has mostly spread on terraces located at various elevation levels (Özşahin, 2011).

Since Hatay province and its surroundings are subjected to intense tectonism, it shows diversity in terms of landforms. The main landforms consist of mountains, plateaus and plains. The most important mountainous area is the Amanos Mountains, which rise like a barrier between the graben area in which the Amik plain is located and the Mediterranean Sea and extend in the northeast-southwest direction (Anonymous, 2020).

2.1.3. Pedology and particle size distribution of soils

The research area is located in the middle of the Amik Plain. Tectonic movements were more effective in shaping the morphological structure of Kumlu and its surroundings. Since the Amanos Mountains broke and rose to form horst areas and the Amik Plain collapsed to form graben areas, Kumlu was located on the graben area (Geçen & Bingöl, 2019). Inceptisol, andisol, entisol and alfisol soil types were formed in the soils of the study area depending on structural features, geomorphological factors, climate and vegetation cover. The soils have silty-clay textures, slightly alkaline pH, contain varying amounts of lime and have no sodic problems. Soils were very rich in exchangeable K, but insufficient in exchangeable Ca, Mg and organic matter (Atasoy, 2017).

2.1.4. Spatial analysis

The analysis results obtained from the study area were transferred to the computer environment using Geographic Information Systems (GIS) software to create the salinity map, and the necessary After digitization processes, the digitized data obtained in accordance with the objectives of the study. The data was modified for the purpose of use with ArcMap-ArcGıs 10.3, one of the GIS software by editing it. In this study, the spherical model suitable for the semivariogram model was used in all data that show variability due to distance and in the mapping of Geographic Information Systems. Mapping was performed in the spherical model using the semivariogram model suitable for the kriging method on the sampling at equal intervals taken with a distance of 5×5 (km) throughout the entire sampling study area. As a result of the application of the formula, the values are between –1 and +1. The accuracy value is increased by applying Threshold for the result obtained. In this study, a Threshold value of 0.40 was used.

2.2. Method

In the study, a total of 60 soil samples were duly taken from 30 different points and two different depths (0–20 and 20–40 cm) according to the agricultural soils of Kırıkhan-Kumlu region located in the Eastern Mediterranean region of Turkey (Figure 1; Table 2). The soil samples were brought to the laboratory on the same day, air-dried in the shade and sieved through a 2 mm sieve to prepare them for analysis. Total soluble salt was determined by measuring electrical conductivity with the help of an electrical conductivity meter in the saturation sludge extract method and pH was measured with a glass electrode pH meter in the saturation sludge extract method (Rhoades et al., 1999). The soluble cations (Na, Ca and Mg) of the soils were determined from the saturation sludge extraction filtrate (Richards, 1954).

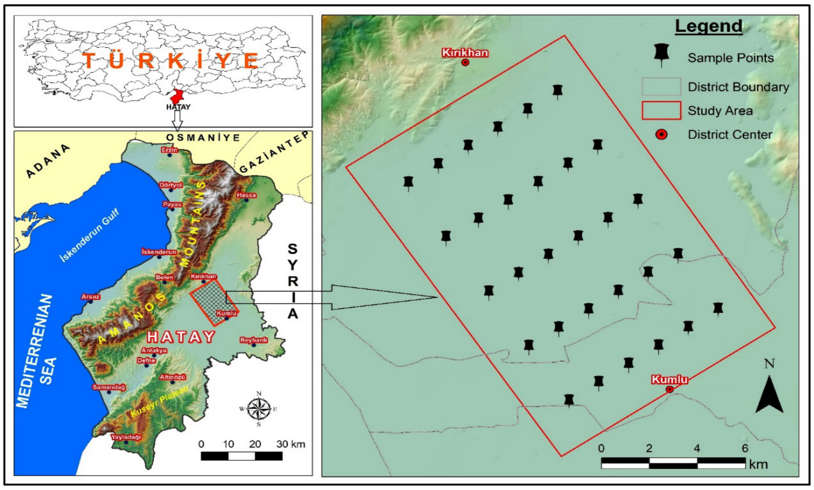

Figure 1. Representation of the soil samples on the map of the Eastern Mediterranean region of Turkey (Distance between points 5×5 km)

Cation exchange capacity (CEC) was determined by sodium acetate (1N pH:8.2) extraction method (Rhoades, 1982) and exchangeable cations (ECC) were determined by ammonium acetate (1N pH:7.0) extraction (Knudsen et al., 1982). Exchangeable sodium percentage (ESP) values were calculated by the equation ESP = (Na/KDK) * 100 (Bower, 1959). Sodium adsorption rate (SAR) is calculated by the equation SAR = $Na/\sqrt{(Ca+Mg)/2}$ (Richards, 1954). Correlation analyses between soil properties and salinity were performed using SPSS 17 statistical program (Düzgüneş et al., 1987).

3. Results and discussion

3.1. Some properties and salinity status of soils in the study area

The results of some properties and salinity status of the soils representative of the agricultural soils of Kırıkhan-Kumlu region located in the Eastern Mediterranean region of Turkey are given in Table 3. The lowest pH content of the soils of the research area was 7.95 and the highest pH content was 8.40. While the average pH content of the soil samples at 0–20 cm depth was 8.13, it was 8.14 in the samples at 20–40 cm depth and 8.14 was found on average at two depths. The pH contents of the soil samples were found to be slightly alkaline according to the limit values given by Eyüboğlu (1999) (Table 3). In the study conducted in the same region, Yalçın and Çimrin (2021a) determined the pH content of the soils between 7.57–8–26 values in a study aiming to determine the nutrient status of the soils of Kırıkhan-Reyhanlı region of Hatay province and their relationship with some soil properties and presented parallel results.

The lowest salt content of the soils of the study area was 0.009% and the highest salt content was 0.115%.

Table 2. Locations of soil samples

Soil Number	Sample Place	N/E with GPS Coordinates	Soil Number	Sample Place	N/E with GPS Coordinates
1	Reşatlı	(54.2910–40.3829)	16	Özkızılkaya-1	(54.4676–40.3183)
2	İçada-1	(54.2162–40.3762)	17	Özkızılkaya-2	(54.3927–40.3116)
3	İçada-2	(54.1415–40.3696)	18	Kumlu-1	(54.3178–40.3049)
4	Karadurmuşlu-1	(54.0667–40.3629)	19	Kumlu-2	(54.9522–40.2931)
5	Karadurmuşlu-2	(53.9920–40.3563)	20	Kumlu-3	(54.8536–40.2898)
6	Torun	(53.9172–40.3496)	21	Akkerpiç-1	(54.7549–40.2866)
7	Baldıran-1	(54.5006–40.3614)	22	Akkerpiç-2	(54.6562–40.2833)
8	Baldıran-2	(54.4258–40.3547)	23	Akkuyu	(54.5575–40.2800)
9	Muratpaşa-1	(54.3511–40.3481)	24	Kumlu-4	(54.4588–40.2767)
10	Muratpaşa-2	(54.2763–40.3414)	25	Kumlu-5	(54.9716–40.2481)
11	Güventaş-1	(54.2016–40.3348)	26	Kumlu-6	(54.8717–40.2477)
12	Güventaş-2	(54.1268–40.3281)	27	Kumlu-7	(54.7718–40.2473)
13	Kangallar-1	(54.6923–40.3383)	28	Muharrem	(54.6719–40.2468)
14	Kangallar-1	(54.6174–40.3316)	29	Kırcaoğlu-1	(54.5720–40.2464)
15	Kangallar-1	(54.5425–40.3250)	30	Kırcaoğlu-2	(54.4721–40.2460)

Table 3. Some soil properties and salinity values of the agricultural soils of Kırıkhan-Kumlu region in the Eastern Mediterranean region of Turkey

Soil Number	Depth (cm)	pH	Salt (%)	ESP	SAR	Exchangeable Cations		CEC	Salt Class	Soluble Cations me/100 g		
						Na	K			Na	Ca	Mg
1	0–20	8.31	0.031	1.19	0.04	0.49	0.31	41.17	Saltless	0.52	27.79	15.60
	20–40	8.24	0.027	1.09	0.04	0.47	0.31	43.39	Saltless	0.57	28.00	15.78
2	0–20	8.10	0.027	0.88	0.03	0.31	0.42	35.74	Saltless	0.31	15.69	8.80
	20–40	8.14	0.025	0.73	0.03	0.27	0.39	37.13	Saltless	0.33	19.74	10.71
3	0–20	8.14	0.025	0.72	0.02	0.30	0.47	42.26	Saltless	0.33	27.58	15.44
	20–40	8.10	0.032	0.69	0.03	0.30	0.45	43.04	Saltless	0.33	23.03	13.98
4	0–20	8.40	0.023	1.29	0.02	0.29	0.14	22.26	Saltless	0.32	28.00	15.77
	20–40	8.39	0.023	1.32	0.02	0.30	0.12	22.74	Saltless	0.30	26.18	13.71
5	0–20	7.99	0.043	1.20	0.05	0.86	0.53	71.48	Saltless	0.95	56.70	30.47
	20–40	8.02	0.059	1.17	0.06	0.85	0.52	72.83	Saltless	1.05	53.90	28.78
6	0–20	8.34	0.015	0.70	0.02	0.21	0.41	29.39	Saltless	0.25	27.16	14.97
	20–40	8.28	0.013	0.69	0.02	0.21	0.44	30.00	Saltless	0.22	31.36	17.29
7	0–20	8.02	0.033	0.72	0.02	0.27	0.75	38.30	Saltless	0.30	38.08	19.54
	20–40	8.02	0.032	0.52	0.01	0.21	0.70	40.22	Saltless	0.21	34.23	19.05
8	0–20	7.98	0.104	4.92	0.15	1.79	0.38	36.35	Saltless	2.00	29.05	16.23
	20–40	7.95	0.109	5.80	0.16	2.16	0.41	37.26	Saltless	2.35	36.05	19.77
9	0–20	8.03	0.033	0.45	0.02	0.31	0.73	69.78	Saltless	0.32	53.41	28.15
	20–40	8.02	0.058	0.49	0.02	0.32	0.71	64.65	Saltless	0.33	47.46	27.30
10	0–20	8.06	0.050	0.91	0.02	0.29	0.37	31.83	Saltless	0.29	29.33	16.37
	20–40	8.13	0.041	0.92	0.02	0.28	0.36	30.78	Saltless	0.28	35.77	19.23
11	0–20	8.18	0.032	1.04	0.04	0.47	0.62	45.30	Saltless	0.50	29.82	16.77
	20–40	8.16	0.051	1.29	0.04	0.58	0.60	45.30	Saltless	0.61	38.92	20.48
12	0–20	8.06	0.033	0.82	0.02	0.38	0.93	45.96	Saltless	0.40	43.54	23.36
	20–40	8.10	0.033	0.93	0.03	0.50	0.93	53.17	Saltless	0.50	42.28	22.12
13	0–20	8.05	0.057	1.54	0.06	0.84	0.84	54.35	Saltless	0.92	40.67	20.93
	20–40	8.13	0.044	1.47	0.06	0.89	0.79	60.74	Saltless	0.95	44.87	24.73
14	0–20	8.08	0.046	2.09	0.06	0.95	0.70	45.61	Saltless	1.04	44.10	24.03
	20–40	8.09	0.059	1.70	0.06	0.91	0.71	53.65	Saltless	1.01	44.59	24.54
15	0–20	8.04	0.054	6.01	0.24	3.31	0.66	55.09	Saltless	3.67	36.82	19.88
	20–40	8.00	0.059	5.09	0.20	2.74	0.64	53.78	Saltless	3.15	40.67	20.95
16	0–20	8.20	0.043	3.29	0.10	1.60	0.96	48.57	Saltless	1.83	49.49	27.30
	20–40	8.22	0.081	3.16	0.10	1.60	1.00	50.43	Saltless	1.84	50.05	27.47
17	0–20	8.31	0.057	1.35	0.05	0.76	0.78	56.09	Saltless	0.89	53.41	28.04
	20–40	8.32	0.052	1.34	0.05	0.80	0.80	59.70	Saltless	0.93	52.64	27.84
18	0–20	8.32	0.020	1.48	0.04	0.60	0.49	40.13	Saltless	0.68	46.41	25.80
	20–40	8.28	0.021	1.44	0.04	0.58	0.50	40.17	Saltless	0.69	45.36	25.10
19	0–20	7.99	0.069	4.68	0.13	1.88	0.53	40.13	Saltless	2.27	46.13	25.63
	20–40	8.11	0.044	3.75	0.11	1.57	0.51	42.00	Saltless	1.88	46.41	25.78
20	0–20	8.07	0.066	2.94	0.10	1.27	0.42	43.22	Saltless	1.53	39.41	19.88
	20–40	8.07	0.071	3.00	0.10	1.26	0.41	41.91	Saltless	1.49	34.72	19.06

End of Table 3

Soil Number	Depth (cm)	pH	Salt (%)	ESP	SAR	Exchangeable Cations		CEC	Salt Class	Soluble Cations me/100 g		
						Na	K			Na	Ca	Mg
21	0–20	8.31	0.028	2.63	0.11	1.61	0.91	61.43	Saltless	1.99	51.59	27.38
	20–40	8.24	0.032	2.60	0.11	1.61	0.94	62.13	Saltless	1.97	47.95	26.21
22	0–20	8.10	0.062	1.74	0.07	1.06	1.14	60.74	Saltless	1.26	46.13	25.70
	20–40	8.14	0.051	2.01	0.09	1.31	1.05	64.96	Saltless	1.64	51.31	27.58
23	0–20	8.14	0.043	2.98	0.14	1.93	0.77	64.83	Saltless	2.28	43.54	23.92
	20–40	8.10	0.045	3.58	0.17	2.24	0.74	62.61	Saltless	2.66	41.23	21.47
24	0–20	8.40	0.031	0.40	0.01	0.17	0.74	42.00	Saltless	0.22	36.54	19.57
	20–40	8.39	0.025	0.67	0.02	0.29	0.74	43.26	Saltless	0.30	36.54	19.54
25	0–20	7.99	0.038	0.66	0.03	0.41	0.63	61.91	Saltless	0.46	52.36	27.80
	20–40	8.02	0.043	0.65	0.03	0.40	0.67	61.04	Saltless	0.49	52.64	27.89
26	0–20	8.34	0.065	2.56	0.09	1.38	0.55	53.96	Saltless	1.50	43.54	23.89
	20–40	8.28	0.074	3.01	0.11	1.66	0.47	54.96	Saltless	1.80	44.59	25.03
27	0–20	8.02	0.043	2.80	0.11	1.69	0.73	60.43	Saltless	1.76	43.33	23.29
	20–40	8.02	0.038	3.26	0.14	2.04	0.62	62.61	Saltless	2.22	42.49	21.95
28	0–20	7.98	0.009	0.28	0.01	0.08	1.13	28.39	Saltless	0.11	37.31	19.90
	20–40	7.95	0.016	0.25	0.01	0.08	1.16	31.83	Saltless	0.10	37.59	19.95
29	0–20	8.03	0.022	0.97	0.03	0.35	0.61	35.65	Saltless	0.42	41.51	21.53
	20–40	8.02	0.047	1.24	0.03	0.49	0.65	39.35	Saltless	0.52	42.00	21.82
30	0–20	8.06	0.076	3.32	0.16	2.26	0.84	68.00	Saltless	2.65	45.08	25.21
	20–40	8.13	0.115	3.27	0.15	2.19	0.81	66.87	Saltless	2.53	47.46	25.92
Min		**7.95**	**0.009**	**0.25**	**0.01**	**0.08**	**0.12**	**22.26**		**0.10**	**15.69**	**8.80**
Max		**8.40**	**0.115**	**6.01**	**0.24**	**3.31**	**1.16**	**72.83**		**3.67**	**56.70**	**30.47**
Aver.	**0–20**	**8.13**	**0.043**	**1.88**	**0.06**	**0.94**	**0.63**	**47.68**		**1.06**	**40.12**	**21.70**
Aver.	**20–40**	**8.14**	**0.047**	**1.91**	**0.07**	**0.97**	**0.64**	**49.08**		**1.10**	**40.67**	**22.03**
Aver.	**Gen.**	**8.14**	**0.046**	**1.93**	**0.07**	**0.98**	**0.64**	**48.50**		**1.11**	**40.26**	**21.80**

While the average salt content of the samples at 0–20 cm depth was 0.043%, it was 0.047% in the samples at 20–40 cm depth and 0.046% in the average of both depths. According to the limit values reported by Richards (1954), the % salt contents of all soil samples were determined as unsalted (Table 3). It can be said that one of the most important reasons why all of the agricultural soils of Kırıkhan-Kumlu region are in the salt-free class is that the farmers of the region use minimum chemical fertilization during agricultural activities. In a study conducted in the same region, Yalçın and Çimrin (2021b) aimed to determine the nutrient status of the soils of Arsuz district of Hatay province and their relationship with some soil properties and reported similar results by determining the total salt content of the soils between 0.013–0.033 values and revealing that all soils were in the salt-free class.

While the lowest ESP values of the soils of the research subject were 0.25, the highest ESP was determined as 6.01. While the average ESP values of the soil samples at 0–20 cm depth were 1.88, the average ESP values of the samples at 20–40 cm depth were 1.91 and the average ESP values of the two depths were 1.93 (Table 3). These results are consistent with some studies in Turkey. For example, in a study conducted in the southwest of Izmir, 30 percent of the soils were found to be slightly saline (Özcan et al., 2011). In addition, pH values in soil samples did not show a significant difference between 0–20 cm and 20–40 cm depths (Özcan et al., 2011). In another study, high soil salinity was found in some fields in Hatay province (Güngörmüş et al., 2010).

Sodium Adsorption Rate (SAR) values of the study area soils were determined as 0.01 at the lowest and 0.24 at the highest. While the average SAR values of the soils at 0–20 cm depth were 0.06, the average SAR values of both depths were determined as 0.07 in the samples at 20–40 cm depth (Table 3). In a study conducted by Erşahin et al. (2014), it was determined that SAR values were generally low in the soils of Çukurova region and most of the samples were classified as non-sodic soils and similar results were obtained. In another study by Yüksel et al.

(2011), it was found that the SAR values of soils in the Mediterranean region of Turkey were low to medium. These results are consistent with the findings of this study, which showed that the SAR values of the soil samples were relatively low.

When the cation exchange capacity (CEC) values of the research soils were analyzed, the lowest CEC value was 22.26 me/100 g and the highest CEC value was 72.83 me/100 g. The average CEC values of the soil samples at 0–20 cm depth were 47.68 me/100 g, while the average KDK value at 20–40 cm depth was 49.08 me/100 g and the average CEC value at both depths was 48.50 me/100 g. The lowest values of exchangeable cations (Na and K) were 0.08 and 0.12 me/100 g, while the highest values of exchangeable cations (Na and K) were 3.31 and 1.16 me/100 g, respectively. The average exchangeable cation (Na and K) values of the samples at 0–20 cm depth were 0.94 and 0.63 me/100 g, while the average exchangeable cation (Na and K) values at 20–40 cm depth were 0.97 and 0.64 me/100 g, and the average values at both depths were 0.98 and 0.64 me/100 g (Table 3). The CEC values determined are consistent with findings from other studies that have investigated CEC values in different soils. For example, a study conducted by Wang et al. (2020) found that CEC values of different soils in China ranged from 10 to 70 me/100 g, which is similar to the range reported in the text. A study by Mohamed et al. (2015) reported exchangeable sodium and potassium values ranging from 0.01 to 2.2 me/100 g in soils from Sudan, which is comparable to the range reported in the text. Another study by Zhang et al. (2017) found that exchangeable sodium and potassium values in soils from China ranged from 0.03 to 4.38 me/100 g, which is also consistent with the values reported in the text.

The lowest values of soluble cations (Na, Ca and Mg) of the agricultural soils of Kırıkhan-Kumlu region were 0.10, 15.69 and 8.80 me/100 g, while the highest values of soluble cations (Na, Ca and Mg) were 3.67, 56.70 and 30.47 me/100 g, respectively. The average values of soluble cations (Na, Ca and Mg) of the soils at 0–20 cm depth were 1.06, 40.12 and 21.70, while the average values of soluble cations (Na, Ca and Mg) at 20–40 cm depth were 1.10, 40.67 and 22.03 me/100 g and the average values were 1.11, 40.26 and 21.80 me/100 g (Table 3). In a study conducted by Aydemir et al. (2017), soluble cation (Na, Ca and Mg) values of soils in Erzurum region of Turkey were reported to be in comparable ranges with the data in this study.

3.2. ESP-SAR regression relationship of soils

Regression analysis showing the ESP-SAR relationship for 0–20 cm, 20–40 cm and total area (0–20 + 20–40 cm) of the agricultural soils of Kırıkhan-Kumlu region of the East-

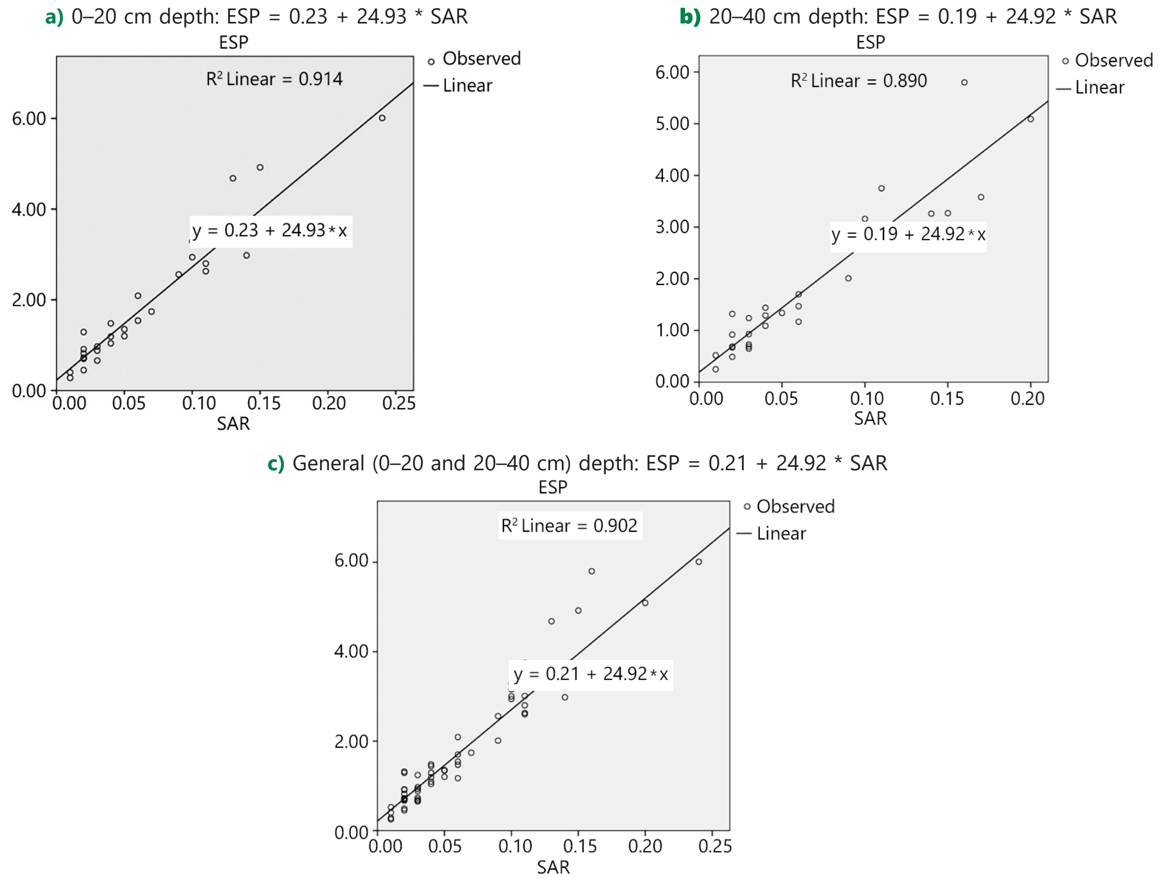

Figure 2. ESP-SAR relationships of soils: a) at 0–20 cm depth; b) at 20–40 cm depth; c) at all depths (general)

ern Mediterranean Region of Turkey (Figure 2). As a result of the comparison of the ESP-SAR equations obtained for 0–20 cm, 20–40 cm and both total depths by substituting the ESP-SAR relationship values determined for the agricultural soils of Kırıkhan-Kumlu region as ESP = Kg * SAR + b as in the y = a * x + b relationship, the Kg value of the soils at 0–20 cm depth was determined as the highest value. In the study area soils, in line with the graph in Figure 2, it is seen that the alkalization problem of the soils increases depending on the SAR value as the soils descend from the surface to the lower layers. At the same time, in the agricultural soils of Kırıkhan-Kumlu region, it was observed that soil alkalinity problem increased with the increase in SAR value. These results were found to be consistent with other studies conducted in Turkey. For example, in a study conducted by Yüksel et al. (2016), it was found that SAR values had a significant effect on soil alkalinity in Konya Plain. Similarly, in another study by Aksoy et al. (2019), it was determined that soil pH values increased with increasing SAR values in agricultural soils in Bursa.

3.3. Relationships between soil salinity and some other soil properties

The relationships between salinity and some soil properties in the study area are given in Table 4. As can be seen from the table, there is a negative significant relationship between salt content and pH content (*r:* –0.29*), while salt content and ESP (*r:* 0.67**), SAR (*r:* 0.63**), exchangeable Na (*r:* 0.63**), CEC (*r:* 0.36**), soluble Na (*r:* 0.62**), soluble Ca (*r:* 0.28*) and soluble Mg (*r:* 0.30*) (Table 4; Figure 3). In addition, a positive significant relationship was determined between ESP values and SAR (*r:* 0.95**), exchangeable Na (*r:* 0.94**) and soluble Na (*r:* 0.94**) values. However, there were significant positive correlations between SAR values and exchangeable Na (*r:* 0.99**), CEC (*r:* 0.41**) and soluble Na content (*r:* 0.99**) values. There were significant positive correlations between the exchangeable Na content of soils and CEC (*r:* 0.46**), soluble Na (*r:* 0.99**), soluble Ca (*r:* 0.31*) and soluble Mg (*r:* 0.31*) values. There was a positive significant relationship between exchangeable K content of soils and CEC (*r:* 0.46**), soluble Ca (*r:* 0.55**) and soluble Mg (*r:* 0.54**) values. There was a positive significant relationship between CEC content of soils and soluble Na (*r:* 0.46**), soluble Ca (*r:* 0.73**) and soluble Mg (*r:* 0.73**) values. A positive significant relationship was determined between soluble Na content of soils and soluble Ca (*r:* 0.32*) and soluble Mg (*r:* 0.33*). A highly significant positive relationship was determined between soluble Ca content and soluble Mg content (*r:* 0.99**). As a result of the evaluation of the relationship between the salinity status of the soils of the study area and some soil properties, it was determined that it was consistent with previous studies showing the relationship between soil salinity and soil properties. For example, Aydın et al. (2016) showed similar results by determining that soil salinity in agricultural soils was negatively correlated with pH content and positively correlated with SAR and ESP values. Similarly, in a study conducted in the Gediz River Basin, it was reported that soil salinity was positively correlated with exchangeable Na, SAR and ESP values (Keskin et al., 2007). On the other hand, in another study, the positive correlation between exchangeable Na content in soil and CEC was also reported in previous studies (Gupta et al., 2017). For example, Şenol et al. (2017) found that soil salinity was positively correlated with soil sodicity represented by ESP and SAR values in agricultural soils in the Çukurova region. Similarly, Özçelik et al. (2016) reported that soil salinity was positively correlated with exchangeable Na and negatively correlated with pH in agricultural soils of Çumra region. The positive relationship between exchangeable Na and CEC found in this study is also supported by the findings of Canbolat and Bilen (2010) on agricultural soils in Konya region.

3.4. Mapping salinity status of soils with geographic information systems

Maps prepared with GIS for the salinity values of the study area are given in Figure 4. The salt content of the agricultural soils of the Kırıkhan-Kumlu region of the Eastern Mediterranean Region of Turkey is highest in the south-eastern and south-western parts of the study area at 0–20 cm depth and is lower in the northern and east-

Table 4. Correlation coefficients (r) between salinity and some soil properties of agricultural soils of Kırıkhan-Kumlu region

	pH	Salt (%)	ESP	SAR	Exchangable Na	Exchangable K	CEC	Soluble Na	Soluble Ca
Sslt (%)	–0.29*								
ESP	–0.21	0.67**							
SAR	–0.23	0.63**	0.95**						
Exchangable Na	–0.20	0.63**	0.94**	0.99**					
Exchangable K	–0.23	0.04	–0.03	0.10	0.15				
CEC	–0.22	0.36**	0.20	0.41**	0.46**	0.46**			
Soluble Na	–0.20	0.62**	0.94**	0.99**	0.99**	0.17	0.46**		
Soluble Ca	–0.15	0.28*	0.16	0.23	0.31*	0.55**	0.73**	0.32*	
Soluble Mg	–0.13	0.30*	0.16	0.23	0.31*	0.54**	0.73**	0.33*	0.99**

Note: * Significant at 0.05 level. ** Significant at 0.001 level.

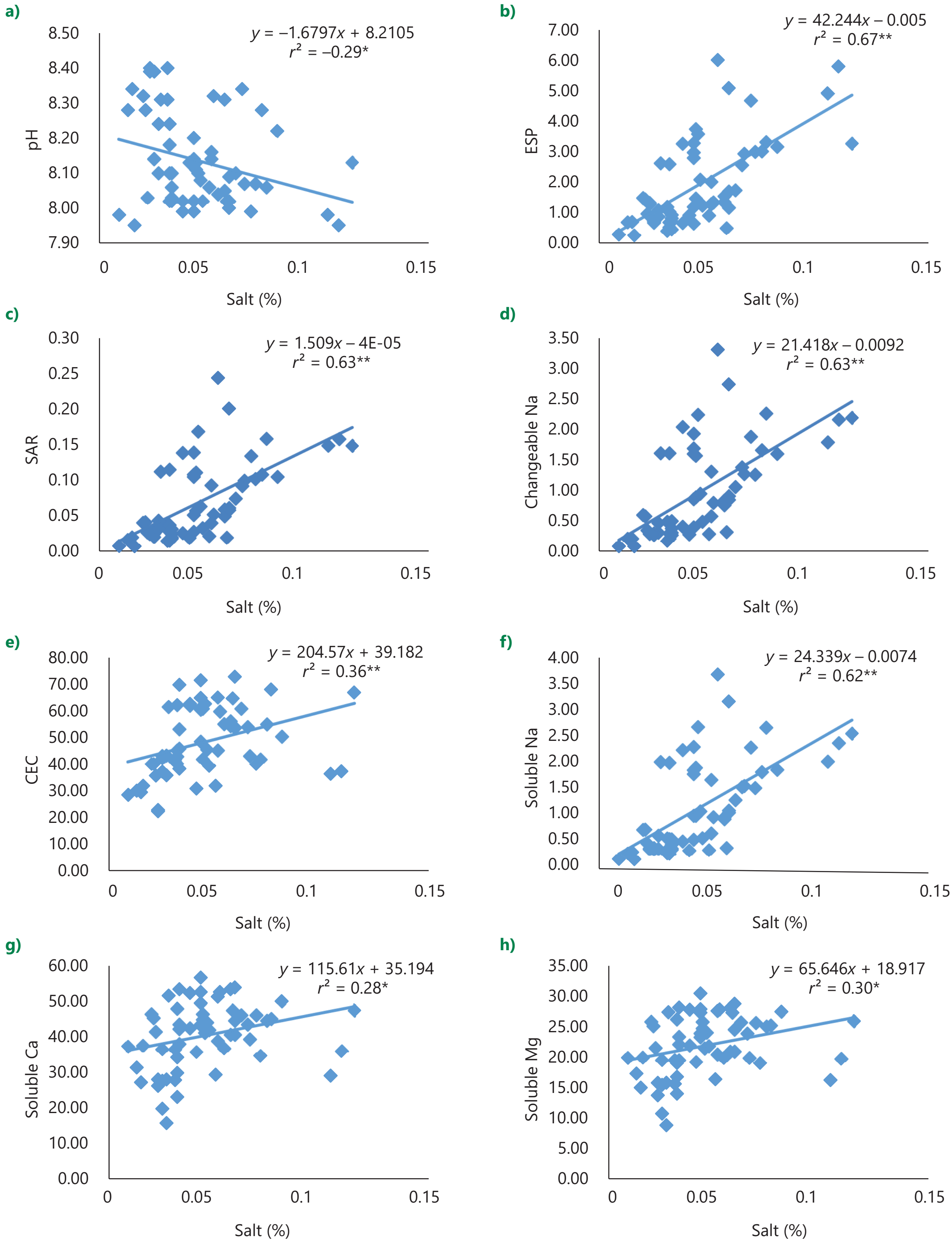

Figure 3. Relationship between salt: a) pH ($y = -1.6797x + 8.2105$ – $r^2 = -0.29$*); b) ESP ($y = 42.244x - 0.005$ – $r^2 = 0.67$**); c) SAR ($y = 1.509x - 4E\text{-}05$ – $r^2 = 0.63$**); d) exchangeable sodium ($y = 21.418x - 0.0092$ – $r^2 = 0.63$**); e) CEC ($y = 204.57x + 39.182$ – $r^2 = 0.36$**); f) soluble sodium ($y = 24.339x - 0.0074$ – $r^2 = 0.62$**); g) soluble calcium ($y = 115.61x + 35.194$ – $r^2 = 0.28$*); h) soluble magnesium ($y = 65.646x + 18.917$ – $r^2 = 0.30$*) contents of soil properties. The total number of points is 30 points for depths of 0–20 cm and 20–40 cm (60 total samples for both depths)

ern parts of the study area. The salt content of the soils of the Eastern Mediterranean region was highest in the south-eastern and inner regions of the study area at a depth of 20–40 cm, and lower in the northern and north-western parts of the study area. As it can be understood from the GIS maps, it is seen that the agricultural soils of the study area are faced with salinity problem. This situation indicates that the salts accumulated on the surface of the soil may have been formed as a result of the inability of moisture to penetrate deeper and accumulate due to the dominance of hot and arid climatic conditions and low rainfall in the study area (Şahin et al., 2016). In addition, ESP values of the soils were highest in the western and inner parts of the region at both depths of the study area and the lowest values were determined in the northern and northeastern parts of the study area. The SAR values of the soils of Kırıkhan-Kumlu region were the highest in the western and inner parts of the study area at

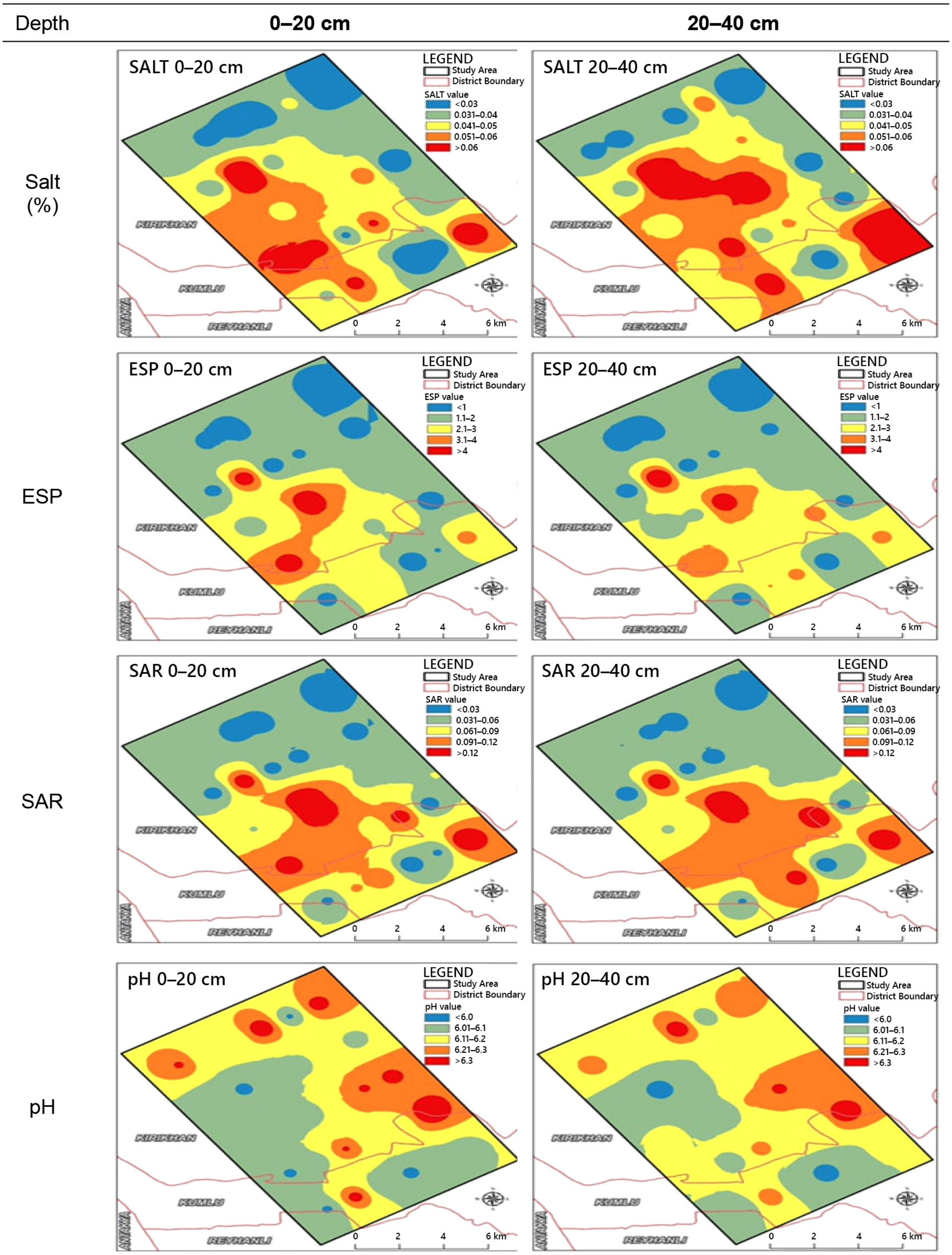

Figure 4. GIS-generated salinity maps of the common soil series of the Kırıkhan-Kumlu region of Hatay province

both depths of 0–20 and 20–40 cm, and were lower in the remaining parts of the study area, mostly in the northern parts. As a result of these data, it is supported by similar studies that the soils in the region face the problem of alkalization (Öztekin et al., 2016; Türkmenoğlu et al., 2014). The pH content of the agricultural soils of Kırıkhan-Kumlu region of the Eastern Mediterranean Region of Turkey was highest in the eastern and northern parts of the study area at 0–20 cm depth and lower in the southern and western parts of the area. The pH content was highest in the eastern and northeastern parts of the study area at 20–40 cm depth and lower in the western parts of the area. These results show that soil properties may show regional differences depending on factors such as geological structure, climate, vegetation, topography (Göktürk et al., 2019). Similar studies support these results (Öztekin et al., 2016) (Figure 4).

4. Conclusions

The salt content of the agricultural soils of Kırıkhan-Kumlu in the Eastern Mediterranean region of Turkey varies between 0.009–0.115% and in terms of salinity classification of the soils of the study area, it was determined that all of the soils were classified as non-saline. Among the soluble cations of the soils, Ca content ranged between 15.69–56.70, Mg content ranged between 8.80–30.47 and Na content ranged between 0.10–3.67. According to the results of the research, sodium adsorption rate (SAR) values ranged between 0.01 and 0.24 and exchangeable sodium percentage (ESP) values ranged between 0.25 and 6.01. The pH values of the soils of the study area were between 7.95–8.40 with a slightly alkaline reaction, the cation exchange capacity (CEC) of the soils ranged between 22.26–72.83 me/100 g, the Na content ranged between 0.08–3.31 me/100 g and the K content ranged between 0.12–1.16 me/100 g.

In terms of total salinity values of the agricultural soils of Kırıkhan-Kumlu region, it was observed that the % total salt values were below 0.150% in all samples and it was determined that the soils of the study area did not have salinity problems. This shows that there is a sufficient amount of drainage system in the soils in the study area, that irrigation is carried out with high quality irrigation water and that there is no high ground water in the agricultural soils. The sodium adsorption rate (SAR) values of the soils cultivated in Kırıkhan-Kumlu region were found to be at very low levels, which caused the sodium content of the agricultural soils to be at low levels and shows that there is no alkalinity problem in the soils. In addition, it was determined that the exchangeable sodium percentage (ESP) of all soils in the region of the study area was less than 15, which revealed that this situation was not at a level that would cause salinity problems in the soils of the study area. One of the most important reasons why all of the agricultural soils in the study area are classified as non-saline and not alkaline is the low levels of ESP and SAR values. As a result of the study, it was determined that the agricultural soils of Kırıkhan-Kumlu region, which is located in the Eastern Mediterranean region of Turkey, do not pose a salinity problem that would affect crop production. At the same time, this research will constitute a very important source for future agricultural studies both scientifically and on the basis of farmers. These results show the variability of soil properties in the region and may be an important factor in terms of productivity in agricultural production.

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