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Soil salinization management and reclamation in Libya. A Case Study of Qararat Alqatf for Bin Walid Region.

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A B S T R A C T

The study is to manage the salinity of the soil. The maximum number of computations, the spatial distribution of the (LR) application over the map, and the leaching requirements (LR) for reclamation purposes for various EC-tolerance crops List the following crops' water requirements: wheat, tomatoes, and grapes. All research areas are to be planted with grapes, tomatoes, and wheat, with 19139396.7 m^3, 969745.57 m^3, and 496236.37 m3, respectively. Grapes are more salt-tolerant than both tomatoes and wheat, and tomatoes are more salt-tolerant than wheat. Thus, the GIS-ESP map identified Three groups of crop soil with ESP tolerance: extremely sensitive crop (327.45 ha), sensitive crop (873.05 ha), and moderately tolerant crop (952.90 ha). Consequently, amounts of 27592.12 and 34490.16 tons of gypsum must be applied such as min and max all over actual GR (ATGR), respectively Gypsum requirements (GR) to reclaim soil to cultivate ESP crops at depth (D) 30 cm for Mapping unit Studied soil required gypsum applications of 4049.82and 8099.65tons as min and max all over net GR (ANGR), respectively. Gypsum requirements (GR) to recover soil at a depth (D) of 120 cm for the cultivation of ESP crops

Keywords: GIS Mapping, GIS-ESP edaphological, leaching requirements (LR) EC tolerance crops and Gypsum requirements (GR).

إدارة التربة الملحية واستصلاحها في ليبيا. (دراسة حالة بمنطقة بني وليد – قرارة القطف).

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الملخص

تهدف هذه الدراسة الى كيفية إدارة التربة واستصلاحها من خلال دراسة عدة خواص كيميائية والفيزيائية للتربة مثل: ملوحة التربة ECوالصوديوم المتبادل ESP وكربونات الكالسيوم $CaCO_3$ ودرجة التفاعل PH واعماق التربة والقوام التربة والتوصيل الهيدروليكي للتربة في منطقة الدراسة ومن خلال هذه الخواص نحدد احتياجات

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الغسيل للتربة المراد زراعتها بالعنب والطماطم والقمح والتي بلغت الى اقصى كمية المياه كالاتي: 19139369.7 م3 و969745.57 م3 و496236.37 م3 على التوالي. بواسطة الحدود المسموحة للصوديوم المتبادل في التربة بواسطة بيانات GIS–ESP للمحاصيل المتحملة للصوديوم ولحسابات متطلبات اضافة الجبس للتحسين واستصلاح التربة. ومن خلال معرفة المساحة التي يتواجد بها الصوديوم بحدوده المختلفة حيث كانت كأتي: ESP محصول حساس للغاية (327.45 هكتار)، ومحصول حساس ESP (873.05 هكتار) ومحصول متوسط التحمل (952.90 هكتار). حالة الاستصلاح للمنطقة المدروسة حسب الخرائط التربة (2 و3) بواسطة هذه المحاصيل عند عمق 120سم، وبالتالي تكون المتطلبات جبسيه بالكميات الاتية: 24832.92 و31041.15 طن كحد أدنى وأقصى لصافي اضافة الجبس على التوالي. وبالتالي يجب ان تكون اجمالي اضافة الجبس بالكميات 27592.12 و34490.16 طن من الجبس كحد الأدنى والحد الأقصى على التوالي. اما عند عمق 30سم فكانت عند الخريطة 1و2 لا توجد إضافات للجبس وتوجد إضافة لخريطة 3 وهي كأتي: الإضافة الصافية للجبس 4049.82 و8099.65 طن كحد أدني واقصى وهي على التوالي اما الإضافة الاجمالية للجبس للخريطة 3 وهي كأتي: 4499.80 و8999.61 طن كحد ادنى واقصى وهي على التوالي.

الكلمات المفتاحية: احتياجات الغسيل، احتياجات الجبس، خريطة، صوديوم، ملوحة التربة.

ntroduction

About 12.5% of Libya's northern region, 16.5% of its western region, and 23.4% of its center region are covered with saline soils. [1]. In addition to being one of the environmental variables affecting agricultural output, salinization is one of the primary causes of soil deterioration in the world. [2,3] A serious issue affecting productivity, agricultural management, and environmental quality is soil salinity. [4] The accumulation of salts in the root zones can hinder crop growth; degrade irrigation water quality, and lower agricultural yields. [5] Agriculture provides for the subsistence of 40 million people. Climate change-related soil salinity is primarily seen in rural coastal areas, where it has a detrimental effect on crop growth development and eventually on agricultural crop productivity and food security. [6]. In saline soils, leaching has been found to be the most efficient way to remove soluble salts from the rhizosphere; in sodic soils, however, reclaiming the soil requires the application of chemical amendments (like adding gypsum) to remove sodium from the cation exchange sites. [7]. The fundamental concept is to try to be objective in the categorization of soils using numerical techniques while minimizing within-class variance and maximizing between-class variation in accordance with some objective criterion. [8]. When agriculture became more prevalent, the population grew, and subsurface freshwater was over extracted, the issue of soil salinization in Libya came to the public's notice. Problems with soil salinity are also exacerbated by the severe climate, which features

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high temperatures and little rainfall. Salt-affected soils are classified as saline, saline-sodic and sodic according to the soil pH, electrical conductivity (EC), and exchangeable sodium percentage (ESP), which indicates the degree to which soil exchange complex is saturated with Na or sodium adsorption ratio (SAR) that gives information on the comparative concentrations of Na, Ca, and Mg in soil solution [9]. Zaman et al. (2018) suggested that a combination of mitigation and adaptation is to be applied. Mitigation aims to reduce soil salinity by applying different technologies to farming, e.g., water management and improvement of soil properties. Instead, adaptation comprehends strategies to allow the use of salt-affected soils by adjusting the agronomic management and reducing the crops' vulnerability to salt stress. Possible examples are the cultivation of less sensitive cultivars or the enrichment of beneficial microbiota in the rhizosphere. . Saline and sodic soils are commonly occurring in most part of the world [10]especially in the arid and semi-arid regions, whereas, globally there are 400 million hectares of land (over 6% of the world land area) affected by either salinity or sodicity [11]. Salt-affected soils (saline, sodic and saline-sodic) differ considerably in use suitability, productivity, ease of reclamation, and management [12.]The leaching has been identified as the most effective method for removal of soluble salts from the rhizosphere in saline soils while application of chemical amendments (such as addition of gypsum) to remove the sodium from the soil's cation exchange sites is necessary to reclaim sodic soils [10]. This study aims to compare and analyze in a geospatial context the GIS maps of soil numerical classification, soil management, and reclamation.

1. Study Area

As shown in Figure 1, the research was conducted in Bin Walid Qararat Alqatf. The research region is situated in Libya's northwest. The study area is located between 483019.349 E and 3513881.161 N and covers 1253.40 hectares. In the research area, where the majority of the land area is significantly affected by varying degrees of soil salt, soil salinity is a salient feature. Approximately thirty percent of people work in agriculture. The principal crops that are grown here are wheat, tomatoes, and grapes, as well as a few vegetables.

2. Datasets

In order to create the basis map of GIS soil maps, the data collection, including topographic maps, was digitized using ArcGIS 10.8 (software 2014). The global position system (GPS) was used to find 25 soil profiles, from which 18 soil samples were taken. To obtain the UTM coordinates of the soil sample, the GPS was calibrated (Figure 3). To reflect all soil variances, soil samples were gathered based on the morphological properties of the soil. To reach the hard layer, which is located closest to the soil surface, or a depth of 176 cm, eighteen soil profiles were excavated.

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3. Soils Physical and Chemical Characterization

Soil Physical Analysis: Texture was determined using sieves and the Hydrometer method [13].

Soil Chemical Analysis: Salinity was measured at in the soil paste extract and pH of 1:2.5 soil suspension by EC meter and PH [14], Sodium adsorption Ration (SAR) was calculated from Ca, Mg, and Na soluble concentrations, soil organic matter content (OM%) was determined by Walkely & Black method [14] and CaCO3% was determined using the pressure calcimeter method [14].

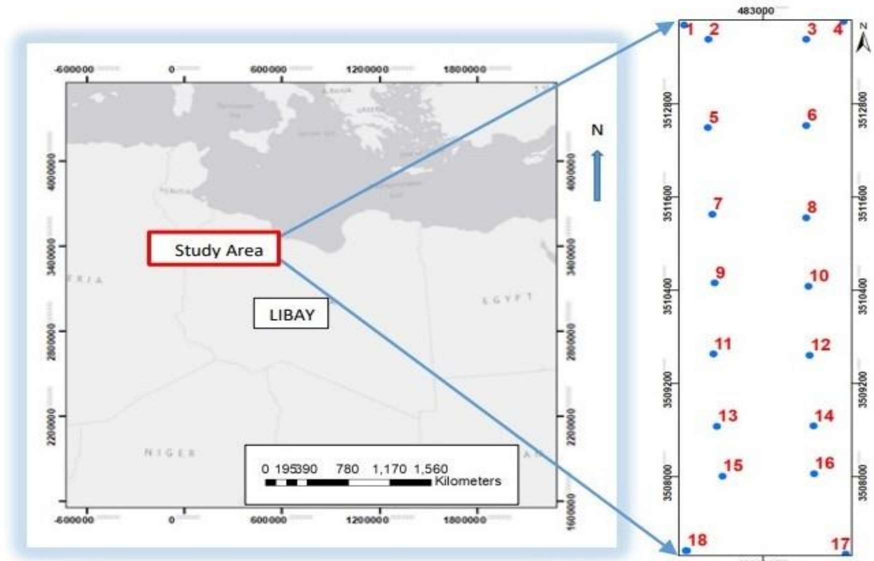

Figure 1. Location of studied area

GIS - data processing of soil chemical and physical:

The data of Soils Physical and Chemical Characterization analysis were weighted by the arithmetic mean (Mishra, 2004) [15] to be processed to output soil maps (ArcGIS 10.8 software, 2014). The following equation (1):

$$WM = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}$$

Where:

WM = Weighted Arithmetic Mean

Xi = Variable value (Soil parameter)

Wi = weighting factor (Horizon thickness)

Determination of leaching requirements (LR):

The following equation (2) can be used to estimate how much water is required to leach salts for reclamation purposes: The following equation (2)

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$$DW = \frac{K \times Ds \times ECei}{ECef}$$

where :

DW = depth of water infiltrated.

Ds = soil depth to be reclaimed = crop rooting depth.

K = 0.30 for fine-textured soils, 0.10 for coarse-textured soils. (0.1 For all soils by sprinkler irrigation and pivot irrigation system).

ECei = initial soil salinity = soil salinity classes thresholds of the mapping.

Accordingly : Minimum. ECein = Minimum. initial soil salinity = The first (lower) and Maximum. ECein = Maximum .initial soil salinity = the second (upper) soil salinity class thresholds of the mapping. (n).

ECef = Desired final soil salinity (target soil salinity) to obtain zero crop yield.

Determination of gypsum requirements (GR)

ESP values and sample coordinates were input to map GIS-ESP edapoloical soil classification. The GIS-ESP map was based on the following information and considerations: The following equation (3)

GR (ton gypsum/ hectares, by rough method) =1.7 * K Naex *D/30. [16]

Where:

D = Crop rooting depth.

N aex = exchangeable sodium (meq/100 gm).

K Na ex = Required Na ex to be removed from the soil.

The actions exchange capacity was used to calculate the exchangeable sodium , The following equation (4) (Naex): Naex (meq/100 gm) = ESP * CEC = ESP * 25.

Initial Naex = Initial soil Naex (Naex before gypsum application).

RNaex = the reference ESP threshold tolerant crop ESP KNaex = Initial Naex - RNaex Min. RNaex and Max. RNaex thresholds, of ESP tolerant crop ESP, representing ESP tolerant crop range Min KNaex = Initial Naex - Min RNaex Max.KNaex = Initial Naex - Max.RNaex.

RESULTS AND DISCUSSION

Management and Reclamation by Soil Physical and Chemical Characterization:

1- Soil Physical-Univariate Numerical Classification:

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▪ Soil Profile Depth: hard layer characterized by Most of the soil profiles; therefore, the classification of the profile depth was based on it (depth and hardness). Soil profiles were classified into phases; shallow soil (< 70 cm), moderately deep soil (70 – 95 cm), and deep soil (> 95 cm) were presented by areas of 257.73, 97.94, and 897.73 hectares, respectively (Table 3 and Figure 2).

▪ **Soil Texture:** Showed that the studied soil was grouped four into textural phases; silty loam, sandy clay Loam, clay loamy, and sandy loamy were presented by areas 225.56, 446.44, 365.43 and 215.96 hectares, respectively (Table 3 and Figure2).

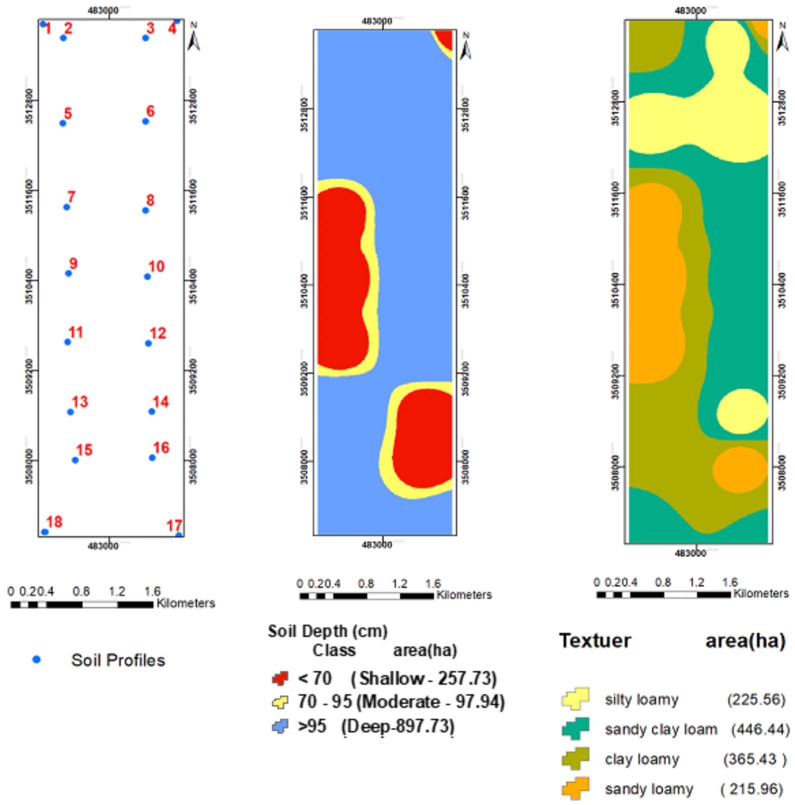

Figure.2 **Soil Physical classes**

▪ Water Holding Capacity (WHC): The studied soil was characterized by the dominance of the phase of low field water holding capacity that represented an area of 883.37 ha. The area (370.026) represented the moderately WHC soil phase. (Table 2 and Figure 3).

▪ Hydraulic Conductivity (Ks): Soil hydraulic conductivity was determined due to the importance of soil permeability in the soil drainage condition and the growth of crops. The hydraulic conductivity values categorized the soil area into two categories; slow permeability (322.81ha) and moderately permeability (930.95 ha) (Table 2 and Figure 3). The moderate permeability phase (930.95 ha) dominated the area.

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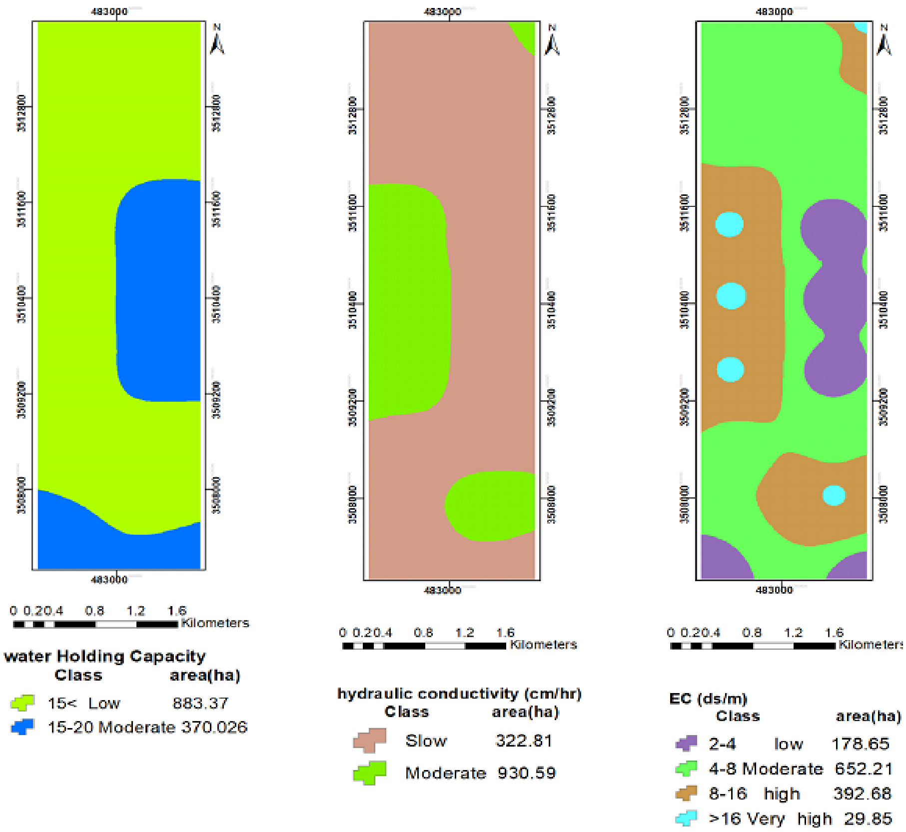

Figure .3 **Soil Physical classes**

Table (1) Main soil physical characteristics

Profile N	Profile Depth (cm)	Sample Depth cm	Ks (cm/hr)	WHC(%)	Textural Class
1	176	0-15 15-50 20-130 130-176	1.8 8.4	14.37 21.90 13.81 9	SCL CL CL LS
2	176	0-15 15-50 20-130 130-176	1.8 8.4	14.37 21.90 13.81 9	SCL CL CL LS
3	150	0-32 32-80 80-150	2.1 2.4	16.42 10.37 12.76	L LS LC
4	>29	0-29 >29	3.0	12.37	LS
5	150	0-32 32-80	2.1 2.4	16.42 10.37	L LI

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Profile		Sample Depth cm	Ks (cm/hr)	WHC(%)	Textural Class
N	Depth (cm)				
		80-150		12.76	LC
6	150	0-32 32-80 80-150	2.1 2.4	16.42 10.37 12.76	L LS LC
7	>29	0-29 >29	3.0	12.37	LS
8	160	0-29 29-66 66-95 95-160	1.5 5.4	15.42 15.89 15.11 21.80	LCS CS LCS L
9	>29	0-29 >29	3.0	12.37	LS
10	160	0-29 29-66 66-95 95-160	1.5 5.4	15.42 15.89 15.11 21.80	LCS CS LCS L
11	>29	0-29 >29	3.0	12.37	LS
12	160	0-29 29-66 66-95 95-160	1.5 5.4	15.42 15.89 15.11 21.80	LCS CS LCS L
13	176	0-15 15-50 20-130 130-176	1.8 8.4	14.37 21.90 13.81 9	SCL CL CL LS
14	150	0-32 32-80 80-150	2.1 2.4	16.42 10.37 12.76	L LS LC
15	150	0-32 32-80 80-150	2.1 2.4	16.42 10.37 12.76	L LS LC
16	>29	0-29 >29	3.0	12.37	LS
17	160	0-29 29-66 66-95 95-160	1.5 5.4	15.42 15.89 15.11 21.80	LCS CS LCS L
18	160	0-29 29-66	1.5 5.4	15.42 15.89	LCS CS

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Profile		Sample Depth cm	Ks (cm/hr)	WHC(%)	Textural Class
N	Depth (cm)				
		66-95 95-160		15.11 21.80	LCS L

* LS= Loamy Sand, SCL= Sandy Clay Loam, LS= Loam Sandy, S=Sand, L= Loam, CS= Sandy Clay, LCS= Loam Clay Sandy, LC=Loam Clay

Table2. Univariant soil physical classification

Soil physical Criteria	Threshold	Soil Phases	Area(ha)
Depth	<70 70-90 >90	Shallow Moderate Deep	257.73 97.94 897.73
Textural	Classes Textural	SL SCL CL	225.56 446.44 365.43 215.96
Hydraulic Conductivity (Ks)cm/hr	0.42 - 1.67 1.67 - 4.17 4.17- 12.50 >12.50	Slow Moderate Good Rapid	322.81 930.59
Holding Capacity (WHC %)	<15 15 – 20 >20	Low Moderate High	883.37 370.026

2- Soil chemical-Univariate Numerical Classification:

A brief overview of some soil chemical properties, including pH, EC, ESP, and CaCO3, is given in Table 3. According to pH readings, soils were naturally alkaline (7.90) to 7.1. Between the minimum value of 0.80 ds/m (subsurface horizon, profiles 8, 10, 12, 17, and 18) and the maximum value of 17 ds/m (surface horizon, profiles 4, 7, 9, 11, and 16), EC showed a wide variation. Classes of soils ranged from extremely sodic, with a maximal ESP of 23.17% (surface horizon, profiles 3, 5, 6, 14, and 15), to nonsodic, with an ESP of 1.25% (surface horizon, profiles 8, 10, 12, 17, and 18). CaCO3 varied from 2.60 percent at the lowest point in a subsurface sample of profile numbers 1, 2, and 13 to 35.00 percent at the highest point in a subsurface sample of profile numbers 3,5, 6, 14, and 15.

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Table 3. Main soil chemical characteristics

Profile	Sample	PH	EC ds/m	ESP%	CaCO3%
1	1	7.4	3.18	14.28	17.6
	2	7.3	5.78	19.03	23.1
	3	7.1	7.09	11.88	25.3
	4	7.2	6.12	4.37	2.6
2	5	7.4	3.18	14.28	17.6
	6	7.3	5.78	19.03	23.1
	7	7.1	7.09	11.88	25.3
	8	7.2	6.12	4.37	2.6
3	9	7.9	2.84	18.34	28.0
	10	7.9	5.54	23.17	35.0
	11	7.3	7.20	21.86	11.9
4	12	7.4	17	14	30
5	13	7.9	2.84	18.34	28.0
	14	7.9	5.54	23.17	35.0
	15	7.3	7.20	21.86	11.9
6	16	7.9	2.84	18.34	28.0
	17	7.9	5.54	23.17	35.0
	18	7.3	7.20	21.86	11.9
7	19	7.4	17	14	30
8	20	7.6	0.80	1.25	17
	21	7.4	0.88	3.45	.17.4
	22	7.5	1.29	1.53	20.5
	23	7.8	1.36	7.58	26.3
9	24	7.4	17	14	30
10	25	7.6	0.80	1.25	17
	26	7.4	0.88	3.45	17.4
	27	7.5	1.29	1.53	20.5
	28	7.8	1.36	7.58	26.3
11	29	7.4	17	14	30
12	30	7.6	0.80	1.25	17
	31	7.4	0.88	3.45	.17.4
	32	7.5	1.29	1.53	20.5
	33	7.8	1.36	7.58	26.3
13	34	7.4	3.18	14.28	17.6
	35	7.3	5.78	19.03	23.1
	36	7.1	7.09	11.88	25.3
	37	7.2	6.12	4.37	2.6
14	38	7.9	2.84	18.34	28.0
	39	7.9	5.54	23.17	35.0
	40	7.3	7.20	21.86	11.9
15	41	7.9	2.84	18.34	28.0
	42	7.9	5.54	23.17	35.0
	43	7.3	7.20	21.86	11.9

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Profile	Sample	PH	EC ds/m	ESP%	CaCO3%
16	44	7.4	17	14	30
17	45 46 47 48	7.6 7.4 7.5 7.8	0.80 0.88 1.29 1.36	1.25 3.45 1.53 7.58	17 17.4 20.5 26.3
18	49 50 51 52	7.6 7.4 7.5 7.8	0.80 0.88 1.29 1.36	1.25 3.45 1.53 7.58	17 17.4 20.5 26.3

Management and Reclamation by using Soil Chemical Classification:

Soil Salinity**:** Based on the electrical conductivity data, the majority of the soils under study fell into the low to moderately saline class, with an area of 831.33 hectares that is appropriate for most crops. Four classifications of soils were created : moderately saline (652.21 ha), high saline (392.68 ha), extremely high (29.85 ha), and low saline (178.56 ha). Showing it is appropriate for both yield decreases and crops that can withstand high salt levels (Table 4 and Figure 3).

▪ Soil Sodicity: Results showed that the non-sodic soil class occupied the majority of the studied area with (903.14 ha). The sodic soil had only (350.26 ha) (Table 4 and Figure 4).

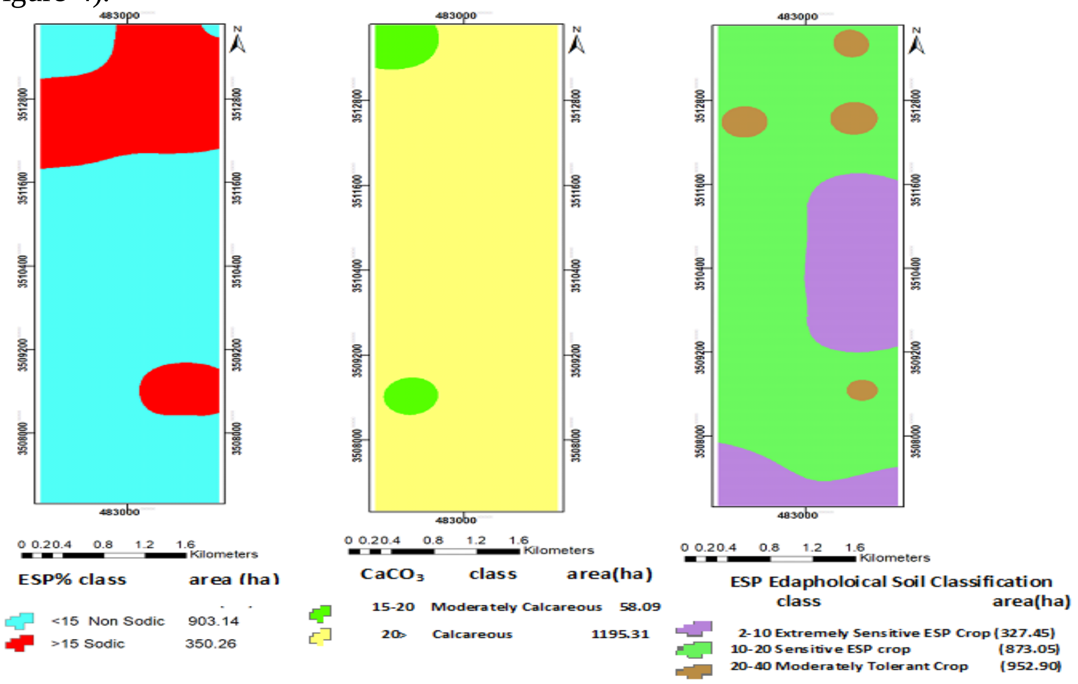

Figure. 4 **Soil chemical classes**

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The study area was classified into two classes according to percentage of calcium carbonate to moderately calcareous soil (98.09 ha) and calcareous soil (1195.31 ha) (Table 4 and Figure 4).

Table 4. Univariant soil chemical l classification

Soil chemical Criteria	Threshold	Soil Phases	Area(ha)
Exchangeable Sodium Percentage (ESP%)	<15	Non-Sodic	903.14
	>15	Sodic	350.26
$CaCO_3$%	<15	Non Calcareous	
	15-20	Moderate Calcareous	58.09
	>20	Calcareous	1195.31

• **Managing Soil Salinity:** The distinguishing characteristic of saline soils from an agricultural standpoint is that they contain sufficient neutral soluble salts to adversely affect the growth of most crop plants. Suitable crops were selected to reduce the problem of soil salinity (Table 5).

Table 5. Crops tolerance and EC soil parameters

Mapping Unit	EC Crop Tolerance	EC (dS/m) tolerant crop range
1	Sensitive EC crops: (Field crops) Sunflower, Soybean, Faba bean, Lins, (Vegetable crops) Sweet corn, Lettuce, Onion, Eggplant, Carrot, (Fruit crops) Date, Olive, Peach, Orange, Grapes	1-4
2	Moderately EC tolerant crops: only field crops Barley, Cotton, Sugar beet, Grain sorghum, Wheat	4-8
3	EC tolerant crops: No crops have 0 % yield reduction	8-16
4	Highly EC tolerant crops: No crops have 0 % yield reduction	16-32

• **Reclamation of saline soil by determination of leaching requirements (LR) for different EC-tolerance crops:** The Bauder et al. (2018 equation. The minimal LF needed over a growing season for a specific water quality to produce the optimum yield of a given crop and the distribution of waters is known as the "leaching requirement" (LR). Table 5 displays the results of the calculation of soil beginning EC (ECei), crop tolerance, and EC soil parameters that are in the in the EC-tolerant crop range. Determine the water infiltration depth (DW) using Table 6.

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Table 6 Depth of water infiltrated (DW)

ECei(ds/m)		Crops					
		Grapes (DM)cm		Tomato (DM)cm		Wheat (DM)cm	
MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
1	4	6.67	26.67	2.80	11.20	0.83	3.33
4	8	26.67	53.33	11.20	22.40	3.33	6.66
8	16	53.33	106.67	22.40	44.80	6.66	13.33
16	17	106.67	113.33	44.80	47. 60	13.33	14.16

Table 6 showed to the following Where: K (constant) =0.10, Ds (rooting depth) = 100, 70 and 50 cm for grapes, tomato and wheat ECef (EC soil paste that enables obtaining zero yield) = 1. 5, 2.5 and 6 (dS/m) for grap, tomato and wheat (Max ECei = max. initial EC of the studied soils 17 (dS/m). DW was used to determine the min and max all over net LR (ANLR), and min and max all over total LR (ATLR), tables (7, 8, and 9).

Table7. Leaching requirements (LR) to reclaim soil to cultivate grapes

Mapping Unit	NLR & TLR (m^3 water/ha)				
	NLRF TLRF		TLRF		Area
	MIN	MAX	MIN	MAX	(ha)
1	233.45	933.45	259.38	1037.16	178.65
2	933.45	1866.55	1037.16	2073.94	652.21
3	1866.55	3733.45	2073.94	4148.27	392.68
4	3733.45	3966.55	4148.27	44407.27	29.85
Mapping Unit	NLRU & TLRU (m^3 water / mapping unit)				
	NLRU		TLRU		
	MIN	MAX	MIN	MAX	
1	41705.84	166760.84	46338.23	185288.63	
2	608805.42	1217382.57	676446.12	1352644.41	
3	732956.85	1466051.14	814394.76	16275906.66	
4	111443.48	118401.51	123825.86	1325557.0	

Table 7 displays the subsequent results. For all examined soil, the allover net LR (AN LR) minimum value is 1494911.59 (m^3/studied soil), the allover net LR (ANLR) maximum value is 2968596.06 (m^3/studied soil), the allover total LR GR (ATLR) minimum value is 1661004.97 (m^3/studied soil), and the allover total LR (ATLR) maximum value is 19139396.7 (m^3/studied soil). Where: NLRF and TLRF = net and total requirements of water leaching per hectare (m^3 water/ha) for reclamation reasons; NLRU and TLRU stand for net and total leaching requirements (m^3 of water per mapping unit) for reclamation applications. ANLR and ATLR stand for net and total water leaching requirements (m^3 water/all examined soils) for reclamation purposes for all mapping units. Leaching application efficiency (LF) = 90%. To grow grapes in the units of mapping 1, 2, 3.

Table 8. Leaching requirements (LR) to reclaim soil to cultivate tomato

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Mapping Unit	NLR & TLR (m^3 water/ha)				
	N LRF TLRF		TLRF		Area
	MIN	MAX	MIN	MAX	(ha)
1	68.6	274.40	76.22	304.88	178.65
2	274.40	548.80	304.88	609.77	652.21
3	548.80	1097.60	609.77	1219.55	392.68
4	1097.6	1166.20	1219.55	1295.77	29.85
Mapping Unit	NLRU & TLRU (m^3 water / mapping unit)				
	NLRU		TLRU		
	MIN	MAX	MIN	MAX	
1	12255.40	49021.56	13617.11	54468.4	
2	178966.42	357932.84	198851.57	397703.15	
3	215502.78	431005.56	239447.53	478895.06	
4	32763.36	34811.07	36403.73	38678.96	

Table 8 displays the subsequent results. Everyone studied the soil. The amounts for the examined soil are as follows: Min all over net LR (AN LR) = 439487.96 (m^3), Max. all over net LR (ANLR) = 872771.03 (m^3), Min all over total LR GR (ATLR) = 488319.94 (m^3), and Max. all over total LR (ATLR) = 969745.57 (m^3). Where: NLRF and TLRF = net and total requirements of water leaching per hectare (m^3 water/ha) for reclamation reasons NLRU and TLRU stand for net and total leaching requirements (m^3 of water per mapping unit) for reclamation applications. ANLR and ATLR = application efficiency of leaching (LF) = 90% and net and total water leaching requirements (m^3 water/all examined soils) for reclamation purposes for all mapping units. In order to grow tomatoes in the units of mapping 1, 2, and 3

Table 9. Leaching requirements (LR) to reclaim soil to cultivate wheat

Mapping Unit	NLR & TLR (m^3 water/ha)				
	N LRF TLRF		TLRF		Area
	MIN	MAX	MIN	MAX	(ha)
1	35	140.41	38.89	156.01	178.05
2	140.41	280.82	156.01	312.02	652.21
3	280.82	562.06	312.02	624.51	392.68
4	562.06	597.06	624.51	663.40	29.85
Mapping Unit	NLRU & TLRU (m^3 water / mapping unit)				
	NLRU		TLRU		
	MIN	MAX	MIN	MAX	
1	6231.75	24927	69256.66	27696.66	
2	91576.80	183153.61	101752	203504.01	
3	110272.40	220709.72	122524.88	245233.02	
4	16777.50	17822.42	18641.66	19802.68	

Table 9 displays the subsequent results. Everyone studied the soil. The amounts for the examined soil are as follows: Min all over net LR (AN LR) = 224858.45 (m^3), Max. all over net LR (ANLR) = 446612.75 (m^3), Min all over total LR GR (ATLR) = 312175.2

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(m^3), and Max. all over total LR (ATLR) = 496236.37 (m^3). Where: NLRF and TLRF = net and total requirements of water leaching per hectare (m^3 water/ha) for reclamation reasons NLRU and TLRU stand for net and total leaching requirements (m^3 of water per mapping unit) for reclamation applications. ANLR and ATLR stand for net and total water leaching requirements (m^3 water/all examined soils) for reclamation purposes for all mapping units. Leaching application efficiency (LF) = 90%. To grow wheat in the units of mapping 1, 2, 3.

• **Managing Sodic Soil**

An excess of soluble salts and Exchangeable Na^+ all adversely affects the chemical and physical characteristics of soil, plant growth, and water quality. To ensure dependable soil administration, ESP irrigation water must be applied to ESP-friendly crops that are tolerant and friendly to the soil. Appropriate crops to grow in the soils under study (Table 10). Nuts, avocado, and citrus are highly sensitive ESP crops that can only be grown in the non-sodic soil class (ESP = 2-10%), according to the table. It is possible to grow sensitive ESP crops, like beans, in soil that has transitioned from sensitive to friendly ESP with a slight yield drop. ESP range: 10 to 20. Soils that are not sodic can be grown in the interim. In various crops.

Table 10. Selection ESP crops tolerant

Soil Chemical Classes	ESP Thresholds	Area (ha)	ESP Crops Tolerant
Non-Sodic	<15	903.14	Extremely sensitive ESP Crops(ESP = 2-10) ; Nuts , Citrus, Avocado Sensitive ESP crops (ESP = 10-20) Beans Moderately tolerant (ESP = 20-40) ; Clover
Sodic	>15	350.20	Tolerant crops (ESP = (40-60); Wheat, Cotton , Alfalfa, Barely , Tomato, Beets, Most tolerant crops (ESP > 60); Tall wheatgrass, Rhodes grass

• Reclamation of Sodic Soil by determination of edaphological soil gypsum requirements for different ESP-tolerance crops:

Gypsum's solubility, affordability, and availability make it the most widely utilized addition for sodic soil reclamation and mitigating the negative impacts of high-sodium irrigation flows. Gypsum can alter permeability in a sodic soil by raising EC and through cation exchange effects. On the other hand, a pedological approach forms the basis of the distribution of sodic soils as well as the conditions that facilitate their production. The goal of this approach is to generate amelioration data regarding the requirements for gypsum (GR) in the study area. Using the GIS-ESP soil map (Figure 4) to determine the determine the GIS-ESP thresholds of tolerant crop ranges (Table 11).

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Table 11. ESP crops tolerance and exchangeable sodium of soil

Studied soil mapping	Crop Tolerance	ESP Tolerance Corps Range	ESP Thresholds		Initial exchangeable sodium	
			Min	Max	Min	Max
1	Extremely sensitive ESP crops: citrus	2-10	2	10	0.5	2.5
2	Sensitive ESP :beans	10-20	10	20	2.5	5
3	Moderately tolerant crops: clover	20-40	20	40	5	10

In order to lower soil salinity, Figure 6 illustrates the various ESP types that must be added to the soil. Based on Table 11, these ESP-bearing crop soils are divided into three categories: extremely sensitive crops (327.45 ha), sensitive crops (873.05 ha), and medium-tolerant crops (952.90 ha). The following results are obtained from calculating the gypsum requirement (GR) for various ESP crops (Tables 12, 13, and 14):

Table 12- a. Thresholds of extremely sensitive ESP crops and exchangeable sodium of soil

Studied soil mapping	ESP Tolerance Corps Range	ESP Thresholds		Initial exchangeable sodium		R exchangeable sodium		K exchangeable sodium	
		Min	Max	Min	Max	Min	Max	Min	Max
1	2-10	2	10	0.5	2.5	0.5	2.5	0	0
2	10-20	10	20	2.5	5	0.5	2.5	2	2.5
3	20-40	20	40	5	10	0.5	2.5	4.5	7.5

Table 12-a shows the different thresholds of interchangeable ESP and sodium yields for soil mapping studied to calculate the gypsum (GR) requirements of different ESP-bearing crops.

Table 12-b. Gypsum requirement (GR) to reclaim soil to cultivate extremely sensitive ESP crops Citrus = rooting depth (D) 120 cm

Studied soil mapping	Area(ha)	NGRU (ha/studied soil)		TGRU (ha/studied soil)	
		Min	Max	Min	Max
1	327.45	No Need for Gypsum Application*			
2	873.05	11873.48	14841.85	13192.75	16490.94
3	952.90	12959.44	16199.3	14399.37	17999.22
∑ studied Soils	2153.4	24832.92	31041.15	27592.12	34490.16
EF = efficiency of gypsum application = 95 %, GP = gypsum purity = 95 % Allover total gypsum requirements (ATGR) = (ANGR) ×100 /90 (ha/ studied soil) *No need for Gypsum Application when RNaex ≥ Soil initial Naex					

Table 12- lists the various gypsum requirements (GR) for the mapping unit at a depth (D) of 120 cm in order to recover soil and develop ESP crops. All crops, including delicate ones like citrus, can be grown using carefully considered soil mapping (1) without the need for gypsum application. A minimum of 24832.92 and a maximum of 31041.15 tons of gypsum were applied in the cultivation case study soil mapping (2 and

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3) by these crops regarding all-over net GR (ANGR). Therefore, 27592.12 and 34490.16 tons of gypsum, respectively, must be applied in the minimum and maximum amounts over actual GR (ATGR) (Table 12-b).

Table 13- a. Thresholds of sensitive ESP crops and Exchangeable sodium parameters

Studied soil mapping	ESP Tolerance Corps Range	ESP Thresholds		Initial Exchangeable sodium		R Exchangeable sodium		K Exchangeable sodium	
		Min	Max	Min	Max	Min	Max	Min	Max
1	2-10	2	10	0.5	2.5	2.5	5	-2	-2.5
2	10-20	10	20	2.5	5	2.5	5	0	0
3	20-40	20	40	5	10	2.5	5	2.5	5

Table 13-a shows the different thresholds of interchangeable ESP and sodium yields for soil mapping studied to calculate the gypsum (GR) requirements of different ESP-bearing crops.

Table 13-b. Gypsum requirement (GR) to reclaim soil to cultivate sensitive ESP crops Beans = rooting depth (D) = 30 cm.

Studied soil mapping	Area(ha)	NGRU(ha/studied soil)		TGRU(ha/studied soil)	
		Min	Max	MIN	Max
1	327.45	No Need for Gypsum Application*			
2	873.05	No Need for Gypsum Application*			
3	952.90	4049.82	8099.65	4499.80	8999.61
∑ studied Soils	2153.4	4049.82	8099.65	4499.80	8999.61
EF = efficiency of gypsum application = 95 %, GP = gypsum purity = 95 % Allover total gypsum requirements (ATGR) = (ANGR) ×100 /90 (ha/ studied soil) *No need for Gypsum Application when RNaex ≥ Soil initial Naex					

The various gypsum requirements (GR) for reclaiming soil to plant ESP crops at a depth (D) of 30 cm for the mapping unit are displayed in Table 13-a. All crops, including sensitive ESP crops like beans, can be grown using soil mapping (1) without the need for gypsum application. In the agricultural instance analyzed in soil mapping (2 and 3), such crops required gypsum applications with maximum and minimum amounts of 8099.65 tons and 4049.82 tons, respectively, all over the net GR (ANGR). Therefore, it is necessary to apply 4499.80 and 8999.61 tons of gypsum as the minimum and maximum amounts over the actual GR (ATGR), respectively (Table 13-b).

Table 14a. Thresholds of to cultivate moderately tolerant ESP crops and Naex parameters

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Studied soil mapping	ESP Tolerance Corps Range	ESP Thresholds		Initial exchangeable sodium		R exchangeable sodium		K exchangeable sodium	
		Min	Max	Min	Max	Min	Max	Min	Max
1	2-10	2	10	0.5	2.5	5	10	-4.5	-7.5
2	10-20	10	20	2.5	5	5	10	-2.5	-5
3	20-40	20	40	5	10	5	10	0	0

Table 14-a shows the different thresholds of interchangeable ESP and sodium yields for soil mapping studied to calculate the gypsum (GR) requirements of different ESP-bearing crops.

Table 14-b. Gypsum requirement (GR) to reclaim soil to cultivate moderately ESP crops Clover = rooting depth (D) = 30 cm

Studied soil mapping	Area(ha)	NGRU(ha/studied soil)		TGRU(ha/studied soil)	
		Min	Max	Min	Max
1	327.45	No Need for Gypsum Application*			
2	873.05	No Need for Gypsum Application*			
3	952.90	No Need for Gypsum Application*			
∑ studied Soils	2153.4	EF = efficiency of gypsum application = 95 %, GP = gypsum purity = 95 % Allover total gypsum requirements (ATGR) = (ANGR) ×100 /90 (ha/ studied soil) *No need for Gypsum Application when RNaex ≥ Soil initial Naex			

The various gypsum requirements (GR) for reclaiming soil to plant ESP crops at a depth (D) of 30 cm for the mapping unit are displayed in Table 14-a. All crops, even clover, which is a moderately ESP crop, may be grown using the soil mapping techniques (1, 2, and 3). Gypsum application is not necessary. The agriculture case study including these crops necessitated gypsum treatments of all-over actual GR (ATGR) and all-over net GR (ANGR) for Table 14-b. Since RNaex ≥ soil initial Naex, GR does not need to plant moderately resistant ESP crops in all studied soils.

CONCLUSIONS

We looked into the physicochemical properties of eighteen different soil profiles. The findings demonstrated that soil characterization produced a numerical classification of the soil that precisely and quantitatively directed soil management and reclamation activities. The various salinity zones can be better managed and improved by dividing the region into zones. Consequently, the management of salt-affected soil, the spatial distribution of leaching requirements for saline soils, and the gypsum requirements for reclaiming sodic soils are all improved by the use of this technique. In order to produce the soil multivariable chemical classification, GIS-EC and ESP overlaid maps are used.

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