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Research Article

Estimate Salinity of Soils, Some Nutrients Solubility and Their Spatial Distribution in Baqubah City - Diyala – Iraq Using Remote Sensing And GIS

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Abstract

Monitoring salinity of soils by using remote sensing data is required to keep changes track in salinity for reclamation and timely using of these soils. A study was conducted to evaluate the concentration of some ionic composition (Ca, Mg, Na, K, Cl, HCO3, and SO4), sodium adsorption ratio (SAR), electrical conductivity (EC) and mapping their spatial distribution in soils of Baqubah governorate – Iraq. Thirty soil samples from 0-30 cm depth at the study area were collected randomly using GPS. The soil soluble cations and anions were determined in laboratory, EC and SAR was calculated. Then, the satellite image of Landsat 8 satellite taken on 23/12/2020 was used for preparing maps for these selected soil samples properties. The results showed that all the soil samples can classify to two categories, slightly (normal soil) and moderate (saline soils) according to EC and SAR values. Keeping monitoring of salt affected areas need continuous updating and that can be achieved with using remote sensing techniques due to field and lab data collection are expensive and time consuming.

Keywords

SAR, Salinity, Remote sensing, GIS

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Introduction

Soil chemical properties are important for evaluating soil quality. These properties such as soil salinity and their elements content are necessary for assessment and management the soil (Machado and Serralheiro, 2017). It is a vital for farmers and researchers attempting to enhance land production from scientific formation regarding spatial distribution of soil properties (Islam et al., 2019). The cations responsible for soil salinity are sodium Na^+, Potassium K^+, Calcium Ca^{2+} and magnesium Mg^{2+}. While, the anions are chloride (Cl^-), bicarbonate HCO^{3-}, carbonate $CO3^{2-}$ and sulfate $SO4^{2-}$. Soils can be classified into four types; normal soils, saline soils, sodic soils and saline-sodic soils based on the value of electrical connectivity (EC), pH and sodium adsorption rate (SAR) Zurqani et al 2018. Because cost and time consuming of laboratory and field work to measurement these soil properties to assessment soil salinity, many studies have been suggested to use remote sensing (RS) and mapping techniques to enhance accurate, speed and cost effectives (Zurqani et al.,2018; Zare et al ., 2015). The use of remote sensing techniques is one of the most effective methods of studying natural resources (soil, water and vegetation), identifying their properties and places of residence, monitoring them and developing plans for their exploitation, as well as their applications in monitoring and tracking environmental phenomena that affect agricultural development processes such as drought, soil degradation, desertification and erosion (GIS) to enter, store and analyze data, information and maps to draw conclusions and indicators that are useful for forecasting in the conditions of the region and the management their resources (Omar and Abdul Samad, 2016; Ismail et al., 2017). Several researchers have studied the soil characteristics using remote sensing techniques and geographic information systems. Ali and others have studied the physical and chemical properties of the soil in the physical units in Muthanna Governorate by using fieldwork and remote sensing technology using GIS software for the study area within the administrative boundaries of Muthanna Governorate for an area of 4654 km^2, The use of Landsat7 TM 2000 satellite and the selection of 6 soil profiles, studied traits, including soil, texture, virtual density, pH, EC, organic matter and calcium carbonate was used in the study. ERDAS 8.4 and ArcView3.3 for the purpose of optimization and engineering And then the process of classification, and the study found that there is a clear difference in the various physical and chemical characteristics studied in the study area. In a study by Muhammad et al. (2017) on the soil of the Eastern Shatt al-Arab region and using fieldwork, 10 pidons was selected and their coordinates were adopted and scientific methods were adopted to analyze the satellite image of Landsat 8 through Erdas and Arc map, It has been classified satellite image based on 5,7 spectral beams and 3 color RGB respectively to form a combination of color is better to distinguish soils study area is the fact that these specialized packages in soil and mineral studies, were soil samples analysis arrived some of the qualities such as Alencjh bulk density organic, salinity, material, etc., and reached The study showed that the texture was soft to medium soft and that the soil of the study area saline as a result of non-exploitation of agriculture and the proportion of organic carbon ranged between 0.40-0.56%. According to Sunita (2016), the most important soil characteristics that can be studied using remote sensing applications are texture, soil minerals, moisture, salinity and carbonate content at the local and regional levels and the various analyses of satellite images through the available software. The researcher Asnake et al. (2017) pointed out that the use of spatial data for the management and sustainability of natural resources is of great importance, especially in the preparation of maps and study the structure or construction of these resources, especially in the field of soil, water and vegetation, and the use of remote sensing techniques and geographic information systems have become factors Encouraging in the study of natural resources. In a study by Nabal et al. (2015) for the use of remote sensing and geographic information systems for the study of some soil characteristics in the Suweida area in Syria, satellite images Landsat ETM had 11 soil samples and used ARC GIS and ERDAS. The most important traits studied were soil texture, Soil porosity and soil depth, the study found that soil, texture ranged from clay to clay - loame and by 36.84% to 63.14%, respectively. In a study of the researcher Engin and Mehmet (2017) to determine the change in soil characteristics using GIS in the Iznik region in Turkey, the number of samples selected for study was 80 samples and 3 depths for each sample are 0-30, 30-60 and 60-90. Soil and especially virtual density and texture by adopting software available in GIS, especially ARC GIS, the study found that there was a change in the percentage of sand, clay and salts by depth, as well as the difference in density from one depth to another. In the study of soil-affected soils using remote sensing techniques, Mohammed and Safa (2013) noted that there is a strong relationship between soil reflectivity and its different characteristics, especially salinity and soil moisture, which helps to use remote sensing and geographic information systems to distinguish and study different earth coverings. EC values between 2-90 ds / m. The aims of this study were to (i) evaluate some ionic composition (Ca, Mg, Na, K, Cl, HCO_3, and SO_4) and soil salinity (SAR and EC) in Baqubah soils and (ii) mapping these selected soil properties to make them easier for researchers to get the require information for management of these soils.

Materials and Methods

Study area

The study area was selected by visiting fields using the Global Positioning System (GPS). The study area is located in Baqubah district which is the capital of Diyala Governorate in Iraq. The area of study are 232,358 km^2 and the coordinates are between 44 ° 35 '21.721'- "44 43° '02.512 north, and 33° 46'47.502" -33° 57'43.223 east. The satellite data was taken on 23/12/2020 from Landsat 8 satellite OLI_TIRS (row 37 and path 168) as shown in Fig. 1.

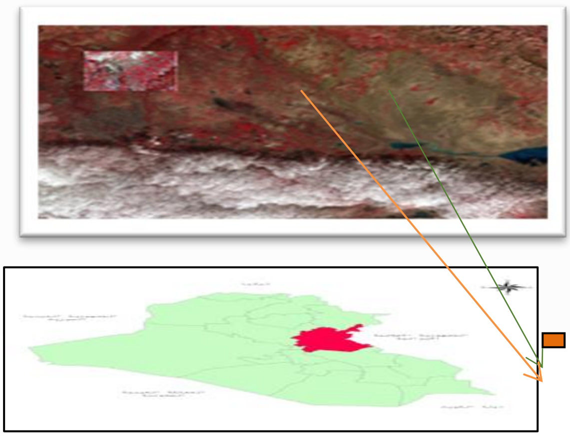

Fig. 1. The satellite image Landsat 8 for the study area in Baqubah is part of Diyala Governorate**.**

The selected area of this study was cut original satellite image by using the Erdas imagine V.2014 program, then by using ArcGIS 10.3.1 and UTM a shape file point layer was created for the 30 sample sites as presented in Fig. 2 and Table 1.

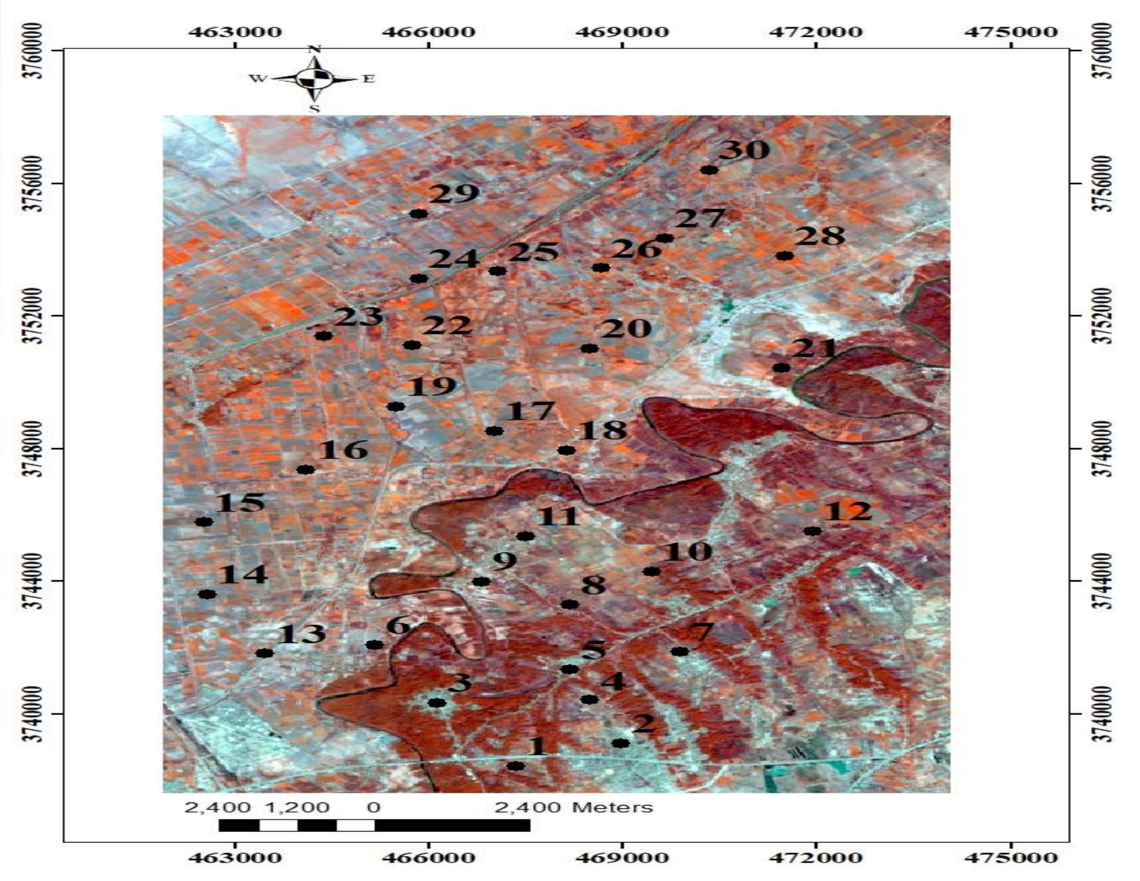

Fig. 2. The satellite image showing site map and samples sites of the study area.

Table 1.
Geographical coordinates and names of study samples

No	Region name	UTM coordinates	
		X	Y
1	Alabara	467285	3738334
2	Alabara	469036	3739130
3	Alabara	466070	3740335
4	Khreisan	468504	3740450
5	Khreisan	468190	3741343
6	Khreisan	465163	3742087
7	Sheikh River	469876	3741889
8	Sheikh River	468190	3743295
9	Sheikh River	466784	3744006
10	Great Zaganeh	469430	3744336
11	Great Zaganeh	467478	3745411
12	Great Zaganeh	471927	3745544
13	Alsada	463460	3741806
14	Alsada	462551	3743658
15	Alsada	462484	3745825
16	Alhadagder	464088	3747382
17	Alhadagder	476999	3748540
18	Alhadagder	468107	3747961
19	Abdul Hamid	465461	3749268

20	Abdul Hamid	468487	3751020
21	Abdul Hamid	471447	3750442
22	Alhakem	465726	3751196
23	Alhakem	464337	3751401
24	Alhakem	465841	3753154
25	Alsawaed	467049	3753336
26	Alsawaed	468619	3753468
27	Alsawaed	469628	3754361
28	Haadmakser	471497	3753865
29	Haadmakser	465841	3755105
30	Haadmakser	470323	3756428

Soil sampling

Soil samples were taken at different locations at the study area from the depth 0-30 cm by using an auger drill. Individual sample was mixed homogeneously and samples were dried, ground by using mortar and pestle and passed through a 2 mm sieve. Then, the samples were stored at room temperature prior to use for analysis.

Soil analyses

The electrical conductivity (EC) of the soils were measured using an EC meter in a (1:1 of a soil to water) (Hesse 1998). Determination of water- soluble basic cations (Ca, Mg, K and Na) and anion (Cl, HCO_3, SO_4) were extracted by end-over-end shaking 4 g soil with 40 mL (1 w:10 v) water for 15 min. The suspension was filtered with 0.45 mm filter paper and the Ca, Mg, K and Na were measured by atomic absorption. The carbonate mineral was estimated using calcemitr and acid HCl-3N as presented in (Al-azzawi et al., 2018). HCO_3, Cl, soluble. Soil sodium adsorption ratio (SAR) was calculated using following equation.

$$SAR = \frac{Na+}{\sqrt{Ca^{2+}+Mg^{2+}}} \quad \text{------------------------ (1)}$$

Table 2.
EC, concentrations of ions and SAR values in soil samples (meq L^{-1})

No	EC	Ca	Mg	K	Na	SAR	Cl	HCO_3	SO_4
1	2.3	4.96	4.8	0.71	5.71	2.59	3.25	1.6	10.45
2	4.09	13.36	13.22	0.42	4.29	1.67	3.85	1.5	25.25
3	3.14	12.76	9.2	0.16	4.69	2	6.25	2.2	16.95
4	7.33	20.76	23.4	0.48	3.31	1	14.4	1.4	42.8
5	5.13	19.36	16.8	1.18	5.09	1.69	12.5	1.3	32.4
6	3.55	13.16	10.6	0.2	1.74	0.71	9.75	1.2	15.55
7	4.29	14.44	14.02	0.69	8.48	3.18	10.95	2	23.05
8	5.47	20.68	19.2	0.26	7.93	2.51	20.75	2.2	26.05
9	5.51	19.36	20.8	1.03	6.01	1.9	7.25	1.8	43.45
10	4.79	24.96	13.8	0.17	1.2	0.39	18.55	2	24.15
11	5.84	25.36	17.6	0.39	7.46	2.28	28.05	1.98	23.17
12	4.97	17.16	17.22	0.22	6.22	2.12	27.75	1.6	14.65
13	2.1	4.16	4.2	0.11	2.94	2.04	6.75	1.42	2.88
14	2.36	8.76	7.8	0.1	1.52	0.75	4.75	2.3	13.45
15	2.43	5.56	8.8	0.11	2.91	1.53	10.75	2.2	5.16

16	0.94	1.76	2.4	0.11	0.94	0.92	2.25	2.4	1.3
17	1.98	6.7	6.4	0.18	1.74	0.96	3.75	2	10.73
18	1.71	2.36	7.2	0.05	2.36	1.53	10.75	2.3	0.91
19	5.84	21.76	25.2	1	8.95	2.61	19.25	4.1	27.85
20	7.96	35.32	40.8	0.57	2.11	0.48	40	4	34.5
21	6.05	17.96	31.8	0.06	8.22	2.33	12.8	2	41.6
22	6.33	25.25	30.6	0.73	5.13	1.37	14.25	2.8	44.55
23	3.65	13.16	13.6	0.25	2.62	1.01	9	2	19.3
24	3.93	13.46	14.1	0.31	6.22	2.37	25.95	2.1	8.51
25	2.39	5.76	5.77	0.41	0.29	0.17	5	2.6	5.11
26	2.25	3.56	4.6	0.87	2.84	1.99	3.25	2.2	6.01
27	2.42	5.16	4.2	1.55	0.28	0.18	2.5	1.9	8.01
28	1.1	2.16	2.8	0.1	0.9	0.81	3.3	1.6	1.31
29	1.01	1.56	2.6	0.3	0.54	0.53	1.9	2	1.34
30	0.87	1.16	2	0.39	1.67	1.88	2.55	1.5	0.44

Results and Discussion

Calcium (Ca)

Calcium is essential nutrient for plant growth and it plays many rules in biochemical functions in plant (Habbasha and Ibrahim, 2016). The soluble calcium in study soils were ranged from 1.16 to 35.32 meq L^{-1} (Table 2). Using ArcMap, the kriging / cokriging analysis was performed to obtain a calcium distribution map for the samples selected at study area in Baqubah as displayed in Fig. 3. Table 2 and Fig. 3, show a difference in soils containing soluble calcium among the sites of the study area. Namely, soil sample (No. 20) showed the highest concentration of soluble Ca (35.32 meq L^{-1}), followed by sample (No. 22) with soluble Ca (25.25 meq L^{-1}). While, the sample (No. 30) gave the lowest concentration of soluble Ca (1.16 meq L^{-1}). From the six classes of soil calcium in Fig. 3, the variety (2.87-5.39) occupied the largest area (63.272) km^2 with a rate of 27.23 %, while the lowest area was the variety (23.02-35.32) by 13.094 km^2 with a rate 5.64 %.

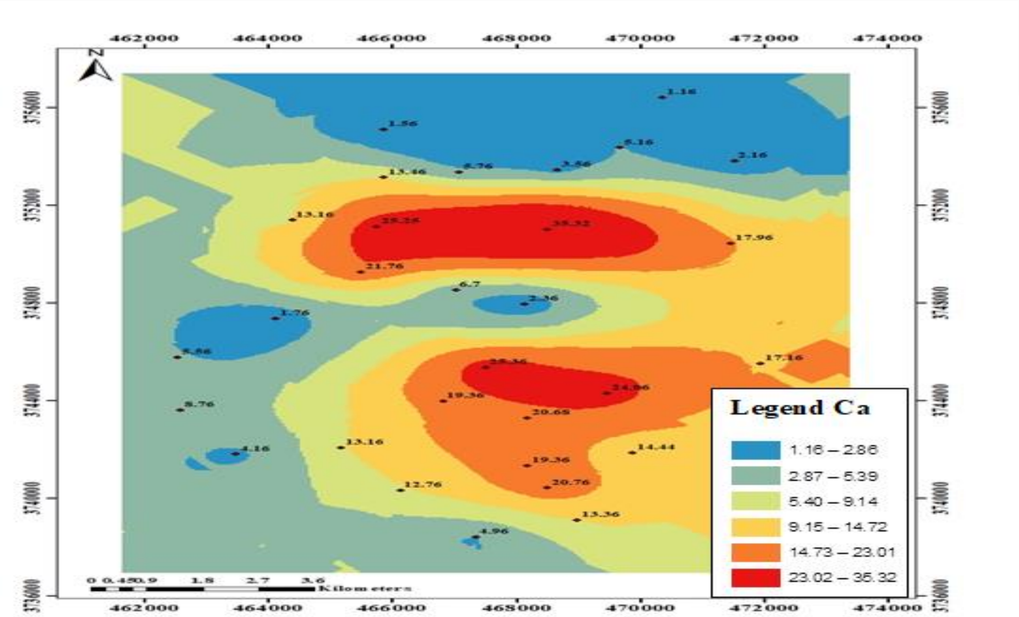

Fig. 3. Map of the spatial distribution of soil calcium for the study area in Baqubah

Magnesium Mg

There was difference in soil Magnesium among the sites of the study area Table 2 and Fig.4. The soil sample (No. 20) showed the highest concentration of soluble Mg (40.80 meq L^{-1}). While, the sample (No. 30) gave the lowest Mg (2 meq L^{-1}). The ArcMap was used to perform a kriging / cokriging analysis to obtain a Magnesium distribution map for the samples selected at study area in Baqubah as displayed in Fig. 4. As shown from Fig. 4, the largest area was the variety (3.31-5.45) with an area of 71.510 km^2 which calculated around 30.78% of total area of study, while the lowest area was the variety (24.67-40.80) with an area of 11.401 km^2 which calculated 4.91 per cent of total study area.

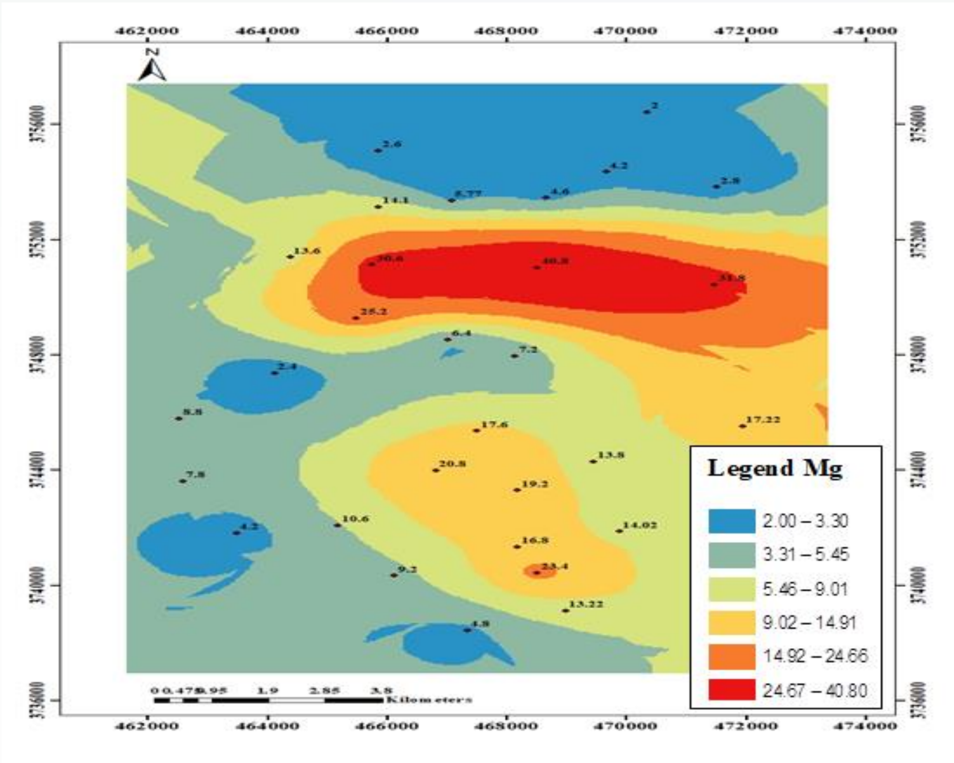

Fig. 4. Map of the spatial distribution of Magnesium for the study area in Baqubah
Potassium K

The highest concentration of soluble K in selected samples was with the sample (No. 5) (1.18 meq L^{-1}), While the sample (No. 18) gave the lowest K (0.05 meq L-1), Table 2. Using ArcMap, we performed a kriging / cokriging analysis to obtain a Potassium distribution map for the samples selected at study area in Baqubah as displayed in Fig. 5. The variety (0.33-0.55) occupied the largest area (59.912 km^2) with percentage 25.78%, while the lowest area was 23.344 km^2 for the variety (0.94 -1.55) which represent around 10.05 per cent of total study area.

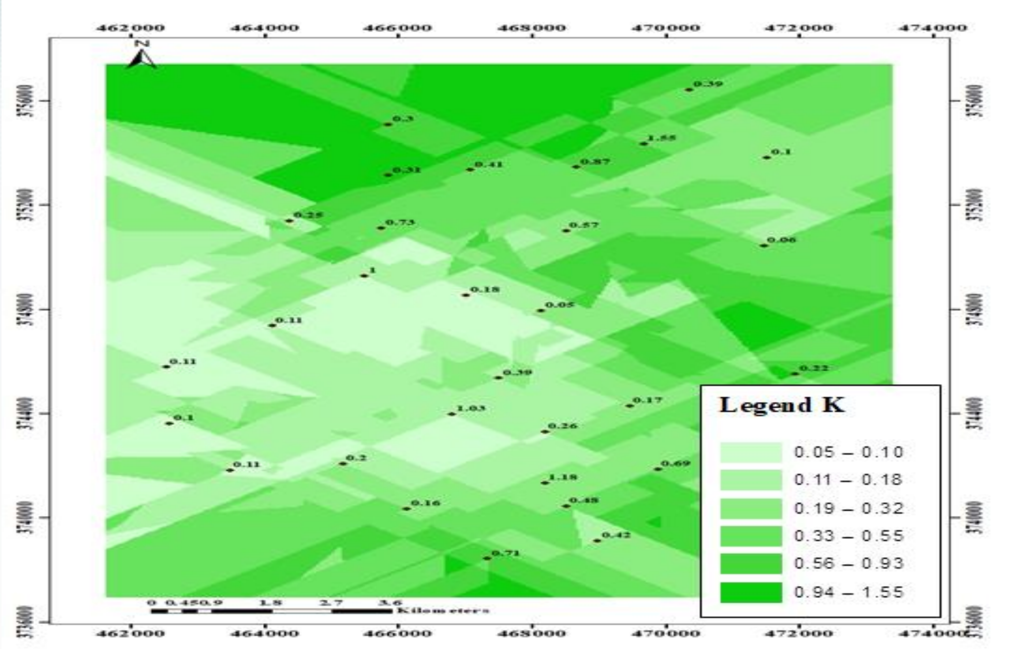

Fig. 5. Map of the spatial distribution of Potassium for the study area in Baqubah
Sodium Na

Table 2 shows the highest concentration of soluble Sodium in sample (No. 19) (8.95 meq L^{-1}), While the sample (No. 27) gave the lowest Na (0.28 meq L^{-1}). Using ArcMap, we performed a kriging / cokriging analysis to obtain a sodium distribution map for the samples selected at study area in Baqubah as displayed in Fig. 6. As the sodium was classified into five classes Fig. 6, the second class (2.58-3.92) occupies the largest area was 56.199 km^2 with total percent area (24.19 %), while the lowest area was (24.640) km^2 for the fifth class (1.37- 2.57), with total area (10.60 %).

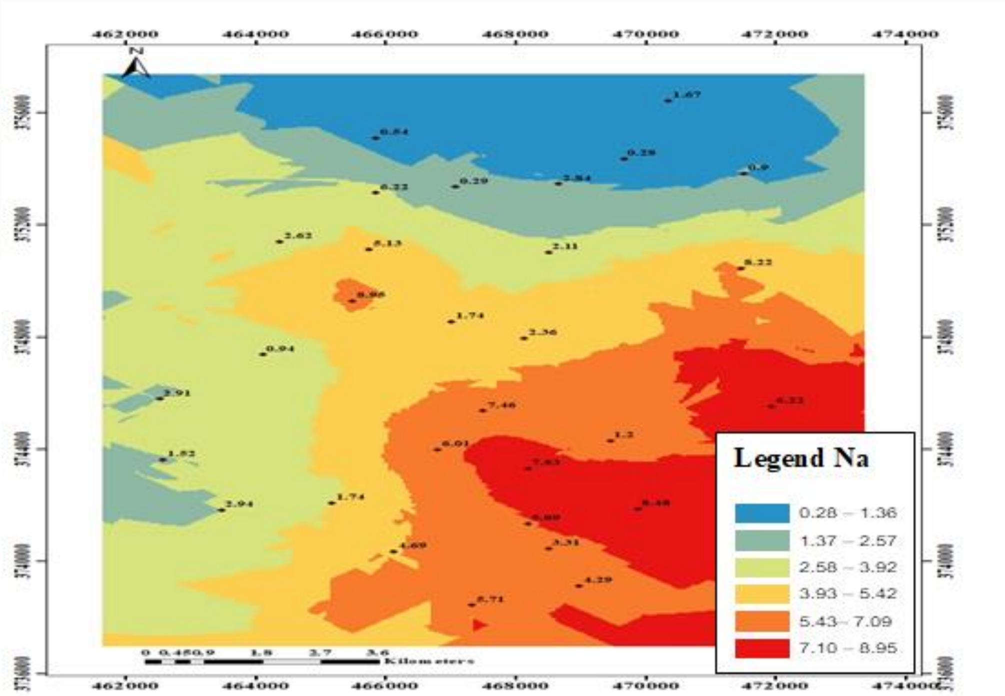

Fig. 6. Map of the spatial distribution of sodium for the study area in Baqubah

SAR

As shown in Table 2, there was differences in SAR values of soil samples for the study area. The soil sample (No. 1) showed the highest value of SAR (2.59 meq L^{-1}). While, the sample (No. 25) gave the lowest value of SAR (0.17 meq L^{-1}). Using ArcMap, we performed a kriging / cokriging analysis to obtain a SAR distribution map for the samples selected at study area in Baqubah as displayed in Fig. 7. The SAR was classified into six classes Fig. 7, and the variety (1.43-1.93) occupied the largest area (49.867) km_2 with a percentage of 21.46%. However, the lowest classes was 22.641 km_2 for (2.52-3.18) which accounted for 9.74 per cent of total study area. From the SAR values for the samples Table 2 which were < 13 can conclude that the samples classify to two class slight and moderate saline soil with considering to the values of EC Table 2 and pH (for all the samples were < 8.5 which were not presented in this study) according to classes of salt-affected soils (Brady and Weil, 2008).

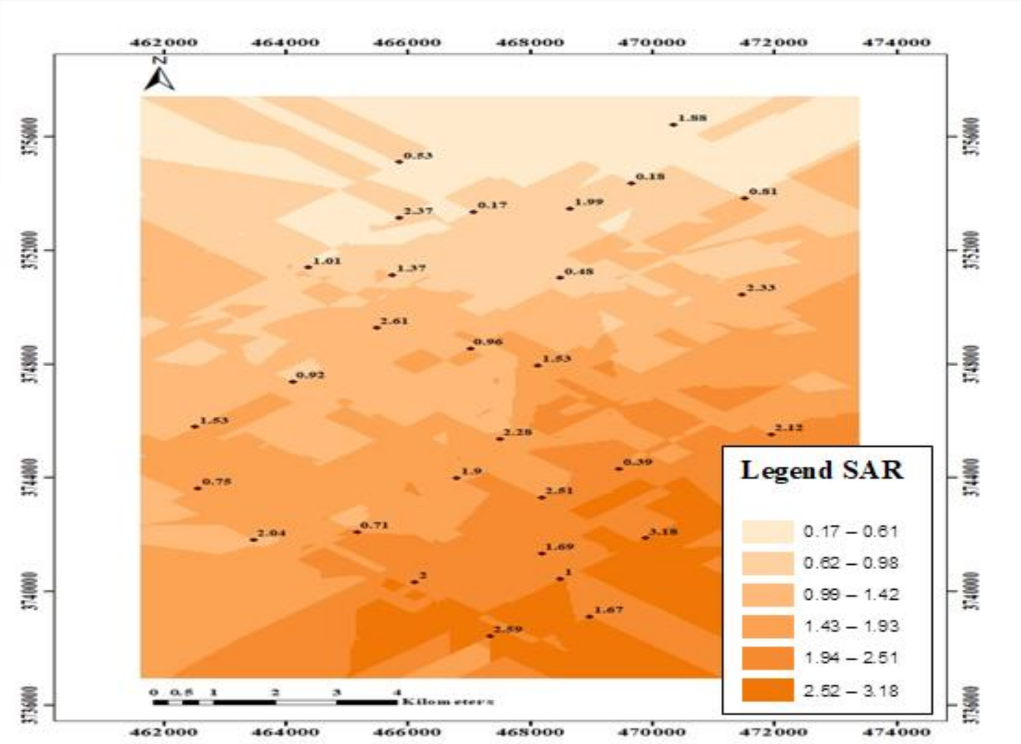

Fig. 7. The spatial distribution of SAR of the study area in Baqubah

Chloride (Cl)

The highest concentration of soluble Cl in sample (No.20 = 40 meq L^{-1}) , While the sample (No. 29) gave the lowest Cl (1. 9 meq L^{-1}). Using ArcMap, a kriging / cokriging analysis was performed to obtain a Chloride distribution map for the samples selected at study area in Baqubah as displayed in Fig. 8. As shown in Fig. 8, the map was divided into six classes of Chloride, the variety (2.88-4.59) occupied the largest area (65.276) km^2 with a rate of 28.09 %, while the lowest area was 3.366 km^2 for the variety (22.79-40.00) and equal to 1.45 %.

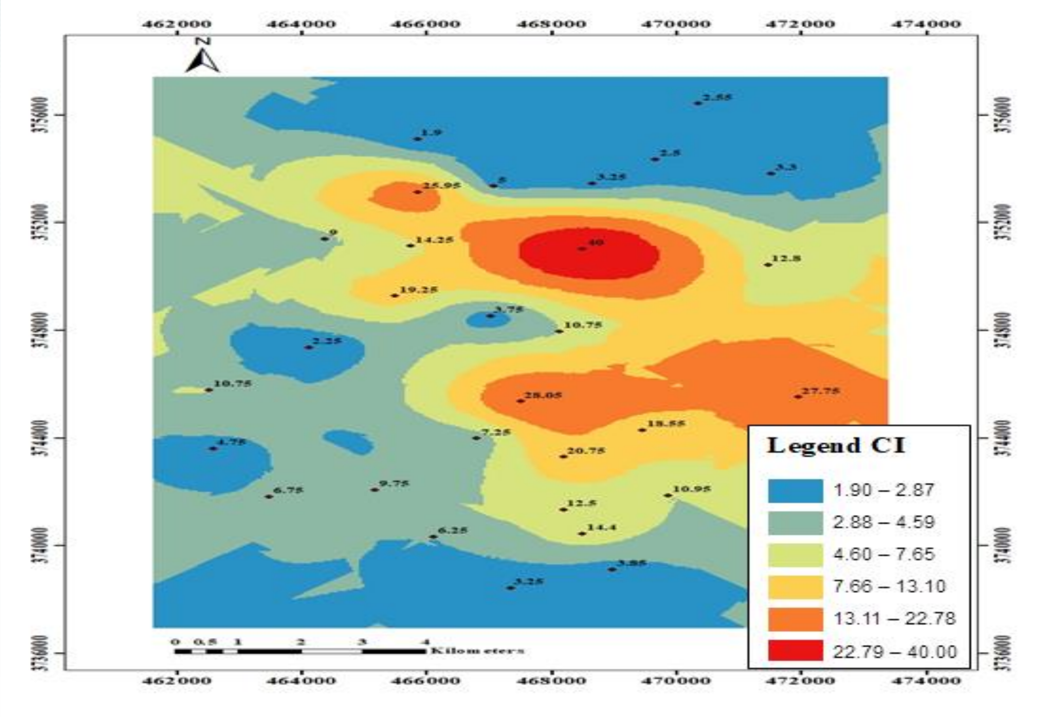

Fig. 8. The spatial distribution of Chloride of the study area in Baqubah

Bicarbonate HCO_3

There was difference in Bicarbonate among the sites of the study area, soil sample (No. 19) showed the highest concentration of HCO_3 (4.01 meq L^{-1}). While, the sample (No. 6) gave the lowest HCO_3 (1.2 meq L^{-1}) (Table 2.). Using ArcMap, we performed a kriging / cokriging analysis to obtain a Bicarbonate distribution map for the samples selected at study area in Baqubah and as displayed in Fig. 9. The HCO_3 was classified into six classes, and the variety (1.74-1.95) occupied the largest area (66.290) km^2 with a percentage of 28.53%, and the lowest value was 8.6071km^2 for (2.80-4.10) which had an area a rate 3.70%.

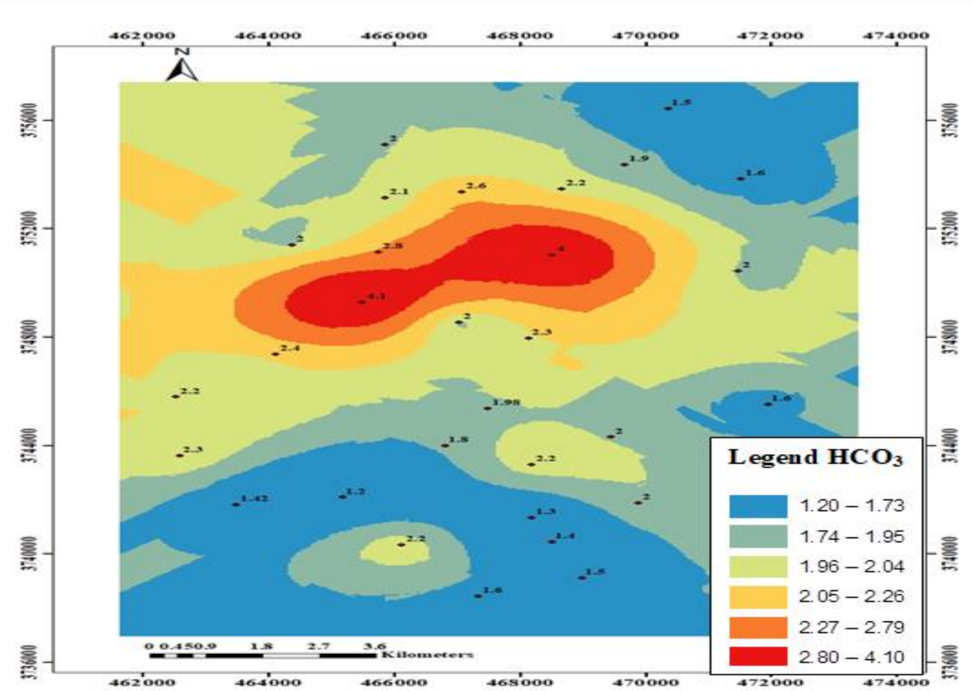

Fig. 9. The spatial distribution of HCO_3 of the study area in Baqubah Sulfate

Sulfate SO_4

The highest concentration of soluble SO_4 in sample (No. 22 = 44.55 meq L^{-1}), While the sample (No. 30) gave the lowest SO_4 (0.44 meq L^{-1}) (Table 2). Using ArcMap, we performed a kriging / cokriging analysis to obtain a SO_4 distribution map for the samples selected at study area in Baqubah and as displayed in Fig. 10. The six classes of SO_4, the variety (4.92-10.27) occupied the largest area (62.149) km^2 with a rate of 26.75%, while the lowest area was 15.487 km^2 for the variety (33.56 - 44.56) and by 6.67 %.

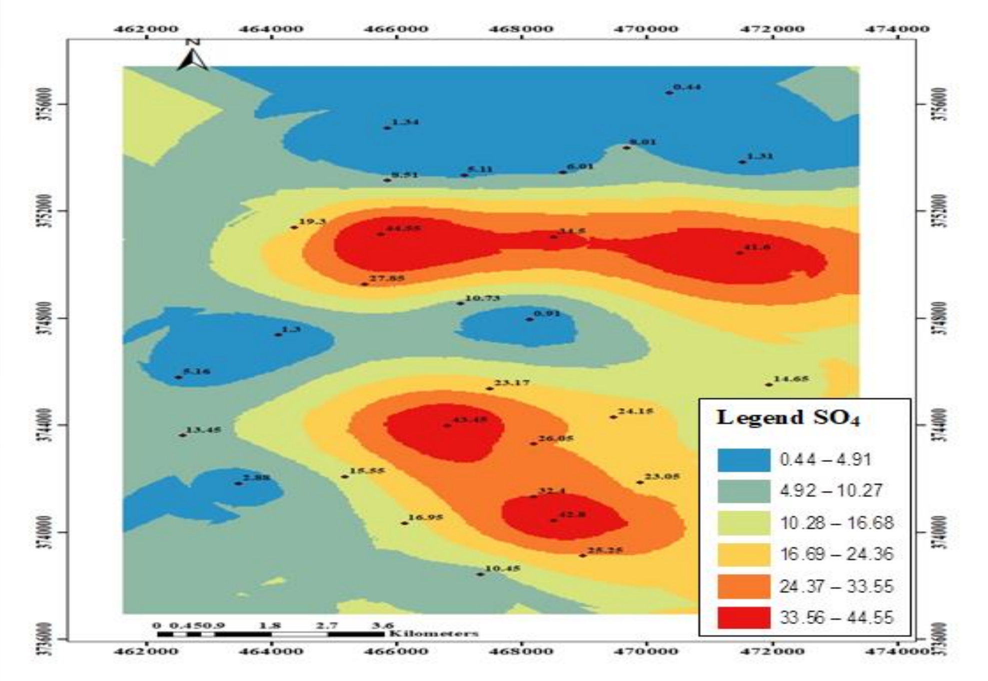

Fig. 10. The spatial distribution of SO_4 of the study area in Baqubah

Soil salinity EC

The highest value of EC in samples was with the sample (No. 4 = 7.33), while the sample (No. 30) gave the lowest EC value (0.87) Table 2.

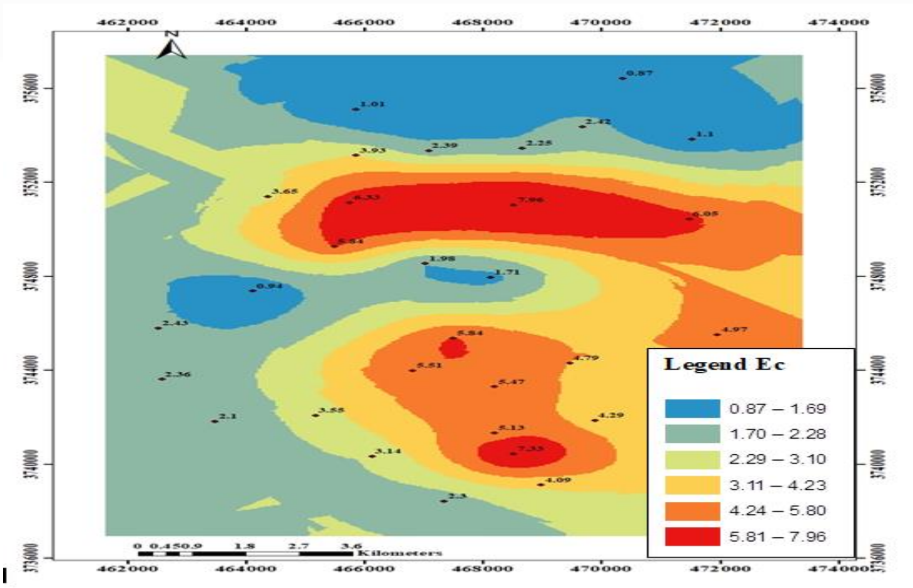

Fig. 11. Distribution of soil salinity (EC) for the study area in Baqubah.

Using ArcMap, we performed a kriging / cokriging analysis to obtain a Soil salinity distribution map for the samples selected at study area in Baqubah as displayed in Fig. 11. For the six classes of EC area Fig 11, the variety (1.70-2.28) occupied the largest area (67.157) km^2 with a rate of 28.90%, while the lowest area was for the variety (5.81-7.96) by 13.492 km^2 and by 5.81 %. From the Table 2 shown the samples with higher EC value were also recorded higher Cl value. This result is agreement with result by Shrestha (2006) who found that there was very strong correlation between Cl concentration and EC value of soil. Depend to the EC values of the samples Table 2, they can categories to two classes normal soils (slight EC < 4) and saline soils (moderate > 4) according to Brady and Weil (2008).

Conclusion

Monitoring soil salinity is useful and simple by using remote sensing data which gives information for large area with time. In this study, the data was presented for Baqubah city – Iraq only for period 2020. All the soil samples can classify to two categories, slightly (normal soil) and moderate (saline soils) according to EC and SAR values. Therefore, it is recommended to use of soil properties and remote sensing data annually to help avoid soil salinization and enhance timely managing strategies for soil reclamation. Keeping monitoring of salt affected areas need continuous updating and that can be achieved with using remote sensing techniques due to field and lab data collection are expensive and time consuming.

Conflicting interest

The authors declare no conflict of interest in the conduct of this research.

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References

Al- Bendawi R, 2014. Interaction between organic fertilization and the amount of water added to the plant nutrient readiness in the soil and (solanum tuberosum L.). PhD thesis, University of Baghdad. college of Agriculture. Iraq.

Al-Azzawi K, Basem R, Al-Bendawi, H, and Al-Saadi K, 2018. Calculation of Calcium Limestone ($CaCO_3$) in soil using CSS technology. Patent of Iraq.

Al-Badairi M, 2018.Preparation of maps of fertility assessment and wheat content in some of the soil of Wasit province using geomagnetic technologies. PhD. thesis. University of Baghdad. college of Agriculture. Iraq.

AL-Duliami A, 2007. Soil color and reflectance and their relationship with some physical and chemical soil properties. M.S. Thesis. Mosul University. College of Agriculture. Iraq

Ali J, Ali H, and Al-Saadi Q, 2015. Determination of Desertification Areas using Remote Sensing Technology and Geographical Information Systems in Muthanna Governorate. Kufa J. Agric. Sci., 7(1):197-219.

Ali N, Hamdallah S, and Abdel Razak A, 2014. Soil Fertility, Arab Society Library for Publishing and Distribution, Amman, Dar Al Kuttab Al-Sallami for Printing, Publishing and Distribution, Baghdad Al-Mutanabi Street.

Al-Khouri E, and Reem B, 2014. The addition of different levels of phosphogisium in the density and the stability of clay soil construction. Al-Baath Univ. J., 36 (10):73-93

Asnake M, Andreas H, and Gete Z, 2017. An automated method for mapping physical soil and water conservation structures on cultivated land using GIS and remote sensing techniques. J. Geog. Sci., 27(1):79-94.

Black CA, 1965a. Methods of Soil Analysis. Part (1). Physical and mineralogical soil properties Am.Soc. Agronom Inc.puplisher Madison ,Wisconsin,USA.

Brady, N. C., Weil, R. R., & Weil, R. R. (2008). The nature and properties of soils (Vol. 13, pp. 662-710). Upper Saddle River, NJ: Prentice Hall.

Day PR. 1965. Particle Fractionation and particle size analysis. IBlack, C. A; D. D. Evans, L. E;

Ensminger, J. L. White, and F. E. Clark (eds.). Methods of soil Analysis Part1. Agronomy9. Am. Soc. of. Agron. Madison,Wisconsin U.S.A.pp.542-567.

Engin O, and Mehmet S, 2017. GIS Usage in Determining the Change of Soil Properties. J. Sci. Eng. Res., 4(5):44-47

Ghauee A, 2016. Natural regeneration of fire-affected forests using remote sensing technologies and GIS in the northern Iraq area of Atroosh. PhD thesis, Mosul University, college of Agriculture, Iraq.

Hesse, P. R. 1998. A textbook of soil chemical analysis. Delhi, India: CBS Publishers & Distributors.

Ismail A, Abdullah R, and Khalaf J, 2017. The use of remote sensing techniques in assessing soil deterioration and vegetation cover west of Makool. Tikrit J. Pure. Sci., 22(4):125-138

Mohamed R, and Abdel Kadhim S, 2013. Study of soils affected by the downstream water using remote sensing techniques. Al-Furat J. Agric. Sci., 5 (2): 239-249.

Mohammed A, Ali H, and Hussain M, 2017. Classification of Soils East of the Shatt Al-Arab Area and Assess their Agricultural Purposes Using Technologies for the Remote Sensing. Assiut J. Agric. Sci., 48 (2) : 139-156.

Nabal A, Waseem S, and Yaghi A, 2015. Use of Geographic Information System and Remote Sensing Techniques in Modeling Water Drainage in the Dahr Al Jabal / Suwayda Region. Damascus Univ. J. Agric. Sci., 31 (2): 121- 134.

NRCS.2005.Soil properties and qualities.Hand book No.: 430-VI-NSSH. USA

Omar D, and Abdul Samad S, 2016.Study of the environmental sensitivity of desertification in the Gemayel area and Zuara in the western coast of Libya using MEDALUS model, remote sensing techniques and GIS. International Geophysical Conference and Exhibition - LibyaGeotech 2, Tripoli, Libya, 6-8 December.

Page A, Miller L, and Kenney D, 1982. Methods of Soil analysis part(2). 2nd ed .Agronomy 9 .Am. Soc. Agron. Madison , Wisconsin .

Shrestha, R. P. (2006). Relating soil electrical conductivity to remote sensing and other soil properties for assessing soil salinity in northeast Thailand. Land degradation & development, 17(6), 677-689.

Sunita S, 2016. Remote sensing applications in soil survey and mapping: A Review Int. J. Geom. Geosci., 7 (2):192-203.

Zare, E., Huang, J., Santos, F. M., & Triantafilis, J. (2015). Mapping salinity in three dimensions using a DUALEM-421 and electromagnetic inversion software. Soil Science Society of America Journal, 79(6), 1729-1740.

Zurqani, H., Mikhailova, E., Post, C., Schlautman, M., & Sharp, J. (2018). Predicting the classes and distribution of salt-affected soils in Northwest Libya. Communications in soil science and plant analysis, 49(6), 689-700.