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Distribution of Gypsiferous Soil Using Geoinformatics Techniques for Some Aridisols in Garmian, Kurdistan Region-Iraq

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Abstract: ***The paper deals with techniques of image classification developed to distinguish gypsiferous soils, using the integration of field observation and remote sensing and more specific Landsat/ETM imagery. A Landsat image was assembled and used in this study. The image was acquired by the ETM/Landsat 7 sensor, which was acquired on August, 2012.Two main data have been used in this research, I) Field and II) Satellite data. The amount of gypsum is different from location to other, may be due to the parent material of some locations of the study area which is rich with gypsum minerals, and there is evidence of Gypsic indopedon horizon. The results indicated that the amount of organic matter decreases with increasing the amount of gypsum. In general, the study area is rich with total lime. These results reflect the effect of decalcification and calcification processes caused the formation of illuvial subsurface (calcic) horizon in some location of the study area.***

The pH values were around neutral to slightly alkaline due to the effect of calcareous parent material and type of climatic conditions. The low ECe values indicate that the soil was non-saline reflected by low values of ECe. The soil classes of the study area are belonging to Haplogypsids, Haplocalcids, Haplocambids, Calciargids and Haplargids. Two maps were prepared to show the distribution of gypsiferous in the study area, the first one is map which shows the output of supervised classification and maximum- like hood for specific, and the second is the thermal-based classification. Thermal-based map could predict the gypsiferous area in a better way, than the classification based only on spectral properties of non-thermal bands.

Key word: Gypsiferous, Aridisols, Remote Sensing, Landsat/ETM imagery, indopedon horizon, Thermal-based map.

1. Introduction

The studies on the distribution of gypsum in Iraqi Kurdistan through a very rare technique were not exist, especially in Garmian Kurdistan region, where the gypsum is important components in several areas such as agriculture, engineering and industry. Where soils gypsum spread over large areas of the world's dry, arid and semi-private regions, including Iraq, where cover more than 1.2 million hectares and about 28.6% of the soil cover of Iraq [1], [2].

Gypsiferous soils represent serious problems in many fields of human activity. They have dramatic impacts on buildings and infrastructure. The gypsiferous soils consist of a secondary gypsum-rich crust within the soil, developed after sedimentation of the soil material by increasing evaporation of saline and sulphate-rich groundwater in arid and warm regions. In fact, gypsiferous soils retain most of the original soil components (clay, silt and sand) but, impregnated by variable amounts of gypsum; as nests or disseminations. Fine-grained soils contain more gypsum than coarse grained soils [3].

Many soil scientists and engineers have studied the gypsiferous soils in variable locations of the world and for different purposes, i.e. agriculture, surveying, civil engineering etc. Among those scientists and engineers, some have given different gypsiferous soils classification systems [4], [5], [6], [7], [8], [9], [10], [11], [12], [13]. Many researchers noticed that the coefficient of compressibility and the in-situ void ratio increase with increasing gypsum content. Also they found that wetting of gypsiferous soils contributes in increasing of compressibility due to gypsum removal and collapse. [14], [15], [11], [16], [17], [18], [19], [20].

Remote Sensing (RS) data and techniques have been widely used to observe the Earth and getting reliable information about the under, above and on the surface of the Earth. Soil science, like many other scientific fields has been using the privileges of RS for more than two decades and there are many remotely sensed models to detect mineral, solve soil challenges, and show different mineral distribution on the Earth's surface. In the field of detecting and mapping gypsum and gypsiferous area distribution, RS shall be used effectively as done in many studies. [21] produced thematic maps indicating gypsiferous, and clayey surface using Landsat/TM bands 3,4, and 5. They declared that TM is valuable aid for mapping soil in arid regions. [22] used decorrelation stretch methods applied on Landsat TM data to map halite, gypsum and their Chilean salt flat. [23] used Landsat TM imagery and spectral mixture analysis to show gypsum, halite, vegetation, and moisture in the Chott el Djerid salt playa, Tunisia. [24] carried a study to identify and decline gypsum mined soils in parts of Coimbatore district, Tamil Nadu State, India using RS focusing on SPOT1 images. [25] used Thermal Infrared Multispectral Scanner (TIMS) to map playa evaporate minerals such as gypsum, and halite at Death Valley, California. The research is focusing on the following aims:

1. Distribution of gypsiferous soil using geoinformatics techniques.
2. Classification of gypsiferous soil.

3. MATERIALS AND METHODS

2. 1. Description of the study area

Garmian is a widely region of Kurdistan, the study area is lies between latitude 34° 36′ 49.3″ in Teran Agha vilage to
34° 46′ 57.6″ N in Kany Maran and longitude 44° 50′ 49.5″ in Kngrean to 45° 35′ 44.7″ E in Masjed village.
The elevation of study area ranged between 161.5 meters in Kngrean village and 487.1 meters in Kany Krmange village. The soil map units of the study area were obtained from the soil map units of Garmian, Iraqi Kurdistan region prepared by [26]. The data of latitudes, longitudes and elevations of soil sample locations were collected using a (GPS) receiver model GARMIN 72.
Geologically the study area lies within the foot hill physiographic unit for Iraq [27], as well as in the tectonic side, it is located in folds' zone [28]. Climate of the study area is continental semiarid by PE (Pontential Evaportrasiration) according to [29]. Soil moisture regime of the study area described as Torric [30]. While the soil temperature regime is hyperthermic [31]. The native vegetation including *Cynodon dactylon*, *Ammi majus* and *Alhagi graeccorum* [32]. The cultivation in the study area depends only on the rainfall.

2.2. Field work

Soil map units prepared by [26], reconnaissance soil survey map prepared by [33] and topographic map [34] were used as basic maps for this study. A total of 52 location of the study area were selected using a grid system method. The locations of points were georefrenced on the satellite image (August, 2012) after coordination of each point was selected. The coordination of each point on the ground was determined using GPS device. Samples of surface soil from a depth of (0-30 cm) were taken from each location (Figure 1). Samples were air-dried, grinded and passed through sieves of (2 mm) opening diameters to determine gypsiferous soil. ArcGIS software package was used to map the gypsiferous soil units.

2.3. Remotely sensed dataset

2.3.1. Remotely sensed

This paper deals with techniques of image classification developed to distinguish gypsiferous soils, using the integration of field observation and remote sensing and more specific Landsat/ETM imagery. A landsat image was assembled and used in this study. The image was acquired by the Landsat 5 TM sensor, which was acquired on 3rd August, 2012.

2.3.2. Dataset

Two main data have been used in this research, I) Field and II) Satellite data. Field data include about 45 soil samples with a widespread distribution. The samples have been all tested in the library to see the presence of gypsum.
The satellite data used in this study is Landsat 7 Enhanced Thematic Mapper Plus (ETM+) Level-1G data which have eight bands sensitive to various wavelengths of Visible Infrared (VNIR), Short Wavelength Infrared (SWIR), and Thermal Infrared (TIR) [35]. Landsat 7 ETM+ Level-1G data were radiometrically and geometrically corrected to the same map projections, image orientations and spatial resolution. The image which is used in this study is taken in September which vegetation cover in the study area is rare.

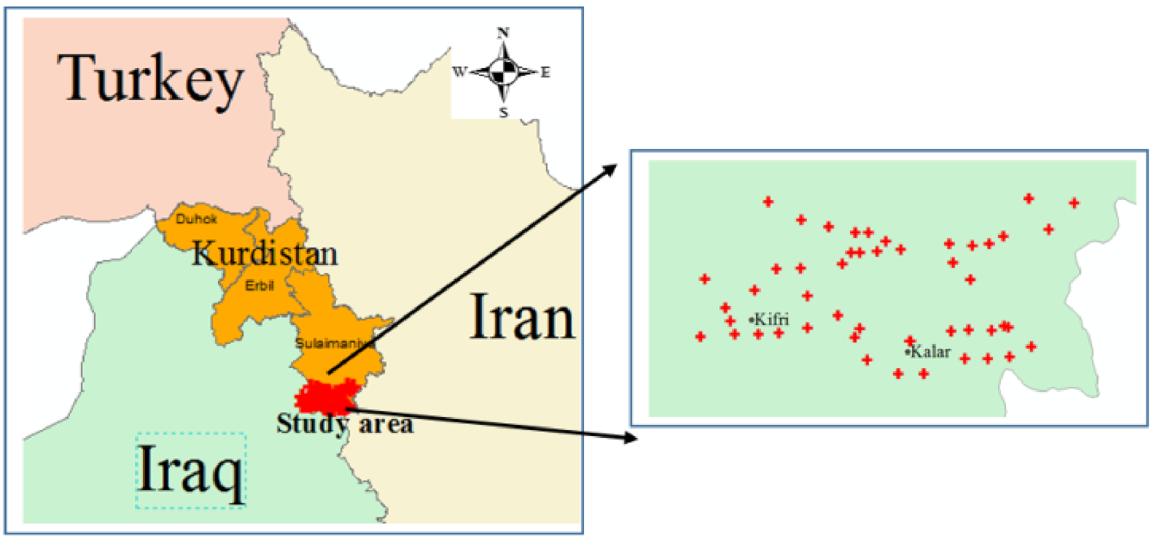

Figure 1: The study area (left) and the way sample points are distributed in the area (right).

2.4. Processing

2.4.1. Laboratory analyses

Soil samples were air dried and mixed to be homogenous, grinded using wood mortar, then passed through 2 mm sieve and kept in plastic containers for Gypsum. Gypsum was determined by shaking 5 gm of soil sample with distilled water and then the gypsum was measured according to the acetone precipitated method [36], [37], [38].

2.4.2. Satellite analysis

Considering different suggested methods for different cases it's decided to use supervised classification. Two kind of classifications have been used resulting in two outputs which lets us to make a comparison different ways and different bands capability, besides assessing the ability of RS to map gypsum in the study area. Using Maximum-likehood classification, at the first place, tried to classify the image using three samples, as training control point, this had been analyzed precisely in laboratory. To get rid of noises, as well as, unnecessary data in the image the classification was proceed with applying Principle Component Analysis (PCA) function on the image [39]. The second scenario was, actually, using thermal band to classify the image knowing that gypsiferous areas show quite specific reflection behavior in thermal bands [40]. Thermal bandshelp thorough displaying Land Surface Temperature (LST). The temperature calibration of the thermal infrared band into the value of ground temperature has been done using the equations below (Eq. 1 and 2), [41].

$$L=L_{min}+((L_{max}-L_{min})/255) \times Q \text{ .... [Eq.1]}$$
$$T=K2 / (\ln (K1/L+1) \text{ .... [Eq.2]}$$

Where L: Value of radiance in thermal infrared.
T: Ground temperature (K).
Q: digital record.
K1,K2: calibration coefficients.
Annual soil temperature (ta) can be predicated from the corresponding annual air temperature (Ta) according to the relationships suggested by the USDA soil taxonomy as:

$$ta = Ta +1^{\circ}C \text{...... [Eq.3] [41].}$$

Only three control points, among about 45 tested field points, have been used to train and classify the satellite image (table 1). The rests have been used to assess how accurate the developed maps could show the distribution of gypsum in the study area. It should be mentioned that the study area is mostly of no tree and very little vegetation cover at the date the image has been taken. Therefore, the thermal band mostly shows the soil surface.

Points	Latitude N	Longitude E	Gypsum g kg $^{-1}$
1	514055	3831740	281.82
2	502174	3843000	219.38
3	494706	3848480	234.78

Table 1: Points which are used to train the model.

3. Results and Discussion

3.1. Gypsum

The results of (table 2) indicated that the amount of gypsum is different from location to other, the high amount was 533 g kg^{-1} soil in Serchem may be due to the parent material of some location of the study area which is rich with gypsum minerals, and evidence of Gypsic indopedon horizon is present [26]. While the lowest amount of gypsum was 0.98 g kg-1 soil recorded in Chala Rash due to parent material which is calcite materials from the soil slum [26].

3.2. Organic matter (OM)

It is clear from the (table 2) that the study area is poor with vegetation cover, where the highest amount which record was 22.46 g kg $^{-1}$ soil in while the lowest amount was 8.02 in Pera Mony because of low rainfall ratio in the region. In general, the results indicate that the amount of organic matter decreases with increasing the amount of gypsum, and thus which mentioned by [43], where Gypsum affects the decomposition of organic matter as a result of increasing the concentration of calcium and sulfate in the soil solution in a way that affects the activity of organisms and its enzymes and there may be an effect of calcium carbonate for the packaging of organic matter [44]. Also the results agree with the results which obtained by [45], where confirmed that the calcium carbonate is a wrapper around organic matter, when he said that the solubility and re-deposition of gypsum may lead to the creation of gypsum covers around the organic material that protects the organic matter from attacking the organism. It is possible that there will be complexes of organic matter (especially polysaccharides) and dissolved calcium ion, which will increase in quantity in gypsum soils, leading to the increase of such complexities. These complexes inhibit the activity of organisms and their enzymes in the decomposition of organic matter [46].

Table 2: The soil sample locations names, their coordinates and some chemical properties.

No.	Soil sample location name	Latitude N	Longitude E	Gypsum	O.M.*	Total L.**	pH	ECe
		(D M S)		g kg-1 soil			(extract)	(ds/m)
1	Kangrean	44°50'46.736"	34°39'15.2"	510.42	8.15	285	7.37	2.76
2	Karez	44°55'24.775"	34°39'34.809"	530.31	8.70	265	7.12	1.87
3	Serchem	44°58'44.885"	34°39'34.889"	533.71	9.34	250	7	0.98
4	Dwanza Emam	45°1'36.41"	34°39'43.474"	484.11	11.22	245	7.1	0.87
5	Gakoli	45°5'25.147"	34°40'13.428"	422.02	15.39	275	7.01	0.79
6	Die Bne	45°13'35.808"	34°36'40.197"	100.36	20.76	255	7.38	1.02
7	Rezgary	45°12'34.5"	34°40'15.2"	3.47	14.88	185	7.51	0.94
8	Qelai Sherwana	45°17'25.274"	34°35'11.094"	3.35	15.33	255	7.66	0.81
9	Wali Aga	45°21'9.612"	34°35'10.503"	2.71	13	245	7.64	0.77
10	Teran Aga	45°26'42.584"	34°37'6.234"	3.05	10.38	250	7.51	0.99
11	Sobhana	45°30'18.609"	34°36'51.649"	4.25	11.80	235	7.44	0.87
12	Seid Mostafa	45°32'56.573"	34°36'58.182"	2.11	8.16	280	7.53	0.96
13	Kany Sheran	45°35'50.623"	34°38'8.064"	3.27	8.23	260	7.41	0.89
14	Masjed	45°35'45.801"	34°54'41.009"	4.49	8.11	280	7.56	1.04
15	Palgy Bchook	44°54'11.499"	34°42'31.836"	493.96	8.19	285	7.47	3.22
16	Kifri	44°54'54.102"	34°41'3.608"	528.39	11.92	280	7.45	2.61
17	Goban	44°58'12.002"	34°44'32.3"	477.80	11.73	260	7.48	2.51
18	Weli Hayer	45°5'24.202"	34°43'52.3"	96.00	10.52	215	7.49	1.08
19	Aola Qot	45°9'34.504"	34°41'39.473"	41.14	12.31	195	7.40	0.96
20	Shakel	45°11'53.999"	34°39'14.664"	2.31	14.84	175	7.53	0.97
21	Kalar	45°19'39.106"	34°38'57.522"	4.12	20.81	285	7.65	1.07
22	Ban Zamen	45°25'2.597"	34°39'52.762"	1.97	22.46	280	7.62	0.74
23	Sangary saroo	45°27'22.401"	34°40'1.037"	2.07	19.47	240	7.65	0.63
24	Sangary Chwaroo	45°30'31.303"	34°39'59.165"	2.19	19.53	255	7.69	0.65
25	Chwar Shakh	45°1'11.9"	34°46'51.172"	152.88	8.09	265	7.45	1.43
26	Kany Maran	45°4'32.201"	34°46'57.536"	37.19	14.26	235	7.66	1.07
27	Mlesora	45°10'11.903"	34°47'27.909"	12.63	18.57	220	7.61	0.88
28	Peaza Jar	45°11'22.101"	34°48'41.236"	4.80	18.59	215	7.64	0.82
29	Poqa	45°12'36.601"	34°48'41.945"	3.72	18.08	205	7.60	0.95
30	Kany Chapllay Saroo	45°14'58.501"	34°48'49"	2.91	17.17	180	7.60	1.02
31	Torka	45°18'9.401"	34°49'0.7"	1.33	16.89	225	7.63	0.77
32	Zamawanga	45°25'17.803"	34°47'30.901"	1.88	17.95	255	7.54	0.56
33	Chala Rash	45°27'40.098"	34°45'37.972"	0.98	9.41	275	7.52	0.32
34	Kany Pamo	45°32'51.797"	34°40'18.409"	1.92	11.63	250	7.82	0.28
35	Barda Soor	45°32'15.497"	34°40'26.135"	3.55	19.05	255	7.81	0.74
36	Kany Krmange	45°38'25.401"	34°51'11.901"	3.66	14.77	205	7.51	0.79
37	Zenanei Bchook	44°51'24.103"	34°45'44.436"	209.40	8.16	280	7.43	3.16
38	Pera Mony	45°0'7.199"	34°54'23.209"	243.30	8.02	240	7.52	1.64
39	Tapa Spi	45°4'34.6"	34°52'19.272"	120.30	9.30	230	7.54	1.13
40	Zhalan	45°8'20.404"	34°51'33.201"	31.80	13.70	200	7.64	0.76
41	Hawaralara	45°11'58.003"	34°50'58.001"	22.90	15.93	255	7.63	0.65
42	Hawara Barza	45°13'43.701"	34°50'56.909"	7.30	15.02	240	7.72	0.604
43	Garmic	45°16'7.103"	34°49'58.774"	3.10	12.70	235	7.62	0.58

Table 2: The soil sample locations names, their coordinates and some chemical properties (complement).

No.	Soil sample	Latitude N	Longitude E	Gypsum	O.M.*	Total L.**	pH	ECe

	location name	(D M S)		g kg-1 soil			(extract)	(ds/m)
44	Soferahim	45°41'55.701"	34°54'6.601"	2.60	11.31	235	7.64	0.55
45	Jolal Kawa	45°24'48.701"	34°49'39.937"	1.70	11.83	230	7.63	0.57
46	Bawanor	45°27'58.398"	34°49'27.435"	1.00	14.26	200	7.71	0.51
47	Ali Pacan	45°30'13.299"	34°49'38.673"	2.50	17.84	155	7.79	0.73
48	Shawaze	45°32'14.703"	34°50'26.239"	3.42	14.83	205	7.54	0.81
49	Palgy Gaora	44°56'20.875"	34°46'43.167"	234.75	8.80	280	7.44	2.56
50	Ebrahim khan	45°1'17.518"	34°43'36.394"	219.38	9.32	245	7.43	1.96
51	Sei Malale	45°9'12.821"	34°37'35.29"	281.82	12.39	205	7.45	0.99
52	Nehrwan	44°48'33.26"	34°40'35.482"	385.07	8.00	295	7.45	3.04

*= Organic Matter, **= Total Lime

3.3. Total lime

Table (2) show that the amount of total lime is ranged between 155 g kg -1 soil in Ali Pacan and 285 g kg -1 in Kangrean and Masjed., in general the study area is rich with total lime because the parent material is calcareous. These results reflect the effect of decalcification and calcification processes caused the formation of illuvial subsurface (calcic) horizon in some location of the study area.

3.4. Soil reaction (pH)

The pH values in (table 2) were around neutral to slightly alkali due to the effect of calcareous parent material and type of climatic conditions. The lowest pH value was 7 in Sercham, while the highest value was 7.82 in Kany Pamo.

3.5. Electrical conductivity (ECe)

The ECe values which shown in (table 2). indicate that the soil was non-saline reflected by low values of ECe. The low soluble salt contents in all location may be due to natural of parent material. In general, the values of ECe of study area ranged between 0.28 ds/m in Kany Pamo, while the highest values were 3.22 ds/m in Palgay Bchook.

Mentioned that the soil of the study area is belong to Haplogypsids, Haplocalcids, Haplocambids, Calciargids and Haplargids. [26].

3.6. Mapping

Classification, as per the methods applied, resulted into two maps (figures 2 and 3). The training points are shown in black triangles, while other field points, which are used as check points, are displayed in different shapes and colors. Figure (2) shows the map which shows the output of supervised classification, maximum- likehood for specific. At the second place, (figure 3) is of the thermal-based classification. Both maps show probable gypsiferous areas in form of some discrete points which their density displays the attendance of gypsum in different places. According to the check points which cover a wide range of gypsum attendance, from about 2 mg to more than 500mg, thermal-based map (figure 3) could predict the gypsiferous area in a better way, than the classification based only on spectral properties of non-thermal bands (figure 2). This results agree with the results of [40] where they explore the possibilities of distinguishing saline from gypsiferous soils, using remote sensing data, especially the Landsat TM sensor. They used supervised image classification to differentiate gypsiferous from other soils as well. Their study offered thermal band of the Landsat TMsensor as the best way to differentiate between gypsiferous and saline soils. It was shown, furthermore, that TM thermal band is quite reliable for mapping soils containing gypsumin a relatively fast and accurate way.

In many areas both maps present gypsum distribution almost the same way, but for the areas of high gypsum attendance, thermal map act, considering field points, more accurate (figure 4). For instance, as seen in (figure 4), the overlap between points of high gypsum (green and blue triangles) and map’s predicted gypsiferous area is higher in the left map, which is thermal-based map. While, in predicting the areas of low gypsum attendance the both map, almost, are doing the same way, as well as, satisfying.

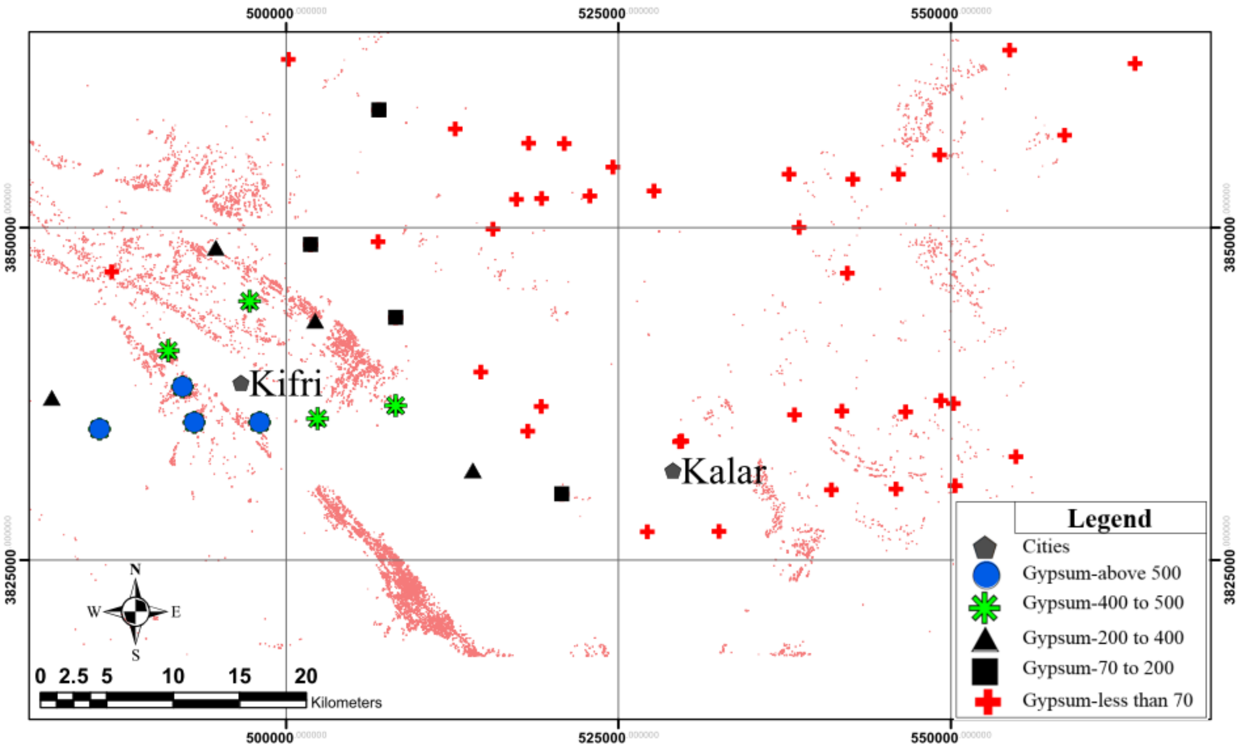

Figure 2: Supervised classification (maximum likehood), preceded by applying PCA on the satellite image. Down-right legend shows the field point and their gypsum level in (mg).

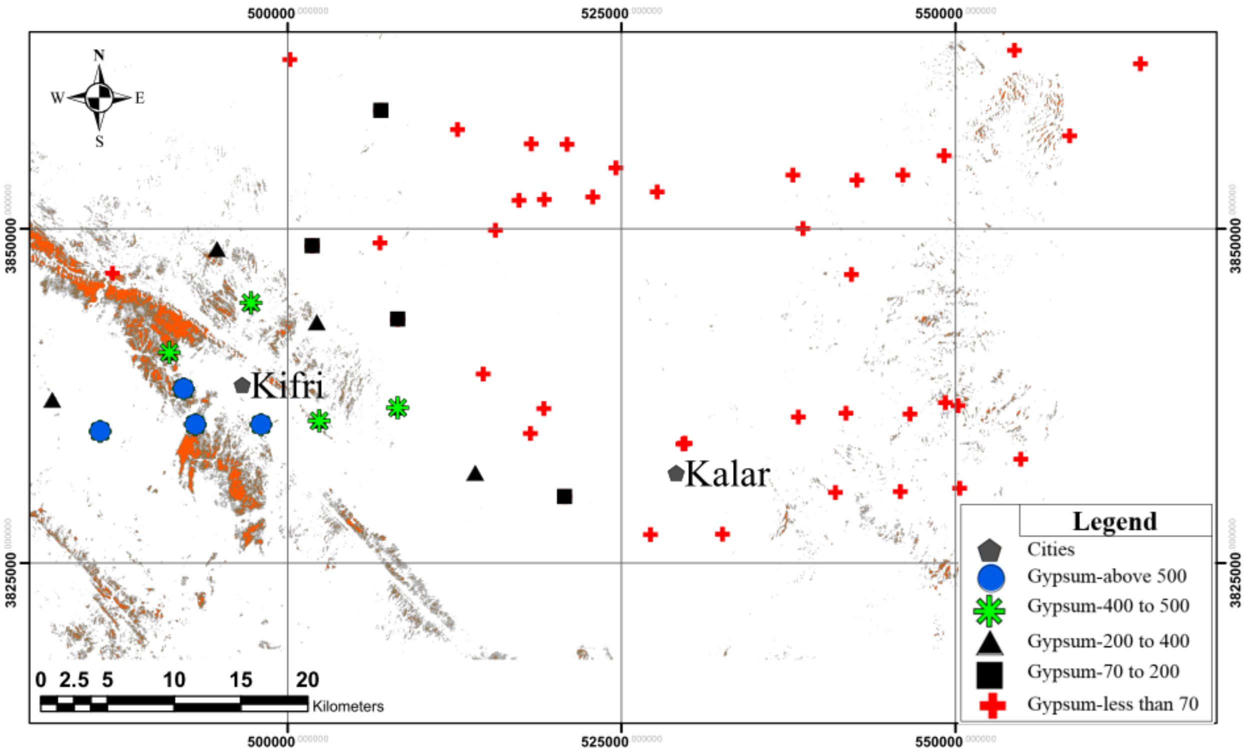

Figure 3: Thermal-based map. Upper-left legend shows the temperature in Kelvin, while down-right legend shows the field point and their gypsum level in (mg).

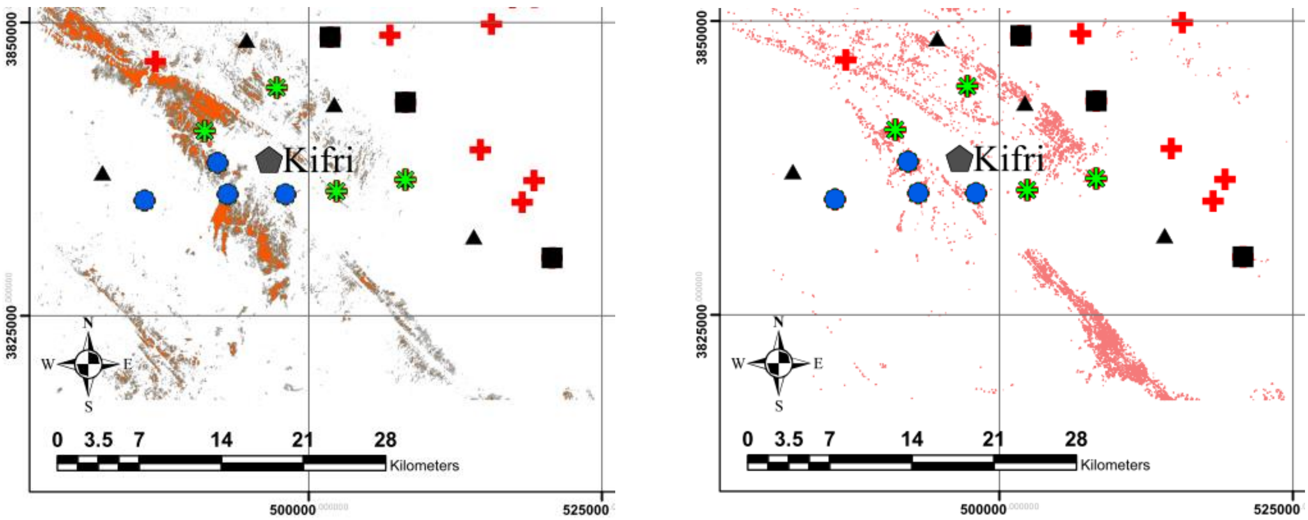

Figure 4: Comparison between two applied methods in terms of precision for prediction high gypsiferous areas. The left is thermal, while the right is supervised non-thermal classified map.

4. RECOMMENDATIONS

It's suggested to use different satellite resources with different spatial and spectral resolution (e.g. Hyperion and Spot), to get more precise and reliable outputs. According to the outputs, therefore, it can be implied that remote sensing integrated with field observations, as control points, can be used successfully to find out where, and to what level, may contains gypsum. It should be mentioned that the precision of the estimation is strongly depends on the spectral and spatial resolution of the image and field observations, as well as the method and necessary corrections which may be needed to be applied on the satellite image.

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