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Description and classification of the dry marsh soil in Al-Muthanna Governorate using geospatial technologies

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Abstract

This study was conducted in the Al-Luqta Al-Jaf marsh area, located within the administrative boundaries of Al-Muthanna Governorate, which lies between the longitudes 30'24°45" and 30'36°45" East and the latitudes 0'21°31" and 0'27°31" North, covering a total area of approximately 20,860 hectares. The purpose was to describe and classify its soil using remote sensing technologies and Geographic Information Systems (GIS). Soil units were delineated using remote sensing technology by employing satellite imagery from the Landsat-8 satellite, captured on 06/17/2024, with twelve spectral bands, and necessary corrections were applied. The unsupervised and supervised classification methods, along with digital indicators, were utilized to prepare a soil units map using Arc Map 10.8, in addition to field observations and the region's topography, to delineate the map units representing the expected soil types in the study area. Where 12 auger drilling sites were identified, six pedons were discovered, and their morphological and genetic descriptions were conducted. Soil samples were taken from each horizon of these pedons for physical and chemical analyses. Subsequently, soil classification was performed, and the results were compiled in a Geographic Information System (GIS) environment to produce the required final maps. The study concluded that: 1- The results of the physical analysis showed a variation in texture in both vertical and horizontal directions, with textures ranging from fine to medium in the soil pedons of the study area, dominated by silt and clay particles and a low percentage of sand. The lowest values of bulk density were found at the surface horizons and increased with depth. 2- The chemical analyses showed that the electrical conductivity values for the soil horizons in the study area ranged between 5.27-38.24 decisiemens m-1 as a weighted average for each soil profile. In the horizons of Pedon 1, the soils ranged from non-saline to low salinity, while the horizons of Pedon 5 were highly saline. The soil pH values ranged from 7.50 to 7.87 as a weighted average per pedon, indicating a neutral to moderately alkaline reaction. It was also observed that the gypsum content decreased in all the study plots, which can be attributed to the nature of the parent material, as well as agricultural exploitation due to the geographical location and the continuous leaching processes these soils undergo during irrigation periods. Due to the fact that the parent material is a limestone-rich sediment, there is a variation in the vertical distribution of calcium carbonate across all horizons of the study plots, ranging between 258.1-498.9 g kg^-1 as a weighted average per plot, with a uniformity with depth. As for the organic matter of the pedons, it ranged between 3.46-10.35 g kg^-1 as a weighted average for each pedon, with the highest values appearing in the surface horizons, particularly in pedons 1 and 2. 3- The results of the morphological, physical, and chemical properties, based on the modern American classification, show that all the pedons fall within the Entisol order. They were classified under the Fluvents suborder and the Torrifluvents great group, and under the Typic Torrifluvents sub-group. Six series were identified: TM556, DM97, TM977, DM97, MM6, and DF97. 4- Unsupervised and supervised classification were conducted on the satellite imagery used for the study area, and the unsupervised classification results suggested 6 land cover classes. The supervised classification was performed on the data after identifying the spectral signatures for each land cover type in the study area. The results indicated the presence of three types of land cover, and six soil pits were selected and described morphologically, in addition to 12 auger holes where the physical and chemical properties of the soil were measured.

Key words: Soil classification, dry marshes, geographic information systems, remote sensing, visual classification

Introduction

Soil is one of the most important natural resources that form the foundation of life on Earth, playing a vital role in agricultural production and maintaining ecological balance. In light of the increasing challenges posed by climate change and human pressures, precise soil studies have become an urgent necessity to ensure environmental and agricultural sustainability (Lal, 2020). The study area holds particular significance, as it represents an example of arid environments suffering from soil degradation and desertification, necessitating systematic studies to assess its natural resources.

Remote sensing is defined as Remote sensing is the science and art of obtaining information about a target, area, or specific phenomenon through the analysis of information obtained by a device that does not touch the targets to be studied. It is used in various fields, including forest studies, agricultural crop monitoring, desertification, land degradation, land use, and soil classification. It should be noted that remote sensing technologies are not a substitute for any traditional technology or method in studying agricultural resources; rather, they are a supportive tool and a complementary means applied in the agriculture sector and other sectors to quickly achieve positive results that help planners and decision-makers in developing sustainable development plans. With the success of this technology, the role of geographic information systems (GIS) has become essential. Geographic information systems (GIS) have become essential due to the increasing volume and diversity of information, as GIS is a special case of general information systems. It contains databases that rely on studying the spatial distribution of phenomena, activities, and objectives that can be geographically located, such as points, lines, and areas. Where Geographic Information Systems process this data to make it ready for retrieval, analysis, and querying, allowing for the matching of satellite imagery with basic map data to obtain the desired results, and presenting these results in a simplified manner to decision-makers. And its effectiveness has been proven in many fields, including environmental protection and urban planning, as well as in emergency medical services, in addition to economic, social, and agricultural studies, the production of land use and natural resource maps, soil classification, and determining the best soils for cultivating a specific crop. And this study aims to the following: 1- Describing the physical, chemical, and morphological characteristics of the soils in the study area to determine the extent of their degradation and the possibilities for their reclamation. 2-Soil classification according to international standards (such as the USDA soil classification). Employing geospatial technologies (GIS and remote sensing RS) in analyzing soil distribution and preparing accurate classification maps. 3-Identifying environmental factors affecting soil properties such as drought, climate changes, and land uses. 4-Providing recommendations for sustainable soil management based on the results of geomorphological classification and characterization. 5-Using digital evidence to determine soil suitability for various uses

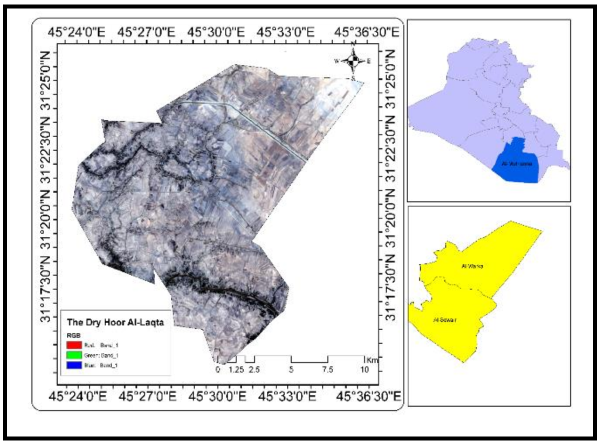
References section at the end of this template.

Material and methods

Geomorphology of the region Al-Muthanna Governorate is located within the unstable shelf zone (the Mesopotamian Valley zone) of the Arabian Plate, interspersed with some sub-surface faults, with a sedimentary cover and the presence of sub-surface anticlines. It is part of the southern regions of the alluvial plain (Buringh, 1960). The geological formations of the region are confined between the deposits of the Tertiary and Quaternary periods, and the most important of these formations are the Quaternary formations, which are divided into Pleistocene and Holocene deposits. These deposits are derived from the riverine sediments of the Tigris and Euphrates rivers and aeolian deposits. These deposits are characterized by a succession system and consist of layers of sand, clay, silt, calcium carbonate, and a small amount of calcium sulfate. The deposits that fill the depressions are made up of clayey-silty materials, while the deposits that fill the valleys consist of sand, clay, and silt, and they also have a fluvial origin. The upper cover of the alluvial plain consists of silty river deposits resulting from continuous irrigation processes over thousands of years. (Issa, 1995).

The study area is confined between the longitudes 30'24°45" and 30'36°45" east, and the latitudes 0'21°31" and 0'27°31" north, covering a total area of approximately 20,860 hectares. It is located about 30 km from the center of Al-Muthanna Governorate, as shown in Figure (1).

Study area



For the purpose of characterizing and classifying the soils of the study area using geospatial technologies, satellite imagery from the Landsat-8 satellite captured on 06/17/2024 was utilized. The imagery, which consists of twelve spectral bands, underwent necessary corrections, and a soil units map was prepared using ArcMap 10.8 software. Based on the results of several field visits to the area and using remote sensing technologies and Geographic Information Systems (GIS), as well as results from digital guides, 12 auger hole sites were identified. Based on this, 6 pedons were discovered for the map units representing the expected soil types in the study area. Subsequently, their coordinates were determined, and their horizons were described morphologically according to the guidelines in the Soil Survey Manual (Soil Survey Staff, 2017). After that, samples were collected from each site and each horizon, numbered, preserved, and brought to the laboratory for the purpose of conducting laboratory analyses of some chemical and physical soil properties using the following methods: The electrical conductivity in the saturated soil paste extract was measured according to the method described by Page et al. (1982). And the soil reaction pH in a 1:1 soil-water suspension was measured using a pH meter as described in (1982) Page et al. The calcium carbonate minerals were estimated according to the method described in Jackson (1958). Calcium sulfate in soil samples was estimated by acetone precipitation according to the method described in Richards (1954). The organic matter was estimated using the Walkley and Black method as described in Jackson (1958). Then, the information and data related to the administrative map were collected for classification purposes. After that, the satellite imagery from the remote sensing environment was downloaded from the USGS website for the Landsat 8 satellite, which was captured on 06/17/2024 and covers the study area. And it was interpreted visually. After that, the digital processing of the satellite imagery was carried out by applying a series of mathematical algorithms to it using the digital processing software 8ArcGIS 10. Most importantly: A- Cropping the satellite image. B- Merging spectral bands. C- Spatial enhancement. C- Aerodynamic correction.

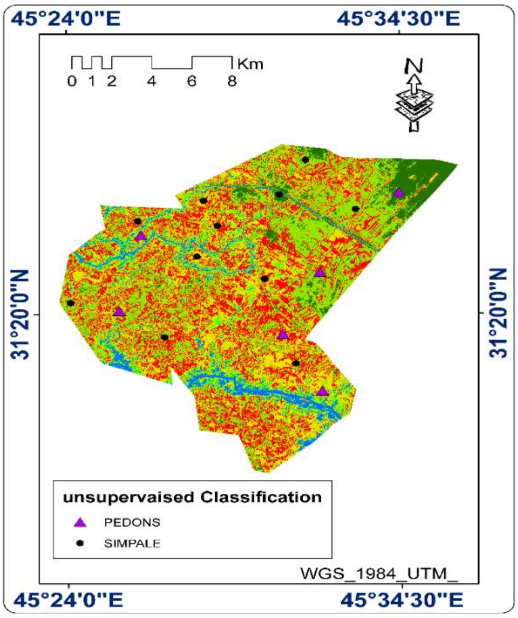


Figure (2) Locations of the auger and pit drilling in the study area

Table 1. Some physical and chemical properties of the bedouin horizons in the study area

NO.	Y	X	depth	pH	EC e	CaSO4	O.M	CaCO3
1	**3474029**	**554606.8**	30-0	7.51	.654	7.567	17.20	43.55
			70-30	7.68	.294	4.586	13.10	45.52
			90-70	7.92	5.14	1.490	9.00	55.28
			90-110	7.96	10.0	1.146	2.10	55.21
2	**3469199**	**550664**	20-0	7.42	15.4	7.689	11.10	21.1
			40-20	7.45	16.99	6.306	2.70	23.3
			80-40	7.47	19.33	5.274	2.20	24.05
			80-140	7.69	23.2	4.701	2.00	53.2
3	**3465420**	**548824**	30-0	7.26	14.4	5.159	10.40	24.2
			45-30	7.55	14.5	5.045	2.50	24.9
			60-45	7.87	14.76	2.751	1.30	25.55
			60-75	7.93	25.4	2.178	1.10	25.3
			75-130	7.82	27.8	1.142	2.01	37.5
4	**3462003**	**550795.4**	20-0	7.62	12.3	7.338	4.20	27.7
			40-20	7.64	13.7	5.962	4.10	26.85
			80-40	7.92	20.87	1.352	4.00	26.05
			80-155	7.98	22.32	3.210	3.10	29.6
5	**3466800**	**540642.6**	0-20	7.41	30.6	6.764	7.60	26.05
			20-40	7.52	39.26	6.306	3.00	38.05
			40-75	7.78	38.01	4.013	2.40	38.05
			75-150	7.86	45.01	2.293	3.00	50.65
6	**3471433**	**541726.8**	0-25	7.78	7.03	8.599	9.33	21.8
			25-50	7.81	7.32	7.108	6.45	23.0
			50-70	7.94	7.12	2.637	3.21	23.15
			70-120	7.95	8.6	1.777	4.20	35.3

				d			re	true density Megagram m-3	Megagram m-3	ity %
1	**3474029**	**554606.8**	30-0	285.7	217.2	497.1	Si L	2.53	1.52	39.92
			70-30	223	276	501	Si L	2.61	1.64	37.16
			90-70	365.5	282.8	351.7	L	2.44	1.69	30.73
			90-110	261	326	413	CL	2.48	1.71	29.91
2	**3469199**	**550664**	20-0	153	416	431	SiCL	2.38	1.31	44.95
			40-20	182	421	397	SiCL	2.34	1.54	34.18
			80-40	201	437.5	361.5	SiC	2.36	1.56	33.98
			80-140	89.4	438	472.6	SiC	2.55	1.45	43.13
3	**3465420**	**548824**	30-0	179	380	441	SiCL	2.24	1.33	40.62
			45-30	136	469	395	SiC	2.53	1.34	47.03
			60-45	133	481	386	SiC	2.42	1.51	37.60
			60-75	120	482	398	SiCL	2.38	1.49	37.39
			75-130	104	542	354	C	2.31	1.53	33.76
4	**3462003**	**550795.4**	20-0	193	361	446	SiCL	2.80	1.37	51.07
			40-20	180	409	411	SiCL	2.31	1.34	41.99
			80-40	166	573	261	C	2.56	1.58	38.28
			80-155	181	559	260	C	2.31	1.56	32.46
5	**3466800**	**540642.6**	0-20	193	355	452	SiCL	2.37	1.24	47.67
			20-40	182	359	459	SiCL	2.27	1.27	44.05
			40-75	127	341	532	SiCL	2.31	1.32	42.85
			75-150	168	361	471	SiCL	2.46	1.35	45.12
6	**3471433**	**541726.8**	0-25	171	398	433	SiCL	2.56	1.26	50.78
			25-50	163	418	419	SiCL	2.51	1.28	49.0
			50-70	120	482	398	SiC	2.56	1.31	48.82
			70-120	118	488	394	SiC	2.31	1.51	34.63

Results and Discussion

The soil in the study area was classified based on its morphological characteristics and laboratory test results, according to the modern American classification (Soil Survey Staff 2017). To the order level, suborder, great group, subgreat group, family. The proposed classification of Iraqi sedimentary soils by Al-Agidi (1976) was also used to determine the series. The dry environmental conditions and lack of vegetation cover in the study area have reduced soil development, as the pedogenic processes were not sufficiently active, in addition to the fact that the parent material of these soils is of recent age (young), which has hindered their full development. Therefore, these soils are characterized by a clear horizontal sequence of their pedogenic horizons of the A-C type. The results in the appendix showed that the soil in this area is classified as Entisols, which are newly formed soils. These soils were formed as a result of recent river deposits. And its characteristics are inherited because they have transferred from one location to another. The absence of subsurface diagnostic horizons, such as the argillic horizon, is noted, indicating that the factor of time has not been sufficient to form this type of horizon. Moreover, all these soils are located within the alluvial plain area, which continuously receives new sedimentary materials, leading to weak pedogenic activity in them. Buringh, 1960 At the suborder level, the soil was classified as Fluvents, as it was found to contain alluvial parent materials and exhibit stratification. At the grand group level, it is classified as Torrifluvents, which are soils containing river deposits, found in a hot and dry climate under a Torric moisture regime. This system is characterized by dry soil most of the time, with temperatures at a depth of 50 cm exceeding 5 degrees Celsius, and moisture is unavailable for periods exceeding 90 consecutive days when the temperature is above 8 degrees Celsius. These soils are considered deep, with the organic matter content decreasing with depth, and their horizons are characterized by fine or moderately fine particles. The groundwater level in these soils reaches a depth ranging between 110-155 cm, and these soils are considered part of the alluvial soils according to the old American system (Al-tai et al 1969). At the level of the suborder, the soils were classified as (Typic Torrifluvents) due to their typical characteristics of this group. According to the classification by Al-Agidi (1976), six soil series were identified. Six families were identified based on soil pedons and their degree of calcareousness (TM556, DM97, TM1167, DM97, MM9, DF97). The prevailing thermal regime was hyperthermic, where the temperature at a depth of 50 cm exceeded 22 degrees Celsius. These soils are classified as calcareous with variations in soil texture among the families. Table (3) shows the classification of the soils in the study area.

Table (3) shows the classification of soils according to the modern American system (2017), (soil survey staff) and the Al-Agidi (1976) classification of series in sedimentary soils .

The series	The family	Under the Grand Group	The Grand Group	Under the rank	Rank	Number the bedouin
TM556	Fine clayey, active, calcareous, hyper thermic , Typic Torrifluvents.	Typic Torrifluvents	Torrifluvents	Fluvents	Entisol	1
DM97	Fine clayey, active, calcareous, hyper thermic , Typic Torrifluvents.	Typic Torrifluvents	Torrifluvents	Fluvents	Entisol	2
TM1167	Fine clayey, active, calcareous, hyper thermic ,	Typic Torrifluvents	Torrifluvents	Fluvents	Entisol	3

	Typic Torrifluvents.					
DM97	Fine clayey, active, calcareous, hyper thermic , Typic Torrifluvents.	Typic Torrifluvents	Torrifluvents	Fluvents	Entisol	4
MM9	Fine clayey, active, calcareous, hyperthermic, Typic Torrifluvents.	Typic Torrifluvents	Torrifluvents	Fluvents	Entisol	5
DF97	Fine clayey, active, calcareous, hyperthermic, Typic Torrifluvents.	Typic Torrifluvents	Torrifluvents	Fluvents	Entisol	6

Classification using satellite imagery

The digital classification, both unsupervised and supervised, was conducted on the Landsat-8 satellite imagery for the year 2024, fully corrected: Unsupervised Classification Classification: The unsupervised classification method was used, which involves determining classes without external intervention, meaning that the computer performed the classification process and repeated it several times to obtain satisfactory results (Meijerink, 1989). In this method, training area data is not primarily used for classification; instead, algorithms examine unknown pixels in the image and group them into several classes based on natural clusters in the pixel values.

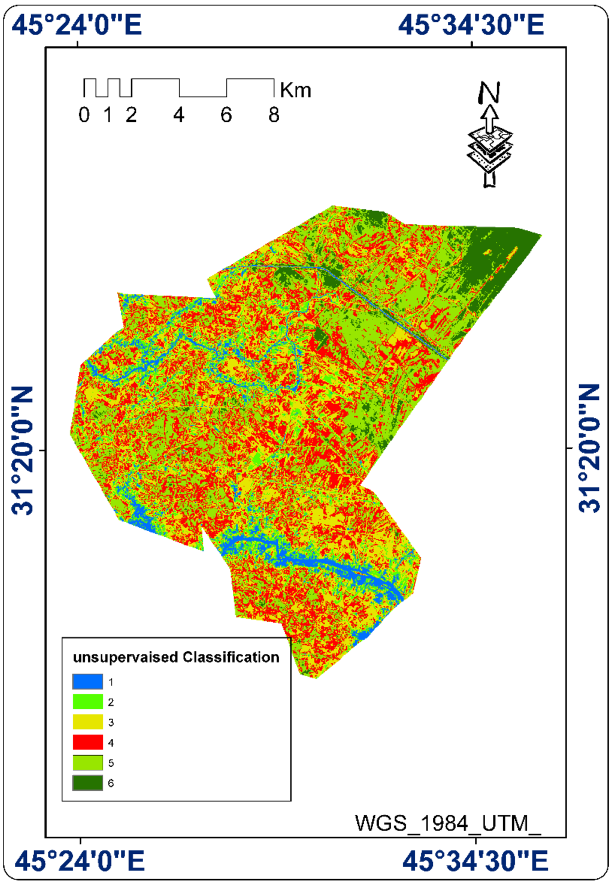


Figure (3) Unsupervised Classification for the study area

Supervised Classification

The supervised classification process was carried out using ArcMap 10.8, where several locations from the satellite imagery were selected to represent the study sites. After that, the spectral signature for each site was extracted as training areas, and the program was directed to search for areas similar to that signature that reflect the surrounding characteristics. The distribution of locations on the image allows the training data to represent all the variables in the existing cover patterns. The spectral signature for each class in the study area was determined (Lilleasand and Kiffer, 2000). The results of the supervised classification showed three classes, as illustrated in the figure, the dominant terrestrial classes in the study area, which resulted from using the spectral signature of the training areas on which the spectral classification of the imagery was based. These areas represent the most important dominant soil units for each spectral class in the spatial data. The classes resulting from the supervised classification of the study area indicate the presence of several soil units.

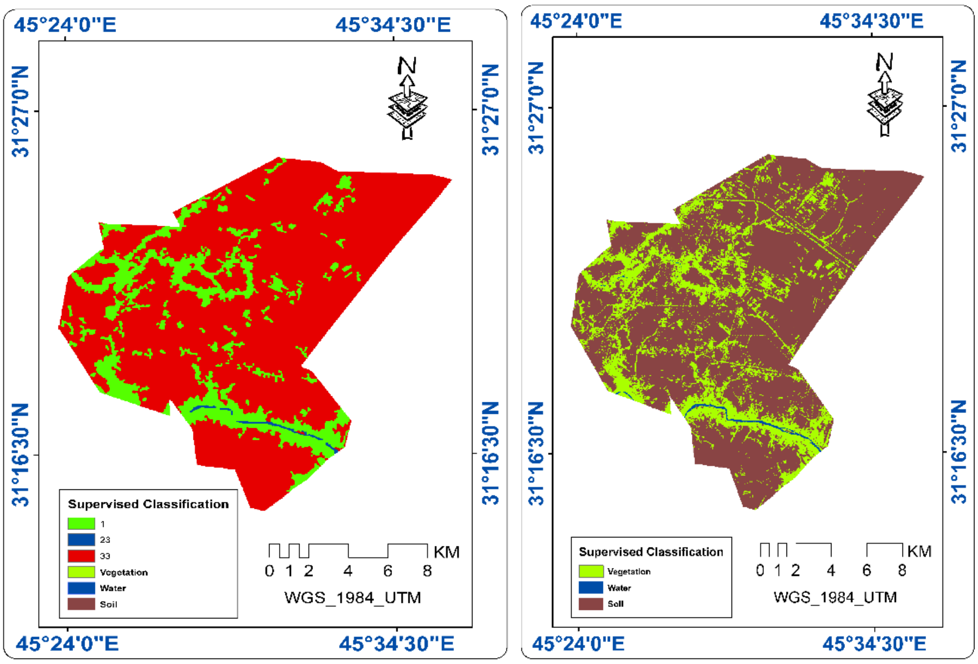


Figure (4) shows the supervised classification wave for the study area.

Wave classification accuracy evaluation

The classification accuracy measurement technique is a fundamental quantitative analysis of the extracted results. They are essential and important in determining the error rate at the end of the work, and they show the extent of the match between the class labels in the classified map and the ground truth or reference data for the same locations. The main objective of accuracy assessment is to estimate the elements and components of the confusion matrix and the various descriptive measurements of ground truth data within the study area (Table 5), thereby providing a decision on the accuracy of the spectral data and the chosen method. Then, the Kappa coefficient is calculated using the following accuracy methods. Producer's accuracy Users' overall accuracy . The Kappa coefficient statistic is the most commonly used measure of the accuracy of the map classification used in the study, as it shows the difference between the actual agreement of the reference data and the expected agreement of the classified data by chance. Koutroumpas and others divided the Kappa coefficient values into five categories of agreement acceptance. It is evident from the table that the accuracy of the soil series unit map in the study area, according to the classification by Koutroumpas et al. It was rated as very good. The statistical value of the Kappa coefficient is 0.93, indicating a 93% statistical agreement between the reference points and their corresponding locations on the classified map. Based on the Kappa coefficient value and the classification proposed by Koutroumpas et al., the overall classification accuracy for all locations in the study area is classified within the very good agreement category between ground truth classes and classified data.

Table (4) shows the ranges of accuracy for the Kappa coefficient and acceptance categories according to the classification by Koutroumpas et al. (2010).

Agreement classes	Kappa Khat coefficientrange
Poor	< = 0.2
Fair	0.21 –0.40
moderate	0.41 –0.60
good	0.61 –0.80
very good	0.81 –1.00

	Refer ence		total row	Useres acc	Error of commission

Table (4) shows the error matrix for evaluating the accuracy of the wave classification.

	Rowid_1	ROWID	agriculture	water	soil			
	1	agriculture	**9**	0	2	11	0.818181818	0.1
classified	2	water	0	**10**	0	10	1	0
	3	soil	0	0	**49**	49	1	0
		total column	9	10	51	70		
		produceres accuracy	1	1	0.960784			
		Error of Omission	0	0	0.041667			
		Overall Accuracy %	19.7					
		kappa value%	0.9364					

Conclusion

The results of the physical analysis of the soils in the study area showed a variation in texture both horizontally and vertically, with a predominance of silt and clay particles, a low sand content, and an increase in bulk density with depth. Chemical analyses showed variation in salinity among the study plots, with electrical conductivity ranging from non-saline to highly saline, moderate to medium values of alkalinity, and a decrease in gypsum content. A variation in the distribution of calcium and an increase in organic matter in the surface layers were recorded. According to the modern American classification, the soils were classified under the Entisols order and the Fluvents suborder. A supervised and unsupervised classification of the satellite imagery was conducted, revealing the presence of three land cover classes. Six pedons were morphologically described, and 12 sites were examined for physical and chemical properties.

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