

# Chapter 4

## Characterization and Classification of Soil Map Units by Using Remote Sensing and GIS in Bahar Al-Najaf, Iraq



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**Abstract** The Bahar Al-Najaf Lands is located in the west of the Al-Najaf Governorate. It is extended between  $31^{\circ} 39' 16''$ – $32^{\circ} 08' 08''$  N and  $43^{\circ} 47' 11''$ – $44^{\circ} 30' 15''$  E with a total area of 2,000.2 Km<sup>2</sup>. This chapter aims to find out the possibility of using Remote sensing (RS) and Geographic Information Systems (GIS) techniques in contributing to soil surveys by selecting soil map units drawing and calculating spectral reflectance by satellite image of Landsat 8 provided with two Sensors; Operational Land Imager (OLI) and Thermal Infrared (TIRS). The image was acquired on 07/13/2014 from the USGS site and shows the nature and interference effect of the relationship between some of the soil physical and chemical properties on its spectral reflectance values by choosing false-color composite RGB (753), which is a specialist for studying soils and minerals and deducing study area using ERDAS imagine 2013. Some enhancements have been made (radiation, spectral and spatial) add to unsupervised classification, as well as using earth indicators (EIs). The used EIs include soil color, texture, natural plants and topography. These EIs are used in determining the researcher movement paths to select 16 Pedon's sites with 21 auger holes to a depth of 75 cm for surveying and isolating expected soil individuals within the study area which are identified using GPS. The unsupervised classification approach has shown considerable potential in the distribution of soil classes are close to supervised classification. The pedons revealed and described, according to the (Soil Survey Staff 1999). Disturbed soil samples were selected from each horizon, air-dried, crushed and passed through sieve openings of 2 mm diameter for execution physical and chemical analysis. The results of particle size analysis show that there is no specific pattern distribution of soil particles whether within the pedon itself or between the pedons. There was no observed variations in textures classes for the vertical direction within the same pedon as in (P9, P4A, P10) or got little changes as in P4B. Horizontally variations observed among sites which returns to the nature of sedimentary additives and helps to occur the Litho-

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logical discontinuities in soils. All the pedon's horizons were strongly calcareous, while they varied in gypsum content in surface and subsurface horizons. Depending on the US modern classification, All the studied soils are within the Entisol order, which classified into two of Suborders. The first is Fluvents including great soil group Torrifuvents and subgroup Typic Torrifuvents which includes 9 Soil series ME1, DW56, TW964, DM44, MW3, TE354, DW124, DE47, DE126. The second is Psamments including two great soil groups, The first Torripsamments containing subgroup Typic Torripsamments including DE33, DE34, DE74, TE334, TW446 soils series. The other quartzipsamments include subgroup Typic quartzipsamments containing two soil series ME1, DM14. The soil series are classified according to the proposed (Al-Agidi 1976). for alluvial Iraqi soils classification, It was diagnosed nine families and 15 soil series in the study area.

**Keywords** Remote sensing · Landsate · Soil image · Classification · GIS

## 4.1 Introduction

Remote sensing (RS) is concerned with the use of devices to collect information about different objects and targets without direct physical contact with them by exploiting electromagnetic waves with their different wavelengths along the electromagnetic spectrum from short to high wavelengths and low frequencies (Elachi and Van 2006). There is an urgent demand for rapid information regarding the classification of soils and their properties. Since there are no adequate studies in this information, thus RS is considered as one of the rapid techniques that can provide these requires using digital classification according to their spectral characteristics producing thematic map used in various fields of sciences especially agriculture (Yousif 2004).

The Iraqi soils are different because of the variation in soil formation factors. Hence, they show different characteristics in both vertical and horizontal directions. Therefore, surveying and classification of these soils and isolation of their units are essential for the preparation of geomorphological and pedological maps. Soil mapping units, in fact, are modified units containing 85% of the characteristics of the nearest taxonomic unit. The spatial pattern and complexity of soil based on the interrelated effect of the soil formation factors at a given location and the extent of their variability within a given distance. Thus, the complexity becomes thornier as these variations become more substantial and on the basis of which the predictability of the pattern is determined at a particular classification level (Mutter 2008). Given the urgent need to increase agricultural production to avoid food shortages in the world, especially Iraq, as well as the severe climate variability facing humanity. There has been a need to use RS and GIS applications due to their economic feasibility in the field of soil survey and classification by speeding up the work, minimizing effort, cost as well as giving them continuous geospatial values of earth characteristics, natural and temporal improvements. The process of linking the soil's physiochemical and morphological characteristics with its spectral properties helps predict a number of

factors affecting the soil conditions and its components. Therefore, it is necessary to conduct the spectral properties measurements of the soil units in each region, which are useful aids in soil surveying and classification (Abbas 2010).

The idea of the study is based on the use of RS techniques on the interactions between the fallen radiation from the electromagnetic spectrum with the soil surface. The reflected radiation depends on the soil's physical and chemical properties such as texture, structure, moisture, soil minerals, organic matter, gypsum, and carbonate which considered an essential feature in recording the spectral signature of the soil. As a result of these interactions, different types of soils can be characterized and separated (AL-Rajehy 2002; Zinck 2008).

For the purpose of codification, all the efforts, cost and time with the accuracy of the separation and classification of Bahar Al-Najaf soils are compared to the traditional methods, which includes the drilling of many profiles and Auger holes, The study is carried out to take advantage of these modern technologies (RS and GIS) to prepare soil map units and achieve the following objectives:-

1. The effect of the soil formation factors on the soil variations of Bahar Al-Najaf region.
2. Separating soil units depending on the variation of the earth's surface spectral reflections. Based on the soil morphological, physical, chemical and spectral characteristics.
3. Soil classification may contribute to the optimum use of good soil for the production of the ideal, and how to expand it within the vision of sustainable agricultural development.

## 4.2 Geology of the Study Area

Bahar Al-Najaf region is a transition zone between the sedimentary plain and the Western desert region, i.e. between the stable pavement and the unstable pier (Sallom and Segar 1994). The study area is located within the stable zone (Al-Rutbha-Al Jazeera) based on the geological divisions of Iraq (Barwari and Slewa 1995). The area is characterized by its simplicity and the lack of surface and sub-surface structures with the extension of the sediments of the Pleistocene and the discoveries of the Tertiary formation. In most parts of the region, they differ in their thickness and texture, where the deposit of valleys extends over areas adjacent to the seasonal valleys, The secondary gypsum deposits are spread over a very large area as a result of carbon rocks erosion belonging to the Tertiary period and the past (Barwari and Slewa 1995).

In some areas, the spread and extension of sand dunes and sediment deposits are noted. Also Bahar Al-Najaf contains natural plants, as well as Palm belt, is extended along Tar Al-Najaf, and it considered a separate limit between Tar Al-Najaf and Bahr Al-Najaf depression. Figure 4.1 shows the sequence of the geological strata of Al-Najaf Governorate.

Era	Period	Epoch	Age	Formation	Lithology	
CENOZOIC	Quaternary	Holocene		Aeolian deposits		
				Valley fill deposits		
				Depression deposits		
		Pleistocene		Gypcrete deposits		
	Tertiary	Miocene	Pliocene		Dibdibba	
				Upper	Injana	
			Middle		Fatha	
Lower	Euphrates					

Fig. 4.1 Sequences of the geological formations of Al-Najaf Governorate from (Barwari and Slewa 1995)

### 4.2.1 Geomorphological and Hydrological Phenomena of the Study Area

#### 4.2.1.1 Bahar Al-Najaf Depression

The Bahar Al-Najaf is a prominent hydrological phenomenon in Al-Najaf Governorate and the Middle Euphrates region. This is the precursor of Al-Najaf city since it was founded twelve centuries ago (Batafu 2002). It is located in the south and southwest of Al-Najaf holy city, and overlooking its plateau at a rate of about 130 m above sea level, within the range of the Iraqi sedimentary plain, The Bahar Al-Najaf lands covered, at the northwestern edge, with deposits of the Quaternary with thickness of (10–20 m) (Yacoub et al. 1981). The area of the Bahar Al-Najaf depression is about 360 km<sup>2</sup>, and the height of its lowest point is 11 m above sea level. On the geological side, the rocky remains of the Anjana and the Dabdaba appear on its western edges (Al-Kadhimi et al. 1996).

The lands of Bahar Al-Najaf penetrated by the valleys, which descend from the western territory of Saudi Arabia Kingdom and have a length of hundreds of kilo-

meters. Most notably the valleys of Shu'ayb Husub, Al-Kher, Al-Jal, Abu Talha, Al-Huwaimi. The waters of these valleys move in the winter and most of it flows into depression, a seasonal lake fed by water from the seasonal streams sloping from the high western parts as well as water from the Tar Al-Najaf after the rains and the surface drainage from all sides in the direction of Bahar Al-Najaf depression (Hassan 1983). The sediments of the Quaternary period, such as wind and mud, cover the slopes. The bottom of the depression is covered with clay, silt, sand and fine gravel with a quantity of salts in the upper layers. In addition, there is a large quantity of modern shells in the upper layers extending up to areas close to the foot of the Tar Al-Najaf indicating the maximum intensities of water level rise (Barwari and Slewa 1995).

#### 4.2.1.2 Tar Al-Najaf

It is an insular line, about 65 km long, extended along the eastern and northern east edge of the study area and Al-Najaf plateau, which almost linearly cut. Its highest level is 188 m, but the point of contact with Tar Al-Sayyid, which lies within the borders of Karbala province is 177 m above sea level. One of the most important phenomena observed in Tar Al-Najaf is the depletion of water from some rock layers, Its groundwater stored in the Al-Najaf plateau (Al-Rawi 2007).

### 4.2.2 *Classification of Iraqi Alluvial Soils*

Buringh (1960) used the old American genetic classification system for classifying the Iraqi alluvial soils, identified as undeveloped soil of Azonal order and the Alluvial Soils for great group. Al-Agidi (1976) proposed a system for the classification of alluvial soils at the series level. It is the first Iraqi classification system to classify these soils which used two classes to diagnose and distinguish the series: Soil texture within the effective series for soil depth of the 120 cm thick and between (30–150 cm) depth as well as the internal drainage is expressed in mottling depth. These two characteristics are associated with many other soil properties.

Al-Ani (2006) studied the classification of agricultural land in the central region of the Iraqi alluvial plain, which represents the physiological units of the rivers and the irrigation channels prevailing in these areas, and based on the results of the morphological description as well as the physical, chemical and mineralogical characteristics of the studied soil pedons. It was found to be within the undeveloped soils of the Entisols order according to the modern American system, based on the presence of Ochric surface horizon and the absence of subsurface diagnostic horizons. The suborder were Fluvents, and Torrifluvents as great soil group and Typic Torrifluvents as subgroup, These soils were classified into nine series based on the Al-Agidi (1976) proposal, named: ME9, DW116, DW25, DE97, DM97, DE44, MW9, DW95, MF8.

In a study conducted in the Iraqi alluvial regions, Hamad (2009) concluded that digital processing for satellite images show a new one that easily distinguishes soil types from other land uses and that the third, fifth and seventh spectral bands are suitable for determining soil units and water studies, With the eighth spectral package. Wahib (2012) showed that soil salinity was significantly correlated with spectral bands 5 and 7 for Landsat 7 satellite with partial correlation coefficients ( $-0.4229$ ,  $-0.4030$ ), respectively in the Al-Salman depression, southern Iraq, and recommended using the values of reflectivity as an alternative to digital numbers because they were more accurate in expressing the results.

### **4.2.3 Remote Sensing**

The primary source of electromagnetic spectral radiation is the sun. When it reaches the earth's surface, it interacts with the atmosphere. Most of it is absorbed or dispersed by the atmosphere's components (water vapor and carbon dioxide and ozone), which prevents electromagnetic energy and specific wavelengths from reaching the earth's surface. The range of wavelengths in which the atmosphere is transmitted for energy, known as atmospheric windows, which also determines the type of sensors that can be used by the wavelength of these spectral bands.

#### **4.2.3.1 Spectral Reflectivity of Soil**

A significant advantage of multi-spectral imagery is the ability to detect important differences between surface materials by combination spectral bands. Different materials may appear virtually the same within a single band. Selecting a particular band combination, various materials can be contrasted against their background by using colors (Yao et al. 2011; Zhang et al. 2017; Mustafa et al. 2019; Al-Wassai 2003). The results showed a relationship between these characteristics and their reflectivity, depending on the degree of soil brightness (Katie and Mahimid 2002). Studied types of desert soils in the Razzaza area, in Karbala Governorate/Iraq, They found that the sandy and gypsious soil showed the highest values of spectral reflectivity comparing to the rest soils found there.

Ben-Dor et al. (2008) developed a method for characterizing soil profiles in the field by reading spectral reflectivity data for subsurface depths. It tested for moisture, organic matter, carbonate, free iron oxides, specific surface area for four sites in Palestine. This method is suitable for giving quantitative information to these pedons without digging trenches or sending soil samples to the laboratory. The results are for the studied sites only and need to be checked through the applications of the method in the future for other locations.

### 4.2.3.2 Digital Classification of Spectral Images

Classification using satellite imagery is one of the most essential techniques that contribute to accurate information about a given location in a short time frame. The classification aims to place all the pixels in groups according to their homogeneity and symmetry in the form of a classification map, through which the features, the types of the earth cover represented by these groups. Also, the accuracy in the production of such maps depends primarily on the accuracy of the process of classification of the study's images (Shuli 2008). Generally, the digital soil classification has two main types; unsupervised and supervised classification.

#### Unsupervised Classification

An implemented automatically without supervision, depending on the degree of similarity and convergence between the spectral signatures without prior knowledge of the identity of these items in the study area. The computer handles the automatic processing of the assemblies and does not require the selection of training areas and is distinguished by the researcher's knowledge of the region, the success of this method depends on two crucial points:

- a. The number of spectral items assumed by the researcher must be sufficient to cover all visual parameters.
- b. This classification is exploratory and requires a little intervention according to our knowledge of the region through a comparison with reference data such as maps and others to make the interpretation successful.

#### Supervised Classification

It is implemented based on preliminary samples of the spectral signatures of each class and their statistical measurements (i.e., the classification is under supervision). Each unit of images is classified on the basis of its affinity and matching with the training samples in terms of spectral response and some statistical calculations. One of its methods is the maximum likelihood classification. It calculates the amount of correlation and variation of the spectral response of the training samples to each other and on the basis of the distribution of unknown pixels to those known on the assumption that the sampling units are systematically distributed and all the spectral bands used. The second method is the classification of the minimum distance to mean classification, where the points of location are chosen accurately. In order to give us a clear reflection, and in this case behave other pixels which unknown reversal (as an unknown goal). It takes a reflectivity of the shortest distance between them and the objectives approaching it. In the case of the using colors, it takes the color of the nearest target, so that the unclassified pixel is similar to the classification closest to the center, so-called (Mean center).

#### ***4.2.4 Accuracy Assessment of Digital Image Classification***

Numerous studies have carried out using both supervised and unsupervised classification methods. Some of which found that the unsupervised classification was more accurate (Borghuis et al. 2007). However the vast majority of studies suggest the opposite is true (Alrababah and Alhamad 2006; Bahadur 2009; Mukherjee and Mukherjee 2009). Accuracy assessment is a crucial part of the image classification process, as it evaluates the degree of acceptance between reference data and classified data (Tso and Olsen 2005). Alrababah and Alhamed (2006) achieved 69.1% overall accuracy of unsupervised classification without spatial improvements on satellite imagery and 73.7% accuracy with spatial improvements, while the overall accuracy of the supervised classification was (82.7, 78.8)% with and without spatial improvements, respectively.

AL-A'araage (2012) used the Landsat ETM + 7 classification technology for Badra City in Wasit Governorate/Iraq, verified the validity of the classified results of five ground covers using 100 control points, the researcher reached an overall accuracy of 92.00% and the statistical Kappa coefficient of 0.8996. Ahmed and Ahmed (2014) used supervised classification with maximum likelihood method of the Landsat TM satellite captured in 2007 for the land use-land cover map for an area of 5,700 Km<sup>2</sup> for Baghdad governorate, the data were classified into five categories. The classification accuracy was 93.7% and the statistical Kappa coefficient of 0.8833. Elkharchy (2015) used the unsupervised classification method for an area in Najran, Saudi Arabia, to separate three categories of ground coverings (urban areas, barren land, agricultural land) using Erdas imagine and ArcGIS. The classification accuracy of all varieties varied between (61–87%). In Delhi, India, Nain and Kumar (2016) applied the unsupervised classification technology for Landsat ETM + 7 using Erdas Imagine to classify ground coverings and the ArcGIS, with an overall accuracy of 91.67% and a statistical Kappa coefficient of 0.896, which means actual acceptance and good performance of the work.

#### ***4.2.5 Applications of RS in the Field of Iraqi Environment and Soils***

Qadir (2007) studied the reflectivity of land use varieties and their relationship to soil characteristics to determine their suitability for planting using B1, B2, B3 bands for Landsat TM. Twelve types of soils were identified in the study area depending on the state of variation in their reflectivity values and indicated a weak correlation between soil reflectivity and its characteristics. Sulaiman and Aboud (2012) conducted a semi-detailed survey in the center of the sedimentary plain south of Babylon province/Iraq to assess the land productivity. They dug 10 pedons representative of the soil series, morphological described and the soil texture estimated with some chemical characteristics. They reach that the soil of the study area is newly



formed, characterized as stratified, medium to fine texture, and soils classified to the Entisols order and subgroups Typic Torrifluent, Aquic Torrifluent, Vertic Torrifluent. The land assessment showed the presence of all land varieties in different proportions.

Azeez (2013) studied the use of Geo informatics techniques (GIS, RS and GPS) using Satellite images of Landsat 5 and 7 to identify and isolate soil map units in an area of 4,087.3 Km<sup>2</sup>, Kurdistan Region, north of Iraq. Soil samples were taken from depth (0–30 cm) for 88 locations to determine physical and chemical properties. A total of 12 pedons were allocated to different map units in order to test the reliability of the soil map units. All pedons at the study area represent developed soils. The supervised classification was more harmony than unsupervised classification, as well as the soil map units in Arc GIS software package was more accordance with physical, chemical and morphological soil properties in comparison with supervised ERDAS classification. Several studies have been conducted on the environmental problems, such as drought events, land degradation, soil salinity, sand dunes encroachments in Iraq using satellite images, remote sensing techniques and GIS analysis in various areas of Iraq (Fadhil 2011; Wu et al. 2019; Fadhil 2009; Almamalachy et al. 2019; Wu et al. 2018; Al-Quraishi et al. 2019; Fadhil 2013).

#### ***4.2.6 Soil Surveying and Classification Studies of Bahar Al-Najaf Region***

Yousif (2004) used Landsat 5 TM images to classify Al-Najaf governorate soil using three spectral bands. The results of the supervised classification using Maximum Likelihood Classifier method gave a good representation of the soil classes with a total accuracy of 92% while the unsupervised classification gave a good representation of some soil classes and merged them. The study found that the color composition 754 was optimal for soil moisture sensitivity and recommended that the thematic map is the best in soil classification and representation of the ground truth compared to the traditional method.

Mahmoud and Mahimid (2011) studied the inheritance and development of some gypsic soils in Iraq included Bahar Al-Najaf soils. They studied the morphological, physical and chemical properties of the pedons. They found that the Bahar Al-Najaf soil series KME 121 is undeveloped and with A-C horizons due to the dry climate, low vegetation cover, and relatively modern sedimentary parent material. All of which have helped to form undeveloped soil.

### 4.3 Methodology

#### 4.3.1 The Geographical Location of Bahar Al-Najaf Region

The Bahar Al-Najaf Region Located in the west to southwestern part of Al-Najaf Governorate/Iraq, limited to longitude ( $43^{\circ} 47' 11''$ – $44^{\circ} 30' 15''$  E) and latitudes ( $31^{\circ} 39' 16''$ – $32^{\circ} 08' 08''$  N), and its area is estimated at 2,000.2 km<sup>2</sup> (Fig. 4.2).

The study area is in the hot and desert climate. The summer is characterized by its length and dryness, winter is relatively short and cold. The rainfall rate in winter is low, with an average of 7.2 mm per year, and the annual accumulated rainfall depth of the 86.2 mm distributed irregularly. The precipitation is interrupted in June, July, August, and September, which is accompanied by a small quantity and irregularity of rainfall in the fall with the rise in annual temperature rates at a value of 25.5 °C with a sharp increase in the summer months to reach the rate of 37.7 °C in July. So the soil of study area classified as hyperthermic type, because the annual average temperature is greater than 22 °C and the differences between the average temperature in summer and winter months are more than 5 °C. Its moisture system is of a Torric (Aridic) type due to the keeping of study area in dry conditions for more than 90 days on a continuous basis Where the amount of rainfall is less than double of the average monthly temperature, as well as the existence of a moisture deficit for an extended period of the year (Soil Survey Staff 1999).

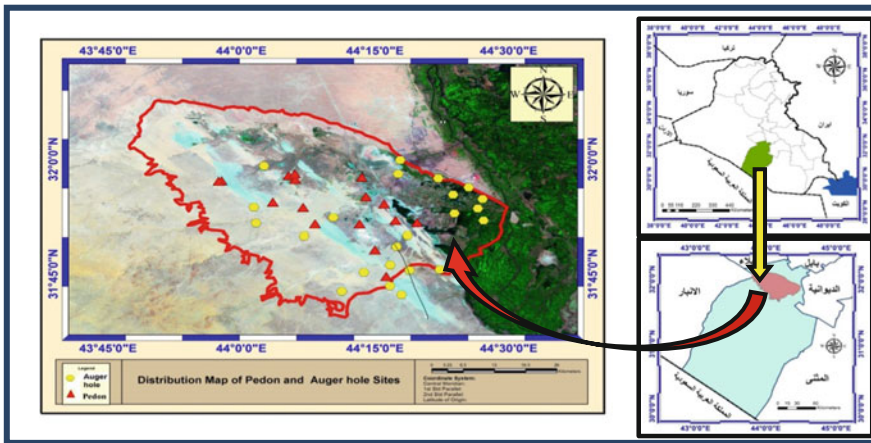


Fig. 4.2 Maps of location of Bahar Al-Najaf region, Al-Najaf governorate, and Iraq

### 4.3.2 FieldWork

Traffic and mobility routes were identified to determine and dug 16 pedons, as well as 21 auger holes, were drilled within the studied area. Their locations were recorded using the GPS type Garmin: GPSMAP76CSx via (Free Lance Soil Survey), while relying on the unsupervised classification for satellite image with some enhancements, as well as the use of land guidelines and directories such as variations in soil texture, natural plants in addition to topography. We relied on region’s altitude levels based on Digital Elevation Model (DEM) files, which downloaded from the Indian Institute of Remote Sensing website (IIRS) (Fig. 4.3) (Table 4.1).

For surveying and isolating the map units representing the soil individuals expected to be present in the study area. The GPS dataset was projected to the geodetic system of UTM\_WGS84\_38N and saved into a text file. This file was imported into Arc GIS10.3 desktop and converted to shapefile layer to be overlapped with the Landsat 8 images. The pedons are morphologically described according to (Soil Survey Staff 1999). Soil samples from each horizon and auger holes surface depths were collected, air-dried, crushed to pass through a 2 mm sieve and analyzed for their physical and chemical properties, the results are shown in (Tables 4.2 and 4.3).

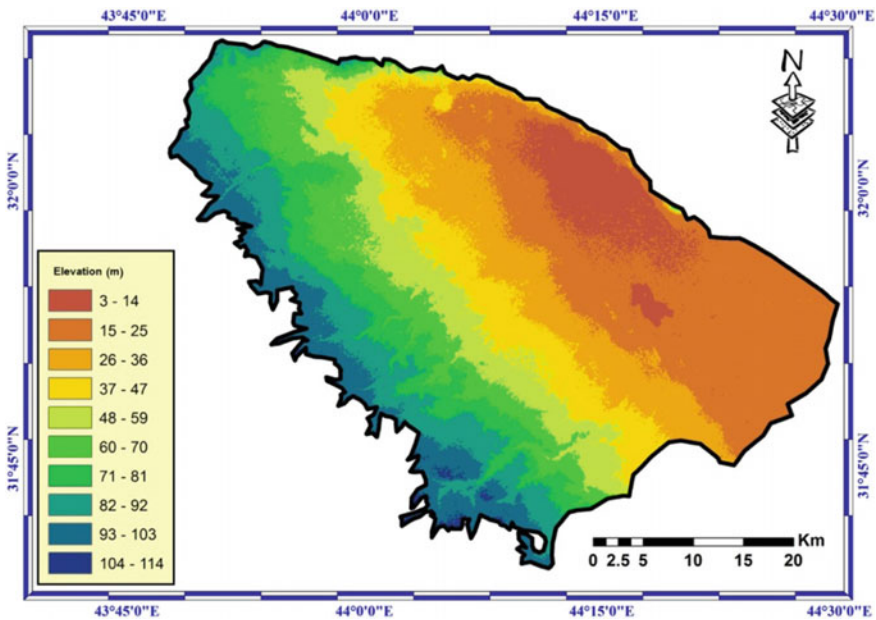


Fig. 4.3 Digital Elevation Model (DEM) of the study area

**Table 4.1** Wavelengths and spatial accuracy of sensors bands (OLI, TIRS) for Landsat 8

Spectral band	Wavelength ( $\mu\text{m}$ )	Resolution (m)
Band 1—Coastal/aerosol	0.433–0.453	30
Band 2—Blue	0.450–0.515	30
Band 3—Green	0.525–0.600	30
Band 4—Red	0.630–0.680	30
Band 5—NIR	0.845–0.885	30
Band 6—SWIR <sub>1</sub>	1.560–1.660	30
Band 7—SWIR <sub>2</sub>	2.100–2.300	30
Band 8—Panchromatic	0.500–0.680	15
Band 9—Cirrus	1.630–1.390	30
Band 10—LIR <sub>10</sub>	10.30–11.30	100
Band 11—LIR <sub>11</sub>	11.50–12.50	100

*NIR* Near Infrared; *SWIR*<sub>1</sub> Short Wavelength Infrared; *SWIR*<sub>2</sub> Short Wavelength Infrared<sub>2</sub>; *LIR*<sub>10</sub> Long Wavelength Infrared<sub>10</sub>; *LIR*<sub>11</sub> Long Wavelength Infrared<sub>11</sub> <http://fas.org/irp/imint/docs/rst/Front/overview.html>

### 4.3.3 Office Work

#### 4.3.3.1 Classification and Distribution of Soil Units in Bahar Al-Najaf Region

The soils were classified into order, suborder, great group and family levels according to the (Soil Survey Staff 1999). While for the series level under the proposed classification of Al-Agidi (1976) for Iraqi alluvial soils (Table 4.4; Figs. 4.4 and 4.7).

#### 4.3.3.2 Remote Sensing Data Used in the Study

The Landsat 8 satellite, which carries two sensors (OLI and TIRS) with 11 bands was adopted to capture study area image on 13-7-2014 was downloaded from the USGS site (Table 4.1). The study area was deducted using the ERDAS Imagine to ensure a complete and accurate form for the study area. RGB (753) False Color Composite was chosen to distinguish terrestrial and geomorphological phenomena as being specialized for soil studies, separation of its units and minerals (Martinez-Rios and Monger 2002; Yacoub et al. 2008; Faleh and Shawan 2012; Al-Issawi et al. 2012).

**Table 4.2** Some physical and chemical properties for soil surface layers of auger holes in the study area

Auger Points	Sand gm kg <sup>-1</sup>	Silt	Clay	Texture	B. D Mg m <sup>-3</sup>	PH	EC ds/m	O.M %	Gyps. g kg <sup>-1</sup>	Lime g kg <sup>-1</sup>	Coordinates	
											X	Y
L1	300	532	168	Si L	1.55	7.6	74.3	0.83	23.97	235	44.453	31.866
L2	780	92	328	S CL	1.23	7.55	177	0.51	52.83	230	44.392	31.772
L3	512	380	108	S L	1.62	7.52	4.07	0.32	14.4	620	44.371	31.76
L4	360	372	268	L	1.49	7.95	49.5	0.44	22.32	220	44.29	31.81
L5	760	72	168	S L	1.52	7.56	5.66	0.27	11.16	290	44.31	31.834
L6	674	198	128	S L	1.48	7.56	3.03	0.18	10.59	245	44.278	31.769
L7	662	78	260	S CL	1.45	7.38	8.77	0.23	13.46	590	44.187	31.713
L8	564	598	328	S CL	1.53	7.36	2.8	0.21	12.36	370	44.229	31.754
L9	552	160	288	S CL	1.09	7.39	2.12	0.11	11.02	230	44.278	31.724
L10	114	718	168	S L	1.46	8.26	41.2	3.22	18.17	315	44.293	31.968
L11	732	240	28	L S	1.57	8.33	3.63	3.15	13.83	120	44.297	31.998
L12	512	360	128	L	1.53	8.37	80.2	2.64	15.76	150	44.426	31.938
L13	422	368	208	L	1.52	7.86	39.5	2.48	24.21	185	44.396	31.923
L14	252	480	268	L	1.51	7.34	9.68	1.53	12.18	45	44.399	31.882
L15	124	648	228	Si L	1.66	7.15	3.04	2.36	13.58	345	44.452	31.913
L16	232	500	268	C	1.63	7.35	65.5	3.37	23.73	475	44.442	31.892
L17	624	248	128	S L	1.37	7.48	1.97	0.48	11.5	505	44.027	31.861
L18	632	340	28	S L	1.66	7.46	1.91	0.62	8.73	235	44.023	31.896
L19	532	400	68	S L	1.44	7.51	28.5	0.54	16.06	225	44.042	31.985
L20	732	198	70	S L	1.25	7.49	1.83	0.17	12.05	505	44.117	31.833
L21	632	200	168	S L	1.46	7.61	35.1	0.68	15.75	180	44.172	31.873

**Table 4.3** Some physical and chemical properties for soil horizons of the pedons in the study area

Pedons	Horizons	Depth cm	Sand gm kg <sup>-1</sup>	Silt	Clay	Texture	B.D Mg m <sup>-3</sup>	PH	Ecc 1:1 dsm <sup>-1</sup>	O.M g kg <sup>-1</sup>	Gyp. g kg <sup>-1</sup>	Lime g kg <sup>-1</sup>	Coordinates	
													X	Y
2	A	0-15	298.4	391.6	310	CL	1.44	7.82	2.99	4.7	10.2	445	43.96	31.95
	C <sub>1</sub>	15-35	244	376	380	CL	1.49	7.71	3.79	4.6	4.23	445		
	C <sub>2</sub>	35-68	242	348.8	407.2	C	1.48	7.75	3.44	3.2	4.34	450		
	C <sub>3</sub>	68-110	569.6	163.2	267.2	SCL	1.5	7.64	2.77	1.8	5.76	500		
	C <sub>4</sub>	110-150	578.7	165.3	256	SCL	1.64	7.68	2.82	0	6.12	535		
3	A	0-10	776	136	88	SL	1.7	7.72	2.5	6.6	10.2	225	44.12	31.89
	C <sub>1</sub>	10-25	796	156	48	LS	1.73	7.68	2.5	4.5	10.4	425		
	C <sub>2</sub>	25-50	684	148	164	SL	1.61	7.48	6.68	2.5	10.9	215		
	C <sub>3</sub>	50-85	824	116	60	LS	1.64	7.59	3.02	1.1	9.95	405		
	C <sub>4</sub>	85+	Rock											
4A	Ap	0-10	485.6	447.1	67.2	SL	1.21	7.28	121	4	26.2	205	44.09	31.97
	C <sub>1</sub>	10-23	635.3	306	58.5	SL	1.12	7.49	47.4	3.5	14.9	163		
	C <sub>2</sub>	23-46	585.6	374.4	40	SL	1.03	7.58	28	2.9	13.6	185		
	C <sub>3</sub>	46-85	545.6	414.4	40	SL	1.11	7.72	11.8	2.7	11.7	180		
	C <sub>4</sub>	85-160	605.6	344.4	50	SL	1.18	7.7	14.9	2.4	10.8	175		
4B	A	0-10	445.6	307.2	247.2	L	1.43	7.46	40	4.1	13.4	525	44.1	31.96
	C <sub>1</sub>	10-38	465.6	494.4	40	SL	1.55	7.74	15	2.4	12.2	575		
	C <sub>2</sub>	38-95	685.6	114.4	200	SL, SCL	1.65	7.63	9.41	3.3	11.3	514		

(continued)

Table 4.3 (continued)

Pedons	Horizons	Depth cm	Sand gm kg <sup>-1</sup>	Silt	Clay	Texture	B.D Mg m <sup>-3</sup>	PH	Ecc 1:1 dsm <sup>-1</sup>	O.M g kg <sup>-1</sup>	Gyp. g kg <sup>-1</sup>	Lime g kg <sup>-1</sup>	Coordinates	
													X	Y
5	C <sub>3</sub>	95-150	705.6	234.4	60	S.L	1.44	7.59	4.7	1.7	11.2	483		
	C <sub>4</sub>	150+	665.6	294.4	40	S.L	1.36	7.51	3.87	0	11.2	455		
	A	0-10	376.8	301.6	321.6	C.L	1.33	7.91	2.46	2.3	10	245	43.96	31.95
	C <sub>1</sub>	10-30	439	496	65	L	1.41	7.7	8.69	4.2	10.7	255		
6	C <sub>2</sub>	30-70	302	288	424	C	1.34	7.64	3.91	3	10.8	300		
	C <sub>3</sub>	70-130	211.2	348.8	440	C	1.45	7.34	2.64	1.5	10.9	355		
	C <sub>4</sub>	130+	Rock											
	A	0-5	785.6	154.4	60	L.S	1.58	7.72	3	2.9	11.8	250	44.1	31.97
7	C <sub>1</sub>	5-15	931.2	31.6	37.2	S	1.62	7.8	2.54	2.4	11.1	220		
	C <sub>2</sub>	15-47	941.2	21.6	37.2	S	1.65	7.79	2.88	2.5	10.8	230		
	C <sub>3</sub>	47-60	931.2	31.6	37.2	S	1.68	7.79	2.7	1.3	10.7	220		
	C <sub>4</sub>	60-103	758	46	196	S.L	1.64	7.67	3.11	0.6	7.57	220		
7	C <sub>5</sub>	103+	Rock											
	A	0-12	776	40	184	S.L	1.69	7.59	9.73	5.1	10.8	570	44.14	31.86
	C <sub>1</sub>	12-26	858.4	111.6	30	L.S	1.65	7.71	3.43	4.8	10.7	475		
	C <sub>2</sub>	26-46	566	390	44	S.L	1.53	7.67	7.88	4	10.5	435		
	C <sub>3</sub>	46-78	731.2	228	40	S.L	1.59	7.68	8.45	4.9	10.7	450		
7	C <sub>4</sub>	78-110	876	70	54	L.S	1.51	7.61	7.91	2.6	11.4	480		
	C <sub>5</sub>	110-150	574	378	48	S.L	1.54	7.53	7.23	0	10.1	490		

(continued)

Table 4.3 (continued)

Pedons	Horizons	Depth cm	Sand gm kg <sup>-1</sup>	Silt	Clay	Texture	B.D Mg m <sup>-3</sup>	PH	Ecc 1:1 dsm <sup>-1</sup>	O.M g kg <sup>-1</sup>	Gyp. g kg <sup>-1</sup>	Lime g kg <sup>-1</sup>	Coordinates	
													X	Y
8	A	0-15	262	288	464	C	1.39	7.41	48.1	3.7	16.4	390	44.23	31.92
	C <sub>1</sub>	15-37	249.6	239.6	514.4	C	1.52	7.68	14.7	5.2	11.9	370		
	C <sub>2</sub>	37-107	312	268	404	C	1.59	7.78	4.6	3.5	11.4	295		
	C <sub>3</sub>	107-180	768	118	114	SL	1.65	7.65	5.17	3.1	10.9	270		
9	A	0-10	549.8	402	48.2	SL	1.33	7.34	88.9	1.5	22.2	245	44.22	31.86
	C <sub>1</sub>	10-38	560	373.5	66.5	SL	1.16	7.44	30.3	1.2	14.2	235		
	C <sub>2</sub>	38-106	568	38.48	47.2	SL	1.13	7.77	5.53	1.6	11.1	260		
	C <sub>3</sub>	106-123	448	495.2	47.2	SiL	1.38	7.74	5.32	2.6	10.8	305		
	C <sub>4</sub>	123-140	608	344.8	47.2	SL	1.47	7.79	4.63	2.2	10.9	345		
10	C <sub>5</sub>	140-185	651.2	271.6	77.2	SL	1.43	7.76	5.47	2.2	10.4	350		
	Ap	0-10	584	358	58	SL	1.41	7.71	3.08	2	11.2	300	44.25	31.8
	C <sub>1</sub>	10-38	568	364	68	SL	1.39	7.62	3.29	1.5	11.1	300		
	C <sub>2</sub>	38-50	528	318	154	SL	1.33	7.58	4.5	0	6.44	280		
	R	50+	Rock											
11	A	0-15	122.4	577.4	300.2	SiCL	1.47	7.42	90	8.5	30.5	168	44.29	31.87
	C <sub>1</sub>	15-37	433	506.3	60.7	SiL	1.53	7.58	45	4.3	12.5	340		
	C <sub>2</sub>	37-60	451.2	307.4	241.4	L	1.49	7.5	18.6	2.5	10.6	472		
	C <sub>3</sub>	60-88	378.1	467.3	154.6	L	1.55	7.8	6.3	1	8.56	426		
	C <sub>4</sub>	88-115	707.1	232.6	60.3	SL	1.53	7.8	5.7	0	7.4	205		
C <sub>5</sub>	115-145	768	118	114	SL	1.48	7.85	4.5	0	8.3	218			

(continued)



**Table 4.3** (continued)

Pedons	Horizons	Depth cm	Sand gm kg <sup>-1</sup>	Silt	Clay	Texture	B:D		PH	Ecc 1:1 dsm <sup>-1</sup>	O.M g kg <sup>-1</sup>	Gyp. g kg <sup>-1</sup>	Lime g kg <sup>-1</sup>	Coordinates	
							Mg m <sup>-3</sup>							X	Y
12	A	0-20	863	56.4	80.6	L S	1.52	7.59	54.3	2.5	10.4	357	44.27	31.9	
	C <sub>1</sub>	20-37	707.1	232.6	60.3	S L	1.48	7.46	45.9	1.7	8.8	448			
	C <sub>2</sub>	37-47	439	496	65	L	1.51	7.32	41.2	0.4	5.41	402			
	C <sub>3</sub>	47-60	732.5	205	62.5	S L	1.49	7.58	42.4	0	10.4	205			
	C <sub>4</sub>	60-88	401.8	291.6	306.6	C L	1.41	7.47	38.2	0	29.6	263			
13	C <sub>5</sub>	88-120	145.6	507	347.4	SiCL	1.45	7.33	34.4	0	14.9	452			
	A	0-25	217.3	561.6	221.1	Si L	1.51	7.44	62.4	6.5	14.4	297	44.33	31.86	
	C <sub>1</sub>	25-50	81.6	562.1	356.3	SiCL	1.5	7.54	14.8	3.7	7.81	248			
	C <sub>2</sub>	50-60	378.1	467.3	154.6	L	1.54	7.39	16.2	1.4	7.94	262			
	C <sub>3</sub>	60-80	18.9	588.8	392.3	SiCL	1.48	7.54	32.4	1.1	10.8	275			
14	C <sub>4</sub>	80-110	32.5	528.2	439.3	SiC	1.46	7.47	38.2	0	12.5	263			
	C <sub>5</sub>	110-140	622	282.7	95.3	S L	1.53	7.25	36.4	0	9.57	227			
	A	0-12	406.2	496.1	97.7	L	1.54	7.41	104	6.5	49.1	204	44.23	31.96	
	C <sub>1</sub>	12-40	368.7	471.2	160.1	L	1.53	7.62	36.5	3.1	16.5	386			
	C <sub>2</sub>	40-70	438	506.6	55.4	Si L	1.56	7.57	11	1	19.2	216			
15	C <sub>3</sub>	70-115	145.4	507.3	347.3	SiCL	1.54	7.58	8.65	0	10.1	361			
	C <sub>4</sub>	115-145	75.5	642.4	282.1	SiCL	1.52	7.64	14.2	0	12.1	376			
	A	0-10	912	60	28	S	1.66	7.76	2.63	2.6	11.6	510	44.06	31.91	
	C <sub>1</sub>	10-60	826	138	36	S L	1.57	7.84	1.89	0.4	2.97	575			
	C <sub>2</sub>	60-90	874	84	42	L S	1.61	7.88	1.45	Nil	2.24	590			

(continued)

Table 4.3 (continued)

Pedons	Horizons	Depth cm	Sand gm kg <sup>-1</sup>	Silt	Clay	Texture	B:D Mg m <sup>-3</sup>	PH	Ecc 1:1 dsm <sup>-1</sup>	O.M g kg <sup>-1</sup>	Gyp. g kg <sup>-1</sup>	Lime g kg <sup>-1</sup>	Coordinates	
													X	Y
16	A	0-12	372	200	428	L	1.52	7.74	1.73	1.4	2.67	210	44.27	31.75
	C <sub>1</sub>	12-33	572	148	280	SCL	1.63	7.78	1.16	0.3	2.47	365		
	C <sub>2</sub>	33-85	812	100	88	L S	1.61	7.85	0.43	Nil	Nil	450		
	C <sub>3</sub>	85-150	592	120	288	S C L	1.55	7.61	1.58	Nil	Nil	485		

CL Clayey Loam; C Clayey; SCL Sand Clay Loam; SL Sandy Loam; LS Loamy Sand; L Loamy; S Sandy; SiCL Silty Clay Loam; SiL Silty Loam

**Table 4.4** Classification of soils according to Soil Survey Staff (1999) and the proposal of Al-Agidi (1976) for Iraqi alluvial soil series

Family	Sub Great Group	Great Group	Sub order	Order	Series	Area km <sup>2</sup>	Pedon No.
Fine silty, mixed, active, calcareous, hyperthermic, Typic torrifuvents	Typic torrifuvents	Torrifuvents	Fluents	Entisols	DE126	10.31	P2
Sandy, mixed, active, gypsic, hyperthermic, Typic Haplocalcids	Typic torrripsamments	Torrripsamments	Psamments	Entisols	DE33	102.83	P3
Sandy, mixed, active, gypsic, hyperthermic, Typic Haplocalcids	Typic torri psamments	Torrripsamments	Psamments	Entisols	DE34	44.97	P4A
Sandy, mixed, active, calcareous, hyperthermic, Typic torrripsamments	Typic torrripsamments	Torrripsamments	Psamments	Entisols	DE74	31.73	P4B
Clayey, mixed, active, gypsic, hyperthermic, Typic torrifuvents	Typic Torrifuvents	Torrifuvents	Fluents	Entisols	DE47	707.9	P5
Sandy, mixed, active, gypsic, hyperthermic, Typic Haplocalcids	Typic quartzipsamments	Quartzipsamments	Psamments	Entisols	DM14	34.37	P6
Sandy, mixed, active, calcareous, hyperthermic, Typic torrripsamments	Typic torrripsamments	Torrripsamments	Psamments	Entisols	TE334	47.49	P7
Clayey, mixed, active, calcareous, hyperthermic, Typic Haplocalcids	Typic torrifuvents	Torrifuvents	Fluents	Entisols	DW124	118.65	P8

(continued)

Table 4.4 (continued)

Family	Sub Great Group	Great Group	Sub order	Order	Series	Area km <sup>2</sup>	Pedon No.
Loamy, mixed, active, gypsic, hyperthermic, Typic Haplosalids	Typic torrifuvents	Torrifuvents	Fluvents	Entisols	TE354	22.89	P9
Loamy, mixed, active, calcareous, hyperthermic, Typic Torrripsamments	Typic torrifuvents	Torrifuvents	Fluvents	Entisols	MW3	168.83	P10
Loamy, mixed, active, gypsic, hyperthermic, Typic torrifuvents	Typic torrifuvents	Torrifuvents	Fluvents	Entisols	DM44	15.94	P11
Sandy, mixed, active, calcareous, hyperthermic, Typic torrripsamments	Typic torrripsamments	Torrripsamments	Psamments	Entisols	TW446	113.58	P12
Loamy, mixed, active, gypsic, hyperthermic, Typic torrifuvents	Typic torrifuvents	Torrifuvents	Fluvents	Entisols	TW964	185.51	P13
Loamy, mixed, active, gypsic, hyperthermic, Typic Haplocalcids	Typic torrifuvents	Torrifuvents	Fluvents	Entisols	DW56	118.42	P14
Sandy, mixed, active, calcareous, hyperthermic, Typic Torrripsamments	Typic quartzipsamments	Quartzipsamments	Psamments	Entisols	ME1	62.35	P15
Loamy, mixed, active, calcareous, hyperthermic, Typic Torrripsamments	Typic Torrripsamments	Torrripsamments	Fluvents	Entisols	ME1	48.19	P16

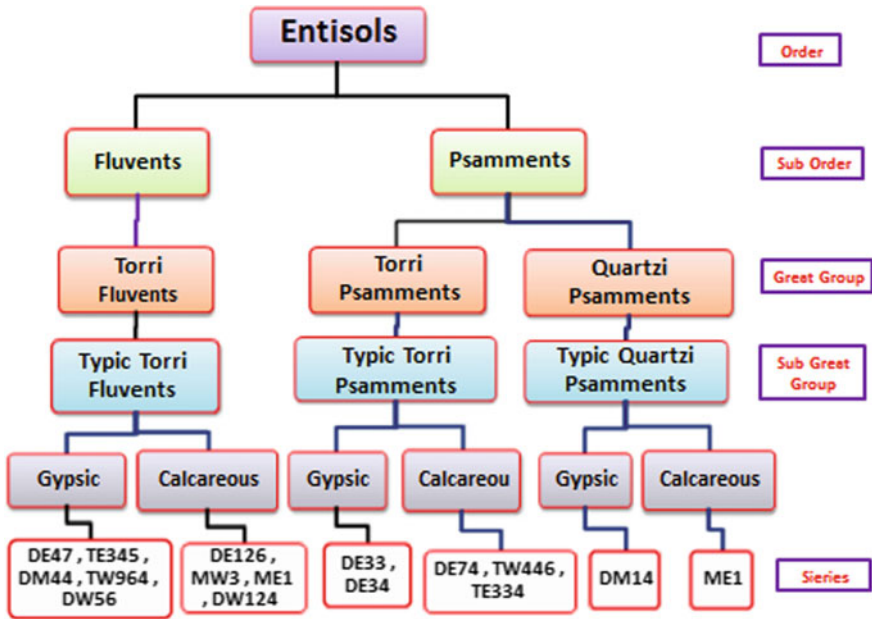


Fig. 4.4 Classification of the study soil according to the modern American system Soil Survey Staff (1999) and Al-Agidi's (1976) proposal for sedimentary soil series

### 4.3.3.3 Satellite Image Enhancement Processing

A series of enhancement processing was applied to the satellite image, which aimed to make the image's information more visible for purposes of visual interpretation. They included:-

#### Radiometric Enhancement

Means the removal of noise or interference of image elements because it affects the values of their spectral reflectivity, especially for red and near-infrared spectral bands.

#### Spectral Correction

Reflectivity is expressed by its true radiation by reversing the numerical numbers of the reflectivity (Digital Number, DN) to the actual radiation values, Top Of Atmosphere radiance (TOA). It considered as a radiometric treatment method which was important in the development of mathematical models that physically attach images data to ground truth (Lillesand and Kiefer 2000).

### Spatial Enhancement

The integration of the spectral band 8 with other satellite bands, facilitated the acceleration of application and the maintenance of information accuracy and results to serve the purposes of the study in terms of the ability to distinguish well the types of soils in the image and to clearly demonstrate the process of integrating layers (Layer Stack) using ERDAS Imagine 2013.

#### 4.3.3.4 Digital Classification of Image

The classification methods include algorithms of both supervised and unsupervised classification. In both cases, the image was divided and classified into categories that give each category a specific color or code for thematic map production.

#### Unsupervised Classification

Unsupervised classification applied using the K-Mean method, to determine the varieties without external interference to obtain an overview of the differences in the reflectivity of the study area soils. The calculator performs the classification process with higher accuracy and less distortion in the isolation of ground parameters (Fig. 4.5), because it works on the basis of pixels values represented by terrestrial

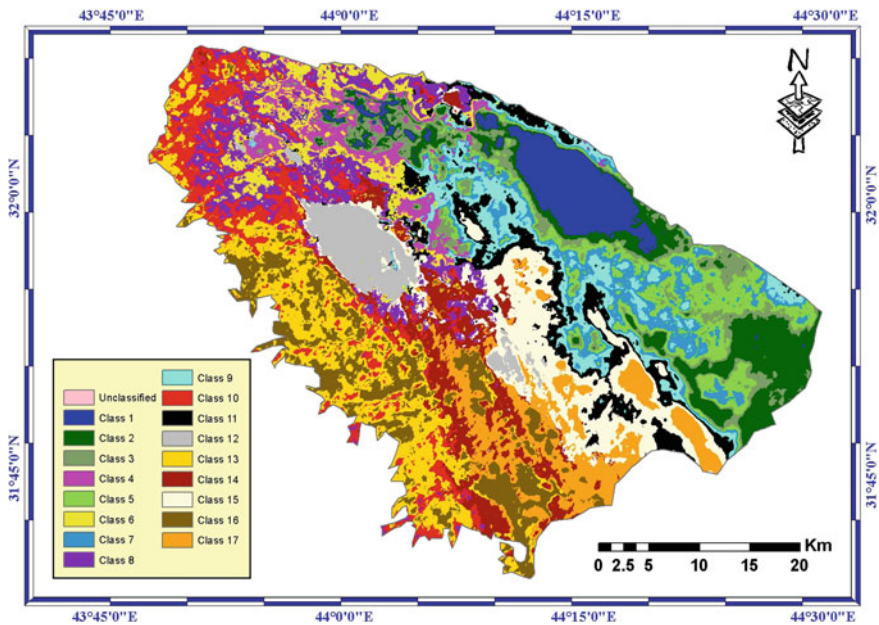


Fig. 4.5 Shows the unsupervised classification results of the study area

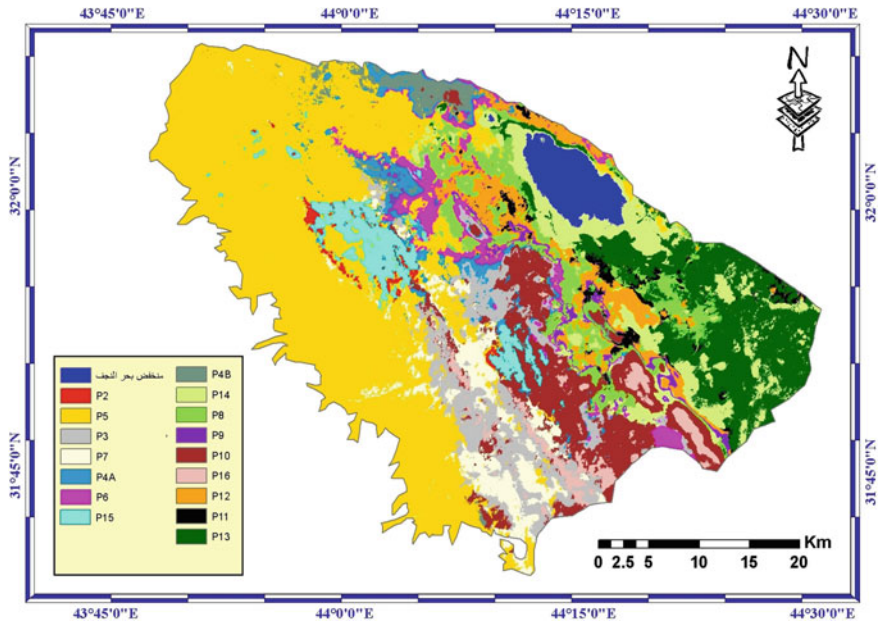


Fig. 4.6 Supervised classification to the study area soils based on pedons sites

features, which are separated and isolated by ERDAS Imagine 2013. This process was repeated several times to obtain satisfactory results (Lillesand and Kiefer 2000).

Supervised Classification

Was carried out using the Maximum Likelihood method, after obtaining the results of samples analysis taken for the pedons sites as in (Fig. 4.2). Training samples were then identified, which included all variances in the study area. The spectral signatures were taken for each training sample. This type of classification includes two stages (training and classification) (Fig. 4.6).

4.3.4 Accuracy Assessment for Digitalmap Classification

The accuracy of the classification was calculated by choosing 256 basis points, and the points outside the study area were excluded. Therefore, 140 points were adopted within the boundaries of the study area which compared with the points and locations of the classes values of the study area image which classified as supervised. The soil category code for each random point was fixed in the reference column of the accuracy assessment window. After the completion of the points, the final report

was prepared to assess the accuracy of the classification, including the calculation of the following methods of accuracy: (Kappa coefficient, Users accuracy, Producers accuracy, Overall accuracy) (Table 4.7).

### **4.3.5 Preparation of GIS Database**

This was done through the creation and implementation of the following measures.

#### **4.3.5.1 Entering Quantity Data**

Tabulated data containing the characteristics of spatial information, represented by the results of physical and chemical analysis of the study pedons were entered into Microsoft-MS Excel, and convert them into a database. So that, they can be joined later with the plan of the units and locations of soil pedons representing soil characteristics required in the production of spatial distribution of soil map units of the study area.

#### **4.3.5.2 Map Digitizing**

Performed by using the Arc GIS 10.3 software and implementing the screen digitization method for mapping soil units and pedons locations, and convert them into digital maps (shp.file) with two types of features: points representing the locations of pedons while polygons for soil individuals.

## **4.4 Results and Discussion**

### **4.4.1 Classification and Distribution of Soil Units in the Study Area**

The soils of the study area were classified at the levels of order, suborder, great soil group, subgroup and family according to (Soil Survey Staff 1999). Moreover at a series level according to the proposed classification of Iraqi alluvial soils by Al-Agidi (1976) (Figs. 4.4 and 4.7; Table 4.4), which depends on the presence of three different layers or textures except for the upper surface which goes to soil type. The thickness requirements of the first layer about  $35 + 5$  cm and  $40 + 5$  cm for the second and third layers (Table 4.3). The soil series was named with the following symbols:

- a. Number of layers: symbolized as (M, D, T) for (1, 2, 3) layers respectively.



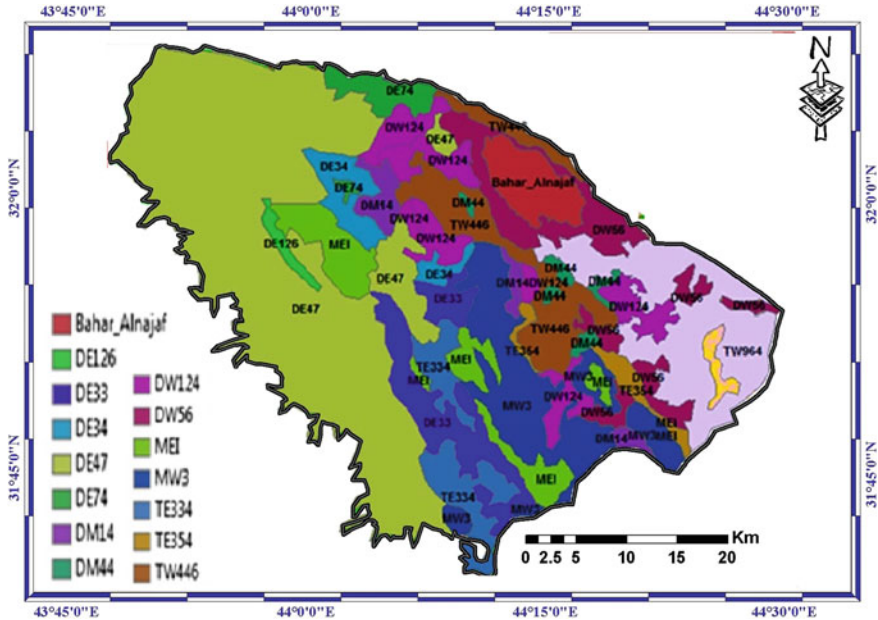


Fig. 4.7 Distribution of the soil series of the study area by adopting the supervised classification

- b. Natural drainage class: This indicates the movement of water in the soil depending on the depth at which the mottling appear via 50% or more of the test exposed surface.

The results of the physical and chemical properties in (Table 4.3) indicate that The soils of the study area were undeveloped, classified as Entisols order. This is due to the nature of the environmental conditions prevailing in the study area as a result of the nature of the dry climate and the non-dense vegetation cover. These factors do not help the activity of the pedogenic processes responsible for the development of soil at an adequate level as well as the shorten chronological age of the parent material of these soils. The results were consistent with Mahmoud and Mahimid (2011) when studying the evolutionary status of Bahar Al-Najaf soils. Since all these soils are located in the alluvial plain, which receives new deposits of sedimentary material at frequent intervals of time. This has helped to weaken the pedogenic activity and characterized as A-C horizons alternation (Buringh 1960).

These soils were recognized by the presence of the surface horizon Ochric. It characterized by light color with low organic matter content and color value 4 or more in the moist state and 6 or more in the dry state, with the dominant of dry, moist system add to the Control section is not moist for most days in the year as well as the soil is unsaturated within the first meter of soil body. The soils order was classified into two suborders. The first Fluvents, which their parent materials are the result of added sediments, while the second Psamment which is located

within the desert region and the parent materials are ancient deposits rich in coarse particles represented by gravel and sand. The main soil groups are, torrifuvents, torripsamments, quartzipsamments and three sub great groups are typic torrifuvents, typic torripsamments, Typic quartzipsamments and nine families, as well as 15 soil series, were named: DE126, DE33, DE34, DE74, DE47, DM14, TE334, DW124, TE354, MW3, DM44, TW446, TW964, DW56, ME1. The largest soil series area DE47 Occupied 707.9 Km<sup>2</sup> from the study area, The smallest area of 10.31 Km<sup>2</sup> was for the DE126 series. The illustrations of these details are shown in (Figs. 4.4 and 4.7; Table 4.4).

#### ***4.4.2 Digital Image Classification Using Remote Sensing Techniques***

The most common methods are:

##### **4.4.2.1 Unsupervised Classification**

Figure 4.5 shows the results of the unsupervised classification of the study area, comprising 17 soil classes as well as unclassified sites located outside the boundaries of the study area.

##### **4.4.2.2 Supervised Classification**

Figures 4.6 and 4.7 illustrate the classification method for the study area soils in addition to the final map sorted to the level of the series with their respective area in Km<sup>2</sup> units.

#### ***4.4.3 Accuracy Assessment of Digital Classification***

The classification accuracy technique is considered to be a quantitative analysis of the results obtained, It is necessary and important to assess the degree of error at the end of the work and to indicate the compatibility of the items titles in the thematic (classified) map with ground truths or reference data for the same sites (Jensen 2007; Taruvinga 2008).

The primary objective of assessing accuracy is to estimate the elements and components of the error or confusion matrix and different descriptive measurements of terrestrial data within the field of study and gives a decision on the accuracy of the spectral data and the chosen method (Nain and kumar 2016; Stehman 2013).

**Table 4.5** The error matrix for the soil series units of the study area from Landsat 8 image

Classified data	Reference Data															Row total	Mapping accuracy (%)	
	P2	P5	P3	P7	P4A	P6	P4B	P14	P8	P9	P10	P16	P12	P11	P13			P15
P2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	50
P5	0	38	0	1	0	0	0	0	0	0	0	0	0	0	0	0	39	95
P3	0	0	9	0	1	0	0	0	0	0	0	0	0	0	0	0	10	81.8
P7	0	1	0	10	0	1	0	0	0	0	0	0	0	0	0	0	12	77
P4A	0	0	1	0	3	0	0	0	0	0	0	0	0	0	1	0	5	43
P6	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	7	87.5
P4B	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	7	87.5
P14	0	0	0	0	1	0	1	9	0	0	0	0	0	0	0	0	11	75
P8	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	5	83.3
P9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	100
P10	1	0	0	0	0	0	0	0	1	0	7	0	0	0	0	0	9	63.3
P16	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
P12	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	100
P11	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	66.7
P13	0	0	0	0	0	0	0	0	0	0	1	0	0	1	20	0	22	87
P15	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	5	6	83.3
Col. Totals	2	39	10	11	5	8	8	10	6	1	9	0	1	3	21	5	140	-

Table 4.5 shows the error matrix for fifteen soil units classified at the series level as suggested by Al-agidi (1976) resulting from a supervised classification using maximum likelihoods classifier. The validity of this classification was based on 140 reference points selected within the study area out of a total of 256 random points using the ERDAS 2013. The error matrix provides information on the correct and incorrect prediction of the image classification by comparing the classified map with the ground information. It works on the basis of class-by-item comparison between source data known as ground truth and the corresponding results on the classified image (Martine—Rios and Monger 2002; Proklamasi et al. 2015; Nash 2016).

The following methods are calculated for accuracy: Users accuracy, Producers accuracy, Overall accuracy, Kappa coefficient. Kappa coefficients are the most commonly used to measure the accuracy of the thematic map, as it shows the difference between actual agreement for reference data and the expected agreement of classified data by chance (Nain and kumar 2016). Koutroumpas et al. (2010) divided Kappa coefficient values into five categories of agreement classes (Table 4.6).

Table 4.7 shows that the producer accuracy of ME1, TW446, and TE354 soil series were 100%, this means that all the reference data pixels classified and located in the thematic map within those soil series. High values of producer accuracy (omission errors) as in the soil series DE47, DE33, TE334, TW964, DW56 are indicated that most of the terrestrial reference data pixels were classified in their corresponding positions in the classified thematic map. According to Koutroumpas et al. (2010) classification. The accuracy of the soil series units map of the study area were classified as very good for soil series ME1, TW964, TW446, TE354, DW124, DE74,

**Table 4.6** Accuracy ranges of Kappa  $K_{hat}$  coefficients and agreement classes by Koutroumpas et al. (2010)

Agreement classes	Kappa $K_{hat}$ coefficient range
Poor	$\leq 0.2$
Fair	0.21–0.40
Moderate	0.41–0.60
Good	0.61–0.80
Very good	0.81–1.00

**Table 4.7** Accuracy evaluation of the error matrix data for soil series of the study area

Class name	Soil series	Reference totals	Classified totals	Number correct	Producers accuracy (%)	Users accuracy (%)	Kappa coefficient
P2	DE126	2	1	1	50.00	100.00	1
P5	DE47	39	39	38	97.44	97.44	0.9645
P3	DE33	10	10	9	90.00	90.00	0.8923
P7	TE334	11	12	10	90.91	83.33	0.8191
P4A	DE34	5	5	3	60.00	60.00	0.5852
P6	DM14	8	7	7	87.50	100.00	1
P4B	DE74	8	7	7	87.50	100.00	1
P14	DW56	10	11	9	90.00	81.82	0.8042
P8	DW124	6	5	5	83.33	100.00	1
P9	TE354	1	1	1	100.00	100.00	1
P10	MW3	9	9	7	77.78	77.78	0.7625
P16	ME1	0	1	0	–	–	0
P12	TW446	1	1	1	100.00	100.00	1
P11	DM44	3	2	2	66.67	100.00	1
P13	TW964	21	22	20	95.24	90.91	0.893
P15	ME1	5	6	5	100.00	83.33	0.8272
Totals		140	140	126			

Overall Classification Accuracy = 90.00%

Overall Kappa Statistics = 0.8846

DM14, DE47, DE33 and good for DM44, MW3, DW56, TE334 as well as Moderate for soil series DE34, DE126 (Tables 4.6 and 4.7).

Generally, it is noted that the overall accuracy of the soil units classification 90%, This means that the probability of 90% of the reference pixels is correctly classified within the classified map (Jensen 2007). The value of the Kappa coefficient is 0.8846. This means that there is a statistical acceptance of 88.46% between the pixels or reference points and their corresponding on the classified map. According to the Kappa equivalent value and the classification proposed by Koutroumpas et al. (2010). The overall accuracy of supervised classification of all sites in the study area

falls within the category very good. It means, that is a very good agreement between ground truths and classified data.

## 4.5 Conclusions

1. There is a weak activity of the pedogenic process affecting the soil formation of the study area. Within the full dominion of the undeveloped soils (Entisols) order, as well as the influence of geomorphic processes. The nature of sedimentation sources from the highlands in the western and southwestern parts of Bahar Al-Najaf Region affects the quantity and nature of the distribution of soil components vertically and horizontally between pedons.
2. The remote sensing and GIS techniques contributed effectively and distinctly the in identification and separation of soil units. The overall accuracy of the matrix error obtained from the supervised classification using was 90% as well as 0.8846 for Kappa statistical coefficient. This means a very good acceptance of the thematic map to classify studied soils.
3. The study demonstrated the importance of remote sensing and GIS techniques for studying natural resources, including soil, its characteristics, depending on the analysis of the satellite images digitally and visually. As well as economic feasibility in the field of survey and classification of soils through the reduction of effort, cost, speed up the completion of work and reducing the difficulties compared to traditional surveys.

## 4.6 Recommendations

1. Emphasize the importance of using RS and GIS techniques in soil survey and classification studies because of the speed and accuracy of the work, preparation of soil survey and classification maps, add to reducing the effort and cost compared to field surveys.
2. Take advantage of remote sensing technologies and digital processing processes by selecting suitable spectral bands and integrating them into combinations that contribute to the study, detection and identification of desertification and land degradation areas.
3. In order to improve the results and to obtain the more specialized spectral signature curves as well as more details of the characteristics studied, especially in the field of surveying and classification of soils. We recommend using data from more than one sensor at the same time as their basis, or using images of sensors with high spectral and spatial discrimination capabilities that have multiple spectral bands with a narrow width (Hyper spectral imagery).

4. The need to use active remote sensing techniques to sense the internal soil characteristics, as well as the possibility of pairing with the passive technology to increase the efficiency of using remote sensing in soil studies.
5. The field measurements of the reflectivity are more accurate than the calculations of the satellite image because of many overlaps between the conditions and time of the images capture and the surface components of the earth coverings, which greatly affect the real values of their reflectivity. This requires calibration of the spectral reflectivity values calculated from the satellite images with the field reading using the spectroradiometer device.

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