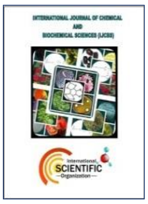
International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html



Thematic maps for soil chemical properties of land resource in El-Qaliobia Governorate, Egypt

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Abstract

The soil chemical degradation is the decline in soil quality mainly due to negative human activities that lead to adverse changes in soil chemical characteristics. This study aims to define the physiographic units over the area, create thematic maps of chemical properties and to evaluate the status of soil chemical properties. A semi detailed land survey was done and remote sensing data were employed to realize these objectives. The obtained results indicated that the majority of soils in the area under study is clayey textured, which had a very significant impact on their chemical properties. Electrical conductivity (EC) values in general vary from 0.4 to 12.1dS/m. The Cations Exchange Capacity (CEC) values were ranges from 2.8 to 53.9 Cmol (+)/kg^{-1}. ESP values changes between 9.9 and 18.8%, $CaCO_3$ in the studied soils ranges from 0.2 to 3.1%. Organic matter values vary between 0.1 and 1.8 %. Available Nitrogen was ranges from 10.7 to 44.8 %. Available phosphorous was ranges from 5.9 to 30.3 %. Available potassium was ranges from 16.2 to 299 %. The soil chemical characteristics were discussed in detail with their spatial distribution over the investigated area.

Keywords: Chemical properties; spatial variability; El-Qaliobia Governorate, Egypt.

Full length article **Corresponding Author*, e-mail: batooladel201793@gmail.com

1. Introduction

The evaluation of agricultural land management strategies requires an understanding of the spatial variability of soil and the interactions among its qualities [10]. One of the definite problems of soil genetic and land reclamation in regions under arid and semiarid conditions is to obtain massive data on saline soils and their properties, areas of distribution, dynamics of salinity process [6]. The impact to agricultural production ranges from slight yield loss to complete crop failure, depending on both the crop type and the physicochemical soil features, including their salt content [13]. [14] reported that organic matter has chosen as an index of soil sustainability and productivity because it contributes significantly to soil fertility and influences many soil properties, acts as a source and sink for nutrients has charge properties and provides sites for ion exchange; modified soil physical structure and influences soil water regimes and many of biological processes in soil therefore, decreases or increases of soil organic matter could affect soil fertility. [8] studied the soils of Qaliobia reporting that the soils are characterized by the following: pH between 7.1 and 7.9, EC between 0.34 to 23.20 dS/m, ESP between 0.49 and 58.89, organic matter between 0.4, 61.6 g/kg, and CEC between 10.0 and 52.0 cmol/kg soil. [1] studied some soils in Qaliobia and reported pH ranged from 7.1 to 8.3, EC of less than 4 dS/m, organic matter less than 23.0 g/kg and CEC of 1.2 to 50.9 cmol/ kg soil. [2] studied soils of Qaliobia and reported the following: Soil pH values lie in general on the alkaline side. All soils had exceeding 8.0, EC values exceeding 4.0 dS/m, CEC ranged between 10.37 and 43.47 cmol/kg soil and organic matter between 4.0 and 51.3 g/kg. The objectives of this work were to study soil chemical properties and their spatial distribution in El-Qaliobia using GIS and remote sensing.

2. Materials and methods

2.1. Study area

El-Qaliobia Governorate located between longitudes 30° 15′ 0″ and 30° 30′ 0″ N and latitude 31° 03′ 30″ and 31° 34′ 30″ E. It covers an area 1022 km^2. In view of the climatic data after the Egyptian Meteorological Authority [3] and the keys to soil taxonomy [16], the soil temperature regime of the area is defined as Thermic, while the soil moisture regime is Aridic. The geographical composition of the region in question is attributed to the late Pleistocene period, characterized by the presence of prenile deposits, isolated hills and Nile silt [4]. the main geomorphologic units over the area include decantation basin, islands, levees, overflow basin, overflow mantle, river terraces, and turtle backs.

2.2. Landform mapping

Digital image processing was conducted on a single Landsat OLI-8 satellite image (path 176, row 39) that was obtained from the Geologic Survey archive of the United States Geological Survey (USGS) in the year 2022. This image was enhanced using the ENVI 5.3 software, and a carefully chosen combination of bands (4, 3, and 2) was selected in accordance with the recommendations of Lillesand and Kiefer (2015). The digital elevation model (DEM) of the study area was extracted from the shuttle Radar Topography Mission (SRTM). ArcGIS 10.8 was the main GIS platform used in this study. GIS tool is applied to manage soil databases developed for the study area, mapping soil variables and modeling. Physiographic map of the study area has been produced using physiographic analysis, then map legend was established according to [17].

2.3. Field work and laboratory analysis

In the study area, an extensive soil survey was conducted with considerable detail. The survey involved excavation of a total of forty-nine profile pits, and the morphological characteristics of the soil were delineated based on the guidelines of the Food and Agriculture Organization [5]. Subsequently, samples were collected for analytical purposes. Soil reaction (pH) was measured in 1:2.5 soil suspension using pH meter [7]. The electric conductivity (EC) was determined conduct-metrically in the soil extract [12]. Calcium carbonate was determined using the Collin's calcimeter method [11]. Organic matter was determined by the modified Walkley and Black method [12]. Cation Exchange Capacity (CEC) was determined using sodium acetate method [15]. Exchangeable cations according to the Tucker's modified method [12]. Available nitrogen was extracted by Kjeldahl method. [12]. Available phosphorus was extracted by Olsen method [12]. Available potassium, which includes soluble and exchangeable K using Flamephotometer [12].

3. Results and Discussions

3.1. Physiography and soil chemical properties

The chemical properties of the studied soil profiles are shown in (Fig. 2) in relation to the soils of the Alluvial plain which consists of a primary landscape with three distinct reliefs:

(1) River terraces, which include two landforms: the highest river terraces and the lowest river terraces

(2) Basin, which includes five landforms: levees (recent sand deposits and sub-recent sand deposits), overflow mantle (relatively high parts and relatively low parts), overflow basin (relatively high parts and relatively low parts), decantation basin (relatively high parts and relatively low parts) and turtle backs (isolated hills)

(3) Nile deposits, with one landform: islands (recent islands and sub-recent islands).

3.1.1. Soils of river terraces

The soils of the unit cover about 252.36 Km^2 and form about 25.8 % of the total area. These soils of this unit divided into two sub-units according to relief, i.e. The highest river terraces (T1), The lowest river terraces (T2). It is represented by soil profiles 10, 11, 12, 20, 21, 22, 29, 30, 40, 41 and 42 are shown in (Table 1).

3.1.1.1. The highest river terraces (T1)

The pH values vary between 7.9 and 8.2. Electric conductivity (EC) ranges between 2.2 and 1.6 dS/m. The calcium carbonate content ranges between 2.0 and 1.9 %. The organic matter content ranges between 0.4 and 1.4 %. The cation exchange capacity values vary from 7.0 to 47.2 Cmol+/kg-1 soil. Exchangeable sodium percent ranges between 10.4 and 16.2 %. The available nitrogen, phosphorous and potassium in the surface layer vary from 10.7 to 44.3, 6.8 to 24.0 and 24.8 to 296 ppm, respectively.

3.1.1.2. The lowest river terraces (T2)

The pH values vary between 8.0 and 8.4. Electric conductivity (EC) ranges between 2.8 and 5.1 dS/m. The calcium carbonate content ranges between 0.4 and 2.2 %. The organic matter content ranges between 0.8 and 1.3 %. The cation exchange capacity values vary from 34.9 to 36.7 Cmol+/kg-1 soil. Exchangeable sodium percent ranges between 12.1 and 18.3 %. The available nitrogen, phosphorous and potassium in the surface layer vary from 34.6 to 35.2, 21.8 to 26.2 and 271 to 292 ppm, respectively.

3.1.2. Soils of levees

The soils of this unit cover about 16.3 Km^2 and form about 1.7 % of the total area. These soils of this unit divided into two sub-units according to relief, i.e. recent sand deposits (L1), sub-recent sand deposits (L2). It is represented by soil profiles 19, 28 and 38 are shown in (Table 1).

3.1.2.1. Recent sand deposits (L1)

The pH values vary between 8.0 and 8.4. Electric conductivity (EC) ranges between 2.8 and 5.1 dS/m. The calcium carbonate content ranges between 0.4 and 2.2 %. The organic matter content ranges between 0.8 and 1.3 %. The cation exchange capacity values vary from 34.9 to 36.7 Cmol+/kg-1 soil. Exchangeable sodium percent ranges between 12.1 and 18.3 %. The available nitrogen, phosphorous and potassium in the surface layer vary from 34.6 to 35.2, 21.8 to 26.2 and 271 to 292 ppm, respectively.

3.1.2.2. Sub-recent sand deposits (L2)

The pH values vary between 8.0 and 8.4. Electric conductivity (EC) ranges between 2.8 and 5.1 dS/m. The calcium carbonate content ranges between 0.4 and 2.2 %. The organic matter content ranges between 0.8 and 1.3 %. The cation exchange capacity values vary from 34.9 to 36.7 Cmol+/kg-1 soil. Exchangeable sodium percent ranges between 12.1 and 18.3 %. The available nitrogen, phosphorous and potassium in the surface layer vary from 34.6 to 35.2, 21.8 to 26.2 and 271 to 292 ppm, respectively.

3.1.3. Soils of overflow mantle

The soils of the unit cover about 115.04 Km^2 and form about 11.7 % of the total area. These soils of this unit divided into two sub-units according to relief, i.e. relatively high parts (OM1), relatively low parts (OM2). It is represented by soil profiles 6, 7 and 18 are shown in (Table 1).

3.1.3.1. Relatively high and low parts (OM1) and (OM2)

The pH values vary between 7.8 and 8.2. Electric conductivity (EC) ranges between 0.5 and 2.9 dS/m. The calcium carbonate content ranges between 0.2 and 1.5 %. The organic matter content ranges between 0.5 and 0.9 %. The cation exchange capacity values vary from 20.0 to 28.3 Cmol+/kg-1 soil. Exchangeable sodium percent ranges between 11.8 and 15.1 %. The available nitrogen, phosphorous and potassium in the surface layer vary from 17.8 to 40.3, 10.3 to 20.4 and 78 to 240 ppm, respectively.

3.1.4. Soils of overflow basin

The soils of the unit cover about 247.3 Km^2 and form about 25.3 % of the total area. These soils of this unit divided into two sub-units according to relief, i.e. relatively high parts (OB1), relatively low parts (OB2). It is represented by soil profiles 1, 2, 3,4, 5, 16, 17, 25, 26, 27, 37 and 48 are shown in (Table 1).

3.1.4.1. Relatively high parts (OB1)

The pH values vary between 7.4 and 8.1. Electric conductivity (EC) ranges between 0.4 and 2.8 dS/m. The calcium carbonate content ranges between 0.6 and 2.5 %. The organic matter content ranges between 1.1 and 1.8 %. The cation exchange capacity values vary from 23.3 to 44.6 Cmol+/kg-1 soil. Exchangeable sodium percent ranges between 9.9 and 14.1 %. The available nitrogen, phosphorous and potassium in the surface layer vary from 16.9 to 42.5, 8.0 to 25.6 and 76 to 287 ppm, respectively.

3.1.4.2. Relatively low parts (OB2)

The pH values vary between 7.3 and 8.1. Electric conductivity (EC) ranges between 1.5 and 2.6 dS/m. The calcium carbonate content ranges between 0.3 and 2.0 %. The organic matter content ranges between 0.8 and 1.3 %. The cation exchange capacity values vary from 25.4 to 42.5 Cmol+/kg-1 soil. Exchangeable sodium percent ranges between 10.4 and 14.3 %. The available nitrogen, phosphorous and potassium in the surface layer vary from 14.0 to 42.0, 6.3 to 30.3 and 90 to 271 ppm, respectively.

3.1.5. Soils of decantation basin

The soils of the unit cover about 327.52 Km^2 and form about 33.5 % of the total area. These soils of this unit divided into two sub-units according to relief, i.e. relatively high parts (DB1), relatively low parts (DB2). It is represented by soil profiles 13, 14, 15, 23, 24, 31, 32, 33, 34, 35, 36, 43, 44, 45, 46 and 47 are shown in (Table 1).

3.1.5.1. Relatively high parts (DB1)

The pH values vary between 7.7 and 8.4. Electric conductivity (EC) ranges between 1.7 and 4.9 dS/m. The calcium carbonate content ranges between 0.4 and 2.8 %. The organic matter content ranges between 0.6 and 1.2 %. The cation exchange capacity values vary from 30.2 to 45.6 Cmol+/kg-1 soil. Exchangeable sodium percent ranges between 12.5 and 18.8 %. The available nitrogen, phosphorous and potassium in the surface layer vary from 33.7 to 43.2, 22.3 to 27.0 and 167 to 289 ppm, respectively.

3.1.5.2. Relatively low parts (DB2)

The pH values vary between 7.8 and 8.4. Electric conductivity (EC) ranges between 1.7 and 12.1 dS/m. The calcium carbonate content ranges between 0.3 and 2.8 %. The organic matter content ranges between 0.4 and 1.7 %. The cation exchange capacity values vary from 21.4 to 46.8 Cmol+/kg-1 soil. Exchangeable sodium percent ranges between 11.9 and 18.1 %. The available nitrogen, phosphorous and potassium in the surface layer vary from 18.5 to 43.1, 9.2 to 30.1 and 88 to 299 ppm, respectively.

3.1.6. Soils of islands

The soils of the unit cover about 17.74 Km2 and form about 1.8 % of the total area. These soils of this unit divided into two sub-units according to relief, i.e. recent islands (I1), sub-recent islands (SI1). It is represented by soil profiles 13, 14, 15, 23, 24, 31, 32, 33, 34, 35, 36, 43, 44, 45, 46 and 47 are shown in (Table 1).

3.1.6.1. Recent islands (I1)

The pH values vary between 7.4 and 7.7. Electric conductivity (EC) ranges between 0.8 and 1.9 dS/m. The calcium carbonate content ranges between 0.9 and 1.6 %. The organic matter content ranges between 0.2 and 1.3 %. The cation exchange capacity values vary from 2.8 to 42.0 Cmol+/kg-1 soil. Exchangeable sodium percent ranges between 11.9 and 12.3 %. The available nitrogen, phosphorous and potassium in the surface layer vary from 14.9 to 44.9, 6.1 to 18.1 and 21.2 to 259 ppm, respectively.

3.1.6.2. Sub-recent islands (SI1)

The pH values vary between 7.2 and 7.3. Electric conductivity (EC) ranges between 1.1 and 1.5 dS/m. The calcium carbonate content ranges between 0.6 and 2.5 %. The organic matter content ranges between 0.1 and 0.2 %. The cation exchange capacity values vary from 3.5 to 4.1 Cmol+/kg-1 soil. Exchangeable sodium percent ranges between 10.6 and 10.8 %. The available nitrogen, phosphorous and potassium in the surface layer vary from 11.1 to 11.3, 6.2 to 8.7 and 16 to 22 ppm, respectively.

3.2. Spatial distribution of soil chemical properties

Spatial interpolation is commonly used for producing continuous information when data are collected at distinct locations (e.g. soil profiles). Inverse Distance Weight (IDW) model is an interpolation method, which weighs the surrounding known values to derive estimations for an unmeasured location. Inverse distance weighted (IDW) is an interpolation method, which uses measured values surrounding the prediction location. The measured values closest to the prediction location have more influence on the predicted value than those further away, thus giving greater weight to points closest to the prediction location, and the weights decrease as a function of distance (Shepard, 1968). Inverse Distance Weight (IDW) of Arc-GIS 10.8 software used to interpolate the soil properties (i.e. $CaCO_3$, EC, OM, CEC, ESP, N, P and K) consequently thematic maps of $CaCO_3$, EC, OM, CEC, ESP, N, P and K produced.

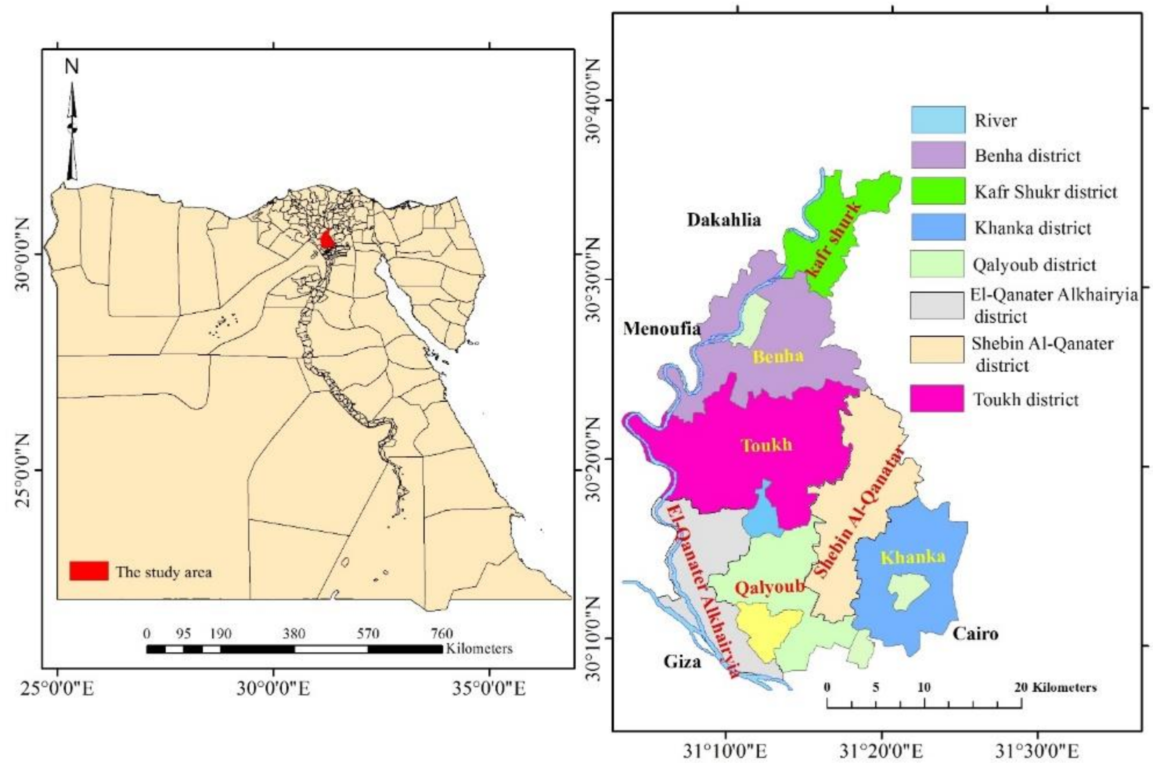

Figure 1. Location of the studied area

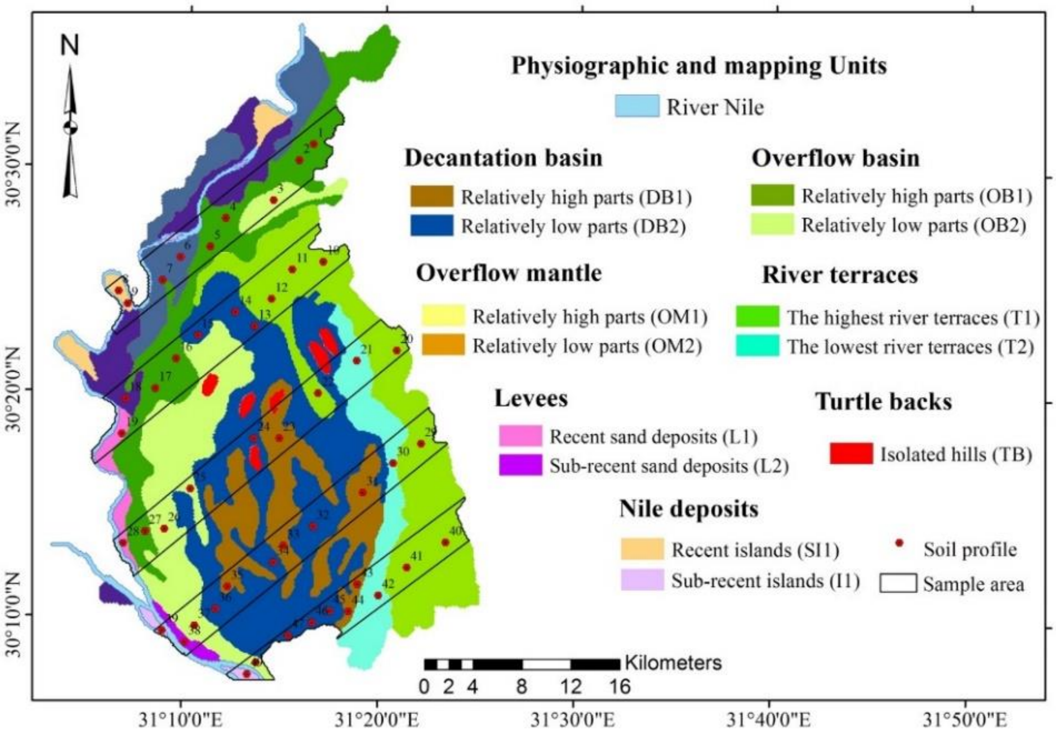

Figure 2. Sample areas and locations of representative soil profiles dated 2022

Table 1. Soil chemical properties in El-Qaliobia Governorate, Egypt

Mapping units	Profile No	pH 1:2.5	EC dS/m	$CaCO_3$ %	O.M %	CEC cmol/kg^{-1}	ESP	Available N	Available P	Available K	Area (km^2)
OB1	1	7.4	2.3	2.3	1.1	34.5	9.9	37.3	19.1	283	124.6
	2	7.9	3.4	1.0	1.8	32.0	13.2	42.5	25.6	287	
	4	8.0	0.4	2.5	1.3	40.1	13.5	35.4	22.5	279	
	5	8.1	2.8	2.5	1.1	31.7	14.1	37.9	22.6	286	
	16	7.7	2.9	2.3	1.4	44.6	12.2	36.7	15.8	269	
	17	7.5	3.0	0.6	1.3	43.8	12.3	41.1	14.2	286	
	27	8.0	3.4	1.4	1.3	23.3	13.7	16.9	8.0	76	
OB2	3	7.3	2.6	2.0	1.3	37.5	10.4	37.0	18.4	257	122.7
	25	8.1	1.8	1.4	0.8	30.9	14.3	33.1	20.7	159	
	26	7.8	1.5	0.3	0.8	25.4	13.6	14.0	6.3	90	
	37	7.6	1.6	1.8	0.8	32.3	11.5	38.0	21.2	270	
	48	8.1	2.1	0.3	1.1	42.5	11.5	42.0	30.3	271	
OM1	18	8.2	2.9	0.2	0.8	28.3	15.1	40.3	20.4	240	54.91
OM2	6	7.8	0.5	0.8	0.5	20.4	11.8	20.1	10.3	98	60.13
	7	8.0	1.8	1.5	0.9	20.0	14.0	17.8	12.7	78	
DB1	23	8.1	2.0	0.4	0.8	30.2	13.5	33.7	22.3	167	101.02
	31	7.7	4.2	2.7	0.6	53.9	13.2	41.8	24.7	279	
	33	8.0	4.9	0.6	1.2	45.6	12.5	42.1	24.7	289	
	35	8.0	1.7	1.9	1.1	39.3	13.2	43.2	25.0	271	
	43	8.4	4.6	2.8	1.1	43.9	18.8	38.1	27.0	280	
	44	8.4	3.1	0.5	0.9	45.5	15.7	38.1	22.6	211	
DB2	13	8.2	2.8	2.8	1.0	46.8	16.4	36.7	20.5	273	226.2
	14	8.4	3.5	0.3	0.4	38.8	17.8	35.2	23.1	255	
	15	8.4	1.9	0.4	0.9	38.2	11.9	31.1	11.3	276	
	24	8.1	2.0	2.1	0.9	21.4	14.4	18.5	9.2	88	
	32	8.4	4.0	0.4	0.8	42.7	17.9	31.2	24.0	271	
	34	8.4	1.7	0.6	0.7	40.5	18.1	35.4	20.2	268	
	36	8.1	12.1	0.3	1.2	44.1	15.1	40.7	30.1	288	
	45	8.5	5.3	0.6	0.5	43.8	13.4	33.5	21.2	293	
	46	8.2	2.1	0.2	0.8	32.7	15.4	38.2	18.9	299	
	47	7.8	4.7	1.1	1.3	46.9	11.7	43.1	28.5	280	
L1	19	8.1	2.6	1.1	1.7	34.7	13.9	40.2	20.1	264	11.02
	28	7.2	0.8	0.4	0.4	5.1	10.9	12.2	6.0	17.4	
L2	38	7.4	1.4	0.6	0.5	6.3	13.2	11.7	5.8	23.6	5.28
I1	39	7.7	0.8	1.6	1.3	42.0	11.9	44.9	18.1	259	4.54
	49	7.4	1.9	0.9	0.2	2.8	12.3	14.9	6.1	21.2	
SI1	8	7.3	1.5	0.6	0.2	3.5	10.8	11.1	8.7	22.2	13.2
	9	7.2	1.1	2.5	0.1	4.1	10.6	11.3	6.2	16.0	
T1	10	7.9	2.2	2.1	0.9	47.2	13.1	37.8	24.0	284	189.02
	11	7.8	2.8	3.0	1.0	29.9	12.9	44.3	23.1	296	
	12	7.3	1.0	3.1	1.2	40.8	10.4	30.7	16.1	272	
	20	8.0	1.3	2.0	0.9	25.4	13.7	31.2	17.0	179	
	22	8.0	0.8	1.5	0.9	27.0	13.8	35.2	18.9	166	
	29	7.9	2.7	1.9	1.4	32.4	16.2	22.1	11.2	111	
	40	8.2	3.2	0.7	0.7	35.4	15.1	36.8	18.1	290	
	41	7.4	1.6	1.4	0.4	7.0	13.4	10.7	6.8	24.8	
T2	21	8.4	5.1	2.2	0.8	34.9	18.3	35.2	22.5	292	63.34
	30	8.0	4.5	0.4	0.8	36.3	12.1	42.1	21.8	287	
	42	8.0	2.8	1.3	1.3	36.7	13.4	34.6	26.2	271	

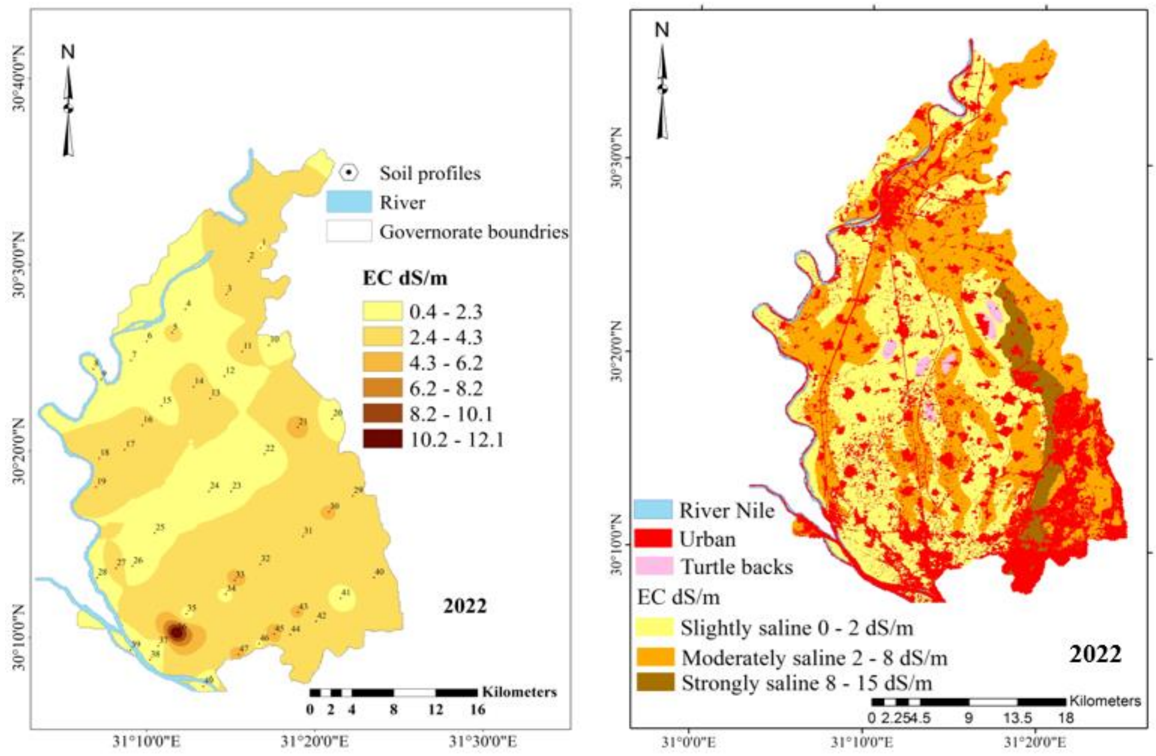

Figure 3. Spatial distribution of EC values (left) and classes (right)

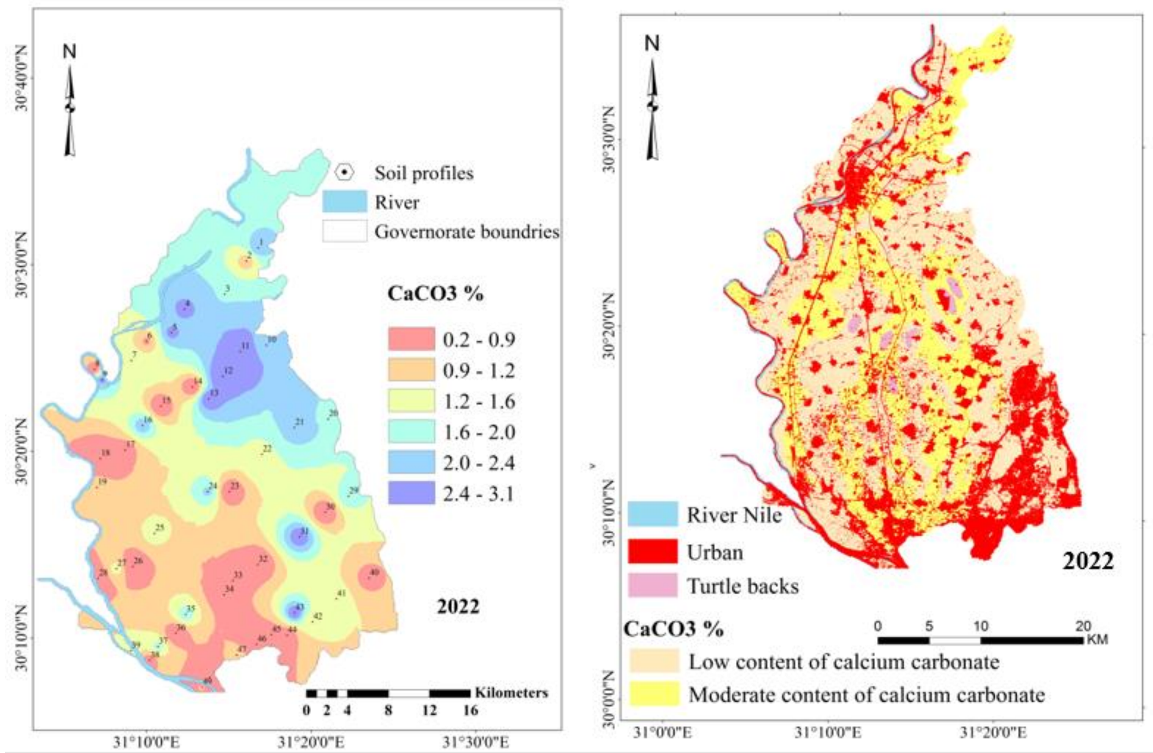

Figure 4. Spatial distribution of $CaCO_3$ values (left) and classes (right)

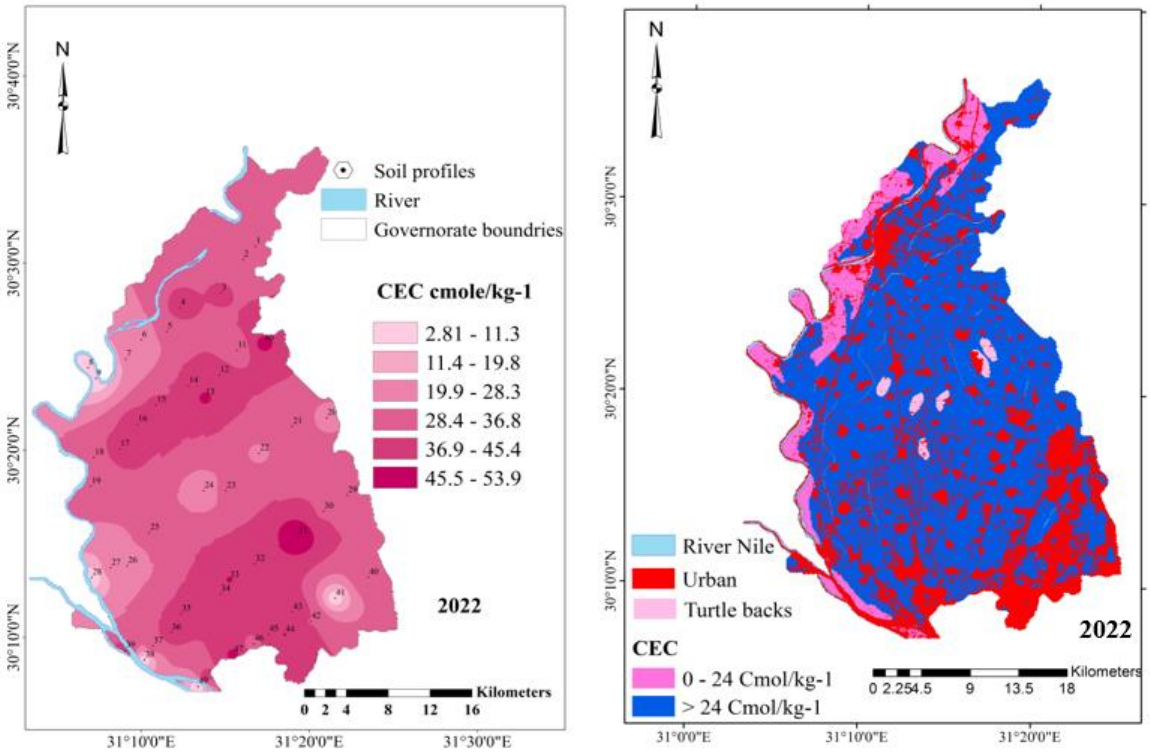

Figure 5. Spatial distribution of CEC values (left) and classes (right)

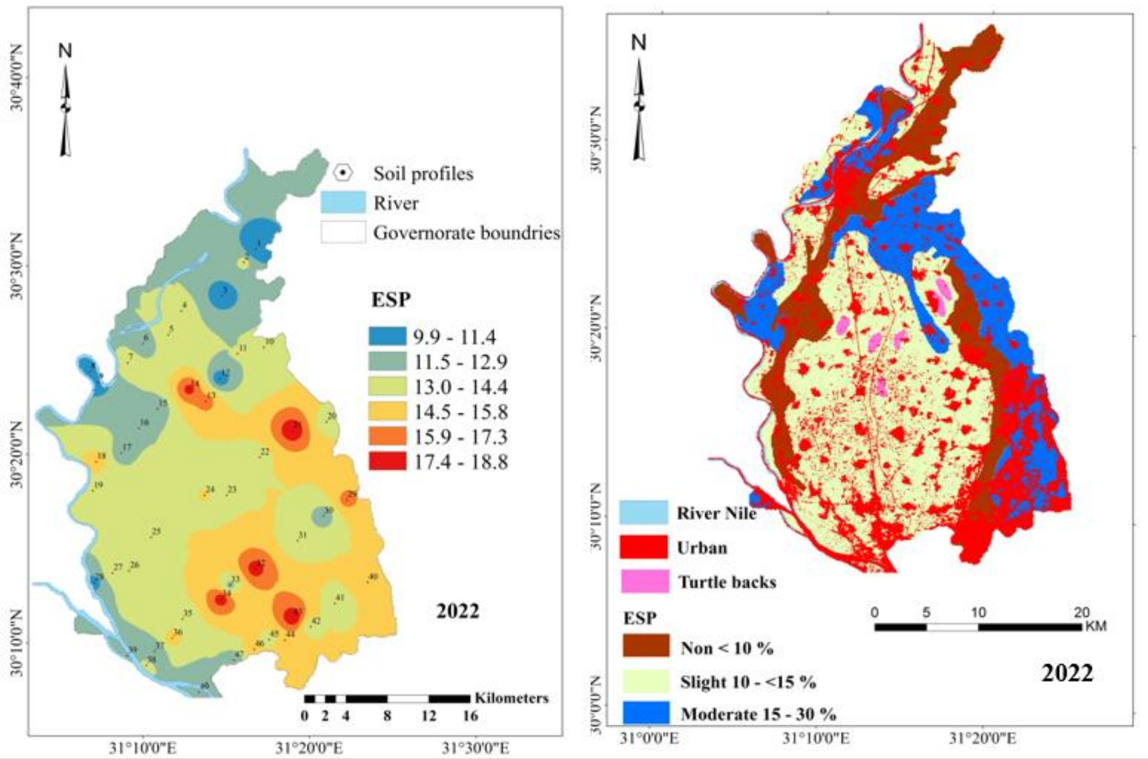

Figure 6. Spatial distribution of ESP values (left) and classes (right)

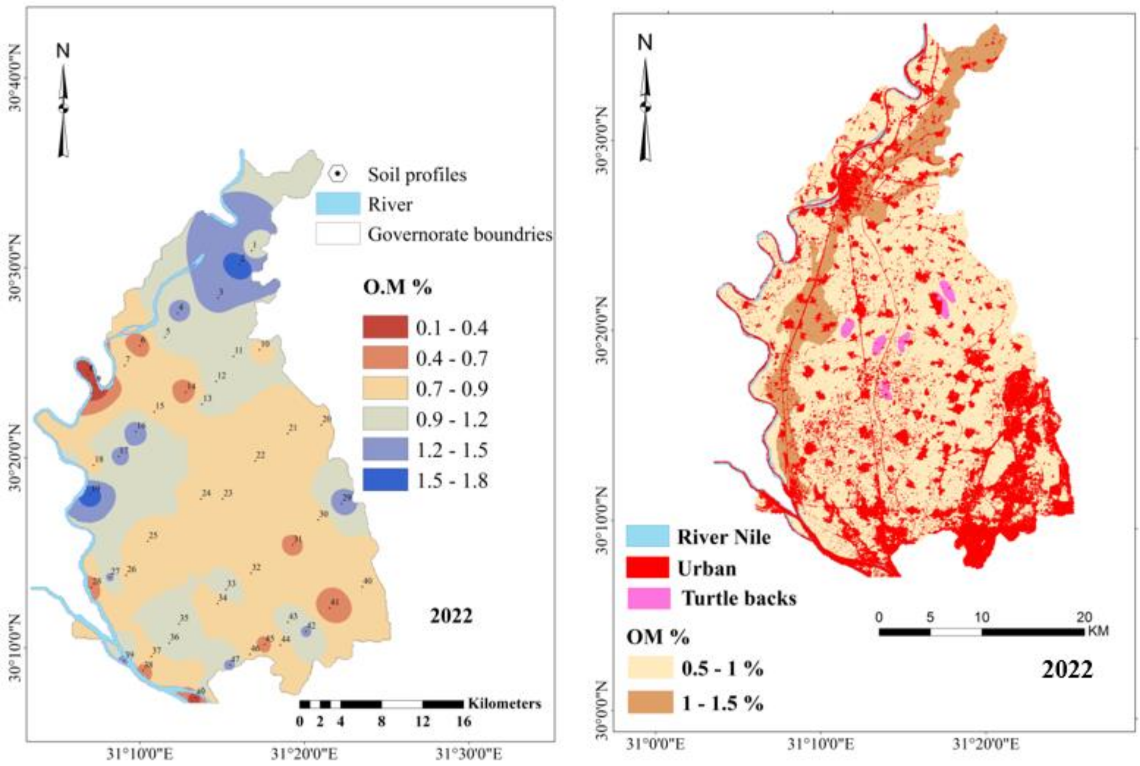

Figure 7. Spatial distribution of organic matter values (left) and classes (right)

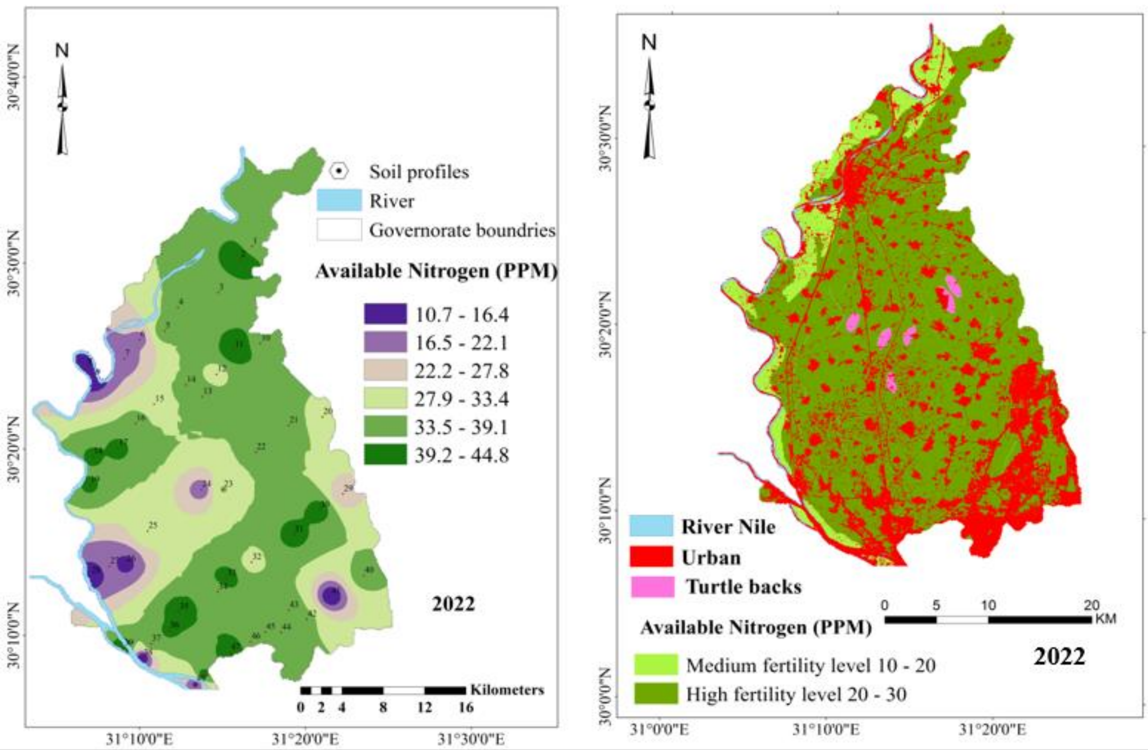

Figure 8. Spatial distribution of Nitrogen values (left) and classes (right)

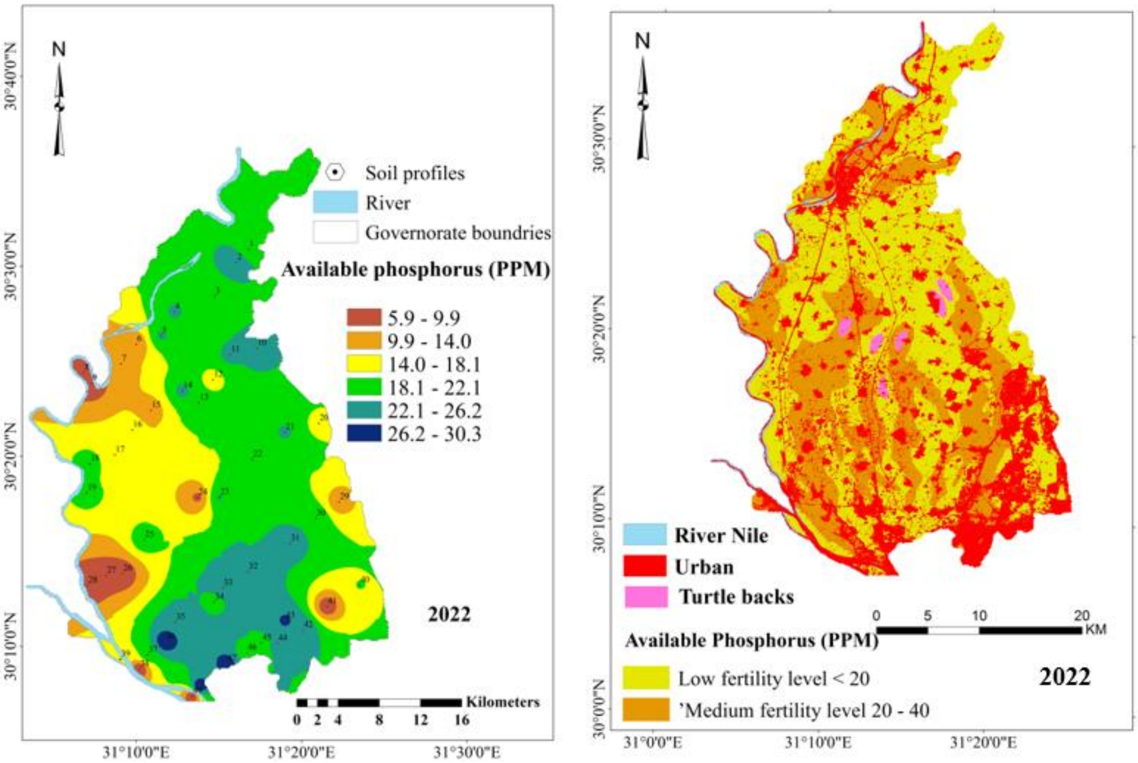

Figure 9. Spatial distribution of Phosphorus values (left) and classes (right)

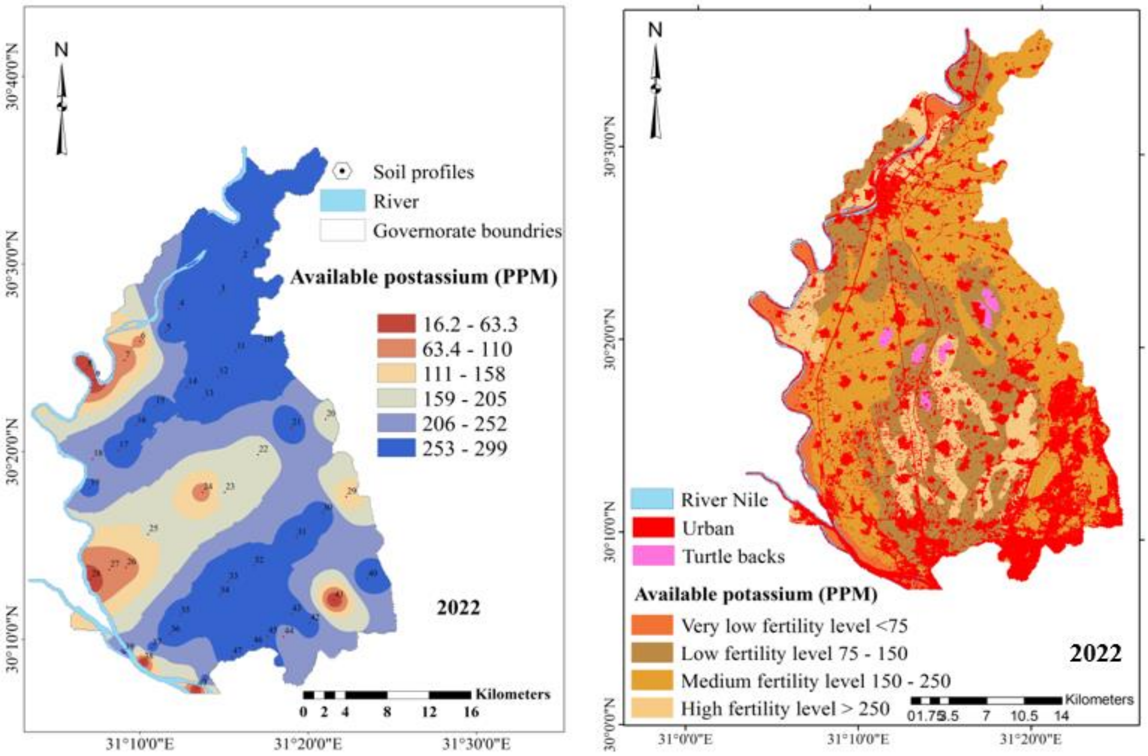

Figure 10. Spatial distribution of Potassium values (left) and classes (right)

Data in (Table 1) and show in (Fig. 3) indicated that the weighted mean value of EC ranges between 0.4 to 12.1dS/m, according to FAO, 2006 about 45.4% of soil samples in the study area is slightly saline, 48.1% are moderately saline, 6.5% are strongly saline. the weighted mean value of $CaCO_3$ ranges between 0.2 to 3.1 %, according to FAO, 2006 about 62.7% of soil samples in the study area is low content of calcium carbonate, 37.3 % is moderate content of calcium carbonate as shown in (Fig. 4). The weighted mean value of CEC ranges between 2.8 and 53.9 $Cmol/kg^{-1}$, according to FAO, 2006 about 79.1 % of soil samples in the study area is lower than 24 $Cmol/kg^{-1}$, 20.9 % is higher than 24 $Cmol/kg^{-1}$ as shown in (Fig. 5). the weighted mean value of ESP ranges between 9.9 to 18.8 %, according to FAO, 2006 about 20.6 % of soil samples in the study area is non-alkaline, 54.4% are slight alkaline, 25.0 % are moderate alkaline as shown in (Fig. 6). the weighted mean value of organic matter ranges between 0.1 to 1.8 %, according to FAO, 2006 about 87.3 % of soil samples in the study area is lower than 1 %, 20.9 % is higher than 1% as shown in (Fig. 7). The weighted mean value of Nitrogen ranges between 10.7 to 44.8 ppm, according to FAO, 2006 about 14.8 % of soil samples in the study area is medium fertility level, 84.2 % is high fertility level as shown in (Fig. 8). The weighted mean value of Phosphorus ranges between 5.9 to 30.3 ppm, according to FAO, 2006 about 35.75 % of soil samples in the study area is low fertility level, 64.25 % is medium fertility level as shown in (Fig. 9). The weighted mean value of potassium ranges between 16.2 to 299 ppm, according to FAO, 2006 about 24.13 % of soil samples in the study area is very low fertility level, 16.1% are low fertility level, 22.7% are medium fertility level and 37.05 % are high fertility level as shown in (Fig. 10).

4. Conclusions

It could be concluded that soils in El-Qaliobia Governorate have great variations in their chemical properties between their mapping units. Most of soil properties were influenced by their origin and physiography. The majority of soils in the study area are pH values were moderately alkaline and the EC values vary from salinity to moderately saline in most soil samples. In most cases, total calcium carbonate varies from low to medium. CEC values were high in most of the studied soils and lowest values of phosphorus and potassium are low fertility level to medium fertility level in Nitrogen of profiles. Optimum management of the soil chemical properties in the study area is required to achieve sustainable land use.

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