Chapter 23
Classification, Characterization, and Management of Some Agricultural Soils in the North of Egypt

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Abstract Present study is completed on soils developed from different sources and types of materials (fluvial, lacustrine, marine, sandy and fluvio-sandy, and calcareous deposits). These soils belong to orders entisols and aridisols. The diverse geological nature of the deposits on which these soils are developed is reflected in the wide variation of soil characteristics (morphologies, clay, cation-exchange capacity, carbonate equivalents, and oxides of Fe, Al, Si, and Mn). All soils are alkaline in reaction, ECe (salinity) ranges between 0.66 and 8.0 dS m^{-1}, clay (6.2–57.5%), cation-exchange capacity (3.0–79.1 cmolc kg^{-1}), organic matter (0.29–2.68%), and calcium carbonate equivalents (0.07–55.62%). Total Fe, Al, and Mn concentrations differed greatly between soils, and the majority of the Fe and Mn occurred in crystalline form. Aluminum oxides are amorphous especially in clayey soils. Total free Si was similar to or exceeded to those of amorphous Si in all soils except calcareous ones. The soils developed from different materials are classified, such as fluvial (Vertic Torrifluvents, Typic Torrifluvents, Typic Fluvaquents, and Typic Ustifluvents), lacustrine (Typic Xerofluvents and Typic Fluvaquents), marine (Typic Xeropsamments and Typic Psammiaquents), sandy (Typic Quartzipsamments and Typic Torripsamments), and calcareous (Typic Haplocalcids).

Keywords Agricultural soils • Classification • Egypt • Macromorphology • Sesquioxides

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23.1 Introduction

The Nile Delta and the Nile River Valley of Egypt is one of the oldest agricultural areas in the world. These areas are under continuous cultivation for at least 5,000 years. Egypt is situated at the northeast extremity of Africa; it lies between the latitudes 31° N and 22° N and between the longitudes 25° E and 34° E. Its gross area is 1,001,450 km^2, of which about 3.6% is suitable for agricultural production. Physiographically, Egypt is divided into three main regions, the delta, the Nile Valley, and the deserts (Amer and Abo-Zeid 1989).

Soil properties and classifications are influenced by the type of materials from which the soils are developed and the conditions of depositional environments. Pedologists intend to establish relationships between the deposition environments and soils morphological, physical, chemical, and mineralogical characteristics as well as soil classifications (Perttjhon 1984).

The soil parent materials could be from sources such as rocks and mineral mixtures, sediments from floods, glacial deposits, and aeolian deposits (Raymond and Roy 1995). Fluvial deposits include all sediments deposited by the running waters. These deposits are generally poorly sorted and reveal evidence of rapid but interrupted deposition. The alluvial soils are developed through the deposition of alluvium brought by streams to the land (Worcoster 1969). The lacustrine deposits are settled out of stagnant lakes, whereas the marine deposits originate from stream action and deposited in the sea (FAO-SF 1964; Selley 1982).

It is well established that the type and source of the soil materials and the depositional environments control the soil properties and classifications due to particle-size distribution and the mineralogical composition. Present study was completed with the objective to investigate the influence of different sources of soil materials on soil properties and classifications and based on the basis of these results to discuss management issues of these soils.

23.2 Materials and Methods

23.2.1 Field Description and Sample Collection

Eighteen soil profiles from cultivated entisols and aridisols representing different geological deposits of Egypt (fluvial, lacustrine, marine, sandy and fluvio-sandy, and calcareous) were selected for the present study. Fluvial soils were selected from the Nile Delta, lacustrine soils (Burullus lake, north of the Nile Delta), sandy marine soils (north of Nile Delta by the Mediterranean sea), and calcareous soils (north of the western desert of Egypt). Soil profiles were dug, various genetic horizons and layers described using standard FAO procedures (FAO 1970), as well as using American system of soil classification (Soil Survey Staff 2006). The horizons were described for soil color (moist, dry), soil texture, structure, and consistence (wet, moist, dry), and effervescence test was made to check calcium carbonates. Soil samples were collected from representative depths of the soil profiles.

23.2.2 Laboratory Procedures

The soil samples were processed prior to their analyses in the laboratory. The samples were air-dried and ground to pass through a 2-mm sieve to obtain fine earth fraction. The soil samples were analyzed for routine physical and chemical characteristics using the procedures referred by Sparks et al. (1996). EC of the soil saturation extract (ECe) was measured by standard EC meter. Soluble cations (Na, K, Ca, Mg) and anions (CO_3, HCO_3, Cl, SO_4) were measured using standard titration method and atomic absorption spectrophotometer (AAS) as appropriate. Soil reaction (pH) was measured in a 1:2.5 soil-deionized water suspension (Thomas 1996). Calcium carbonate equivalents were determined by calcimeter. Organic matter content was determined by the Walkley-Black method (Walkley 1947). Cation-exchange capacity (CEC) was measured by saturating the soil exchange complex with 1N ammonium acetate solution at pH 7 (Sumner and Miller 1996); the ammonium was replaced and measured to represent CEC. Extractable cations (Na, K, Ca, Mg) were determined in 1N ammonium acetate extract; the difference between the extractable and soluble cations represented as exchangeable cations. Particle-size distribution analysis was accomplished by standard pipette method (Gee and Bauder 1986) following by wet sieving to quantify five sand subfractions (very coarse, coarse, medium, fine, and very fine). Soil texture was determined using USDA textural triangle (Soil Survey Division Staff 1993). Total Fe, Al, and Mn were extracted by using mixture of concentrated nitric acid, concentrated hydrochloric acid, and 30% hydrogen peroxide according to USEPA method (USEPA 1995). Total free iron oxides (FIO) were extracted with 3 M sodium citrate, 1 M sodium bicarbonate, and 1 g sodium dithionite in a water bath at 85 °C (Mehra and Jackson 1960); Al, Mn, Si, and Ca were also measured in the same extract. Amorphous Fe oxides as Fe (Feox) were extracted with 0.175 M ammonium oxalate + 0.1 M oxalic acid adjusted to pH 3.0. Calcareous soils were pretreated with 1N sodium acetate (pH 5.5) to remove carbonates according to Loeppert and Inskeep (1996). The P, Al, Mn, Si, and Ca were measured in this extract. The Fe, Al, Mn, Si, and Ca were measured by atomic absorption spectrometry (Varian, SpectrAA-400 Plus, Australia).

23.3 Results and Discussion

In this section, soils developed from different sources of materials are described.

23.3.1 *Fluvial Soils*

23.3.1.1 Field Description, Soil Classification, Physical, and Chemical Characteristics

Table 23.1 illustrates general aspects and soil classification of the fluvial soil profiles. Generally, the soil color is very dark grayish brown (moist) and dark grayish brown (dry); massive structure and soil consistency is sticky and plastic (wet), firm (moist), and hard (dry). These properties are due to the type of sediments with varying clay contents, cemented materials, and type of clay minerals. Based on the genetic horizons development and the sequence in the profiles, the fluvial profiles are classified as Typic Torrifluvents, Typic Fluvaquents, Typic Ustifluvents, and Vertic Torrifluvents (Table 23.1).

Silty clay (heavy) is the common soil texture in various soil horizons of all soil profiles (Table 23.2), except at few depths where other textures were found (clay loam, silty clay loam). The ranges of primary soil particles are clay (17.0–57.5%), silt (14.1–53.8%), and sand (<1–68.9%). The sand was irregularly distributed with depth, the dominant being in the fine and very fine fractions (250–50 μm).

Data in Table 23.2 showed that fluvial soils (P1, P2, P4, and P5) are either nonsaline (ECe < 2 dS m^{-1}), or they are (P3 and P6) slightly saline (ECe 4–8 dS m^{-1}). There is slight but an insignificant in-depth difference of salt distribution within the profile. The highest ECe was recorded at the subsurface (P6); this could be attributed to the mobility of salts downward with descending irrigation water or from below through rising water table. Relatively water soluble Na^+ is dominant over the Ca^{2+}, Mg^{2+}, and K^+. General trend for cations (Na > Ca + Mg > K) and anions ($Cl > SO_4 > HCO_3 > CO_3$) was observed. In P1, different trend exists for cations (Ca > Mg > Na > K) and anions ($Cl > HCO_3 > SO_4 > CO_3$). Increasing and decreasing trend of other properties is shown in Table 23.2. The soil reaction (pHs) in general is in the moderately alkaline range (7.9–8.4).

The organic matter is low (0.88–1.26%). The relatively high value at the surface is due to the residual effect of cultivation on these soils and the addition of organic manure and plant residues to improve soils physical and fertility aspects. All profiles indicate different trends in distribution of total $CaCO_3$ with depth. However, most of them present less than 3%, other between 3 and 5%. From such low quantities, it is difficult to confirm the calcification process. Higher quantities at surface (Sparks 1995) can be due to secondary carbonates.

The CEC values are due to higher clay contents in the profiles. The CEC shows irregular trend of distribution in the profiles; this could be due to the type of sediments, clay minerals, and organic matter and perhaps due to fine clay illuviation; however, this has not been confirmed in the present study. The values of the exchangeable Na and CEC were used to determine soil sodicity, which shows soils to be in general highly sodic with ESPs ranging between 27.6 and 60.6.

Table 23.1 The location, general description, and soil classification of fluvial soil profiles

			Soil description								
			Color				Soil consistencies				
Profile no.	Site	Depth (cm)	Moist	Dry	Texture-class[a]	Structure	Wet	Moist	Dry	General features	Soil CLASSIFI-CATION
P1	Soils of an island in Disuq district, Kafr El-Sheikh Governorate, 100 m to the west of Disuq Damanhur road	0–20	Very dark grayish brown 10YR 3/2	Grayish brown 10YR 5/2	SiC	Massive	Sticky and plastic	Firm	Hard	Few fine roots of Zea mays, few shell fragments, and weak effervescence with HCl. Ten-cm deep and 1-cm wide surface cracks	Typic Torrifluvents
		20–80	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/3	SiC	Massive	Very sticky and very plastic	Firm	Hard	Few fine and very fine roots, few small shell fragments especially in 50–80 cm layer, and weak effervescence with HCl	
		80–120	Olive brown, 2.5Y 4/4	Light olive brown, 2.5Y 5/6	SiC	Granular	Slightly sticky and slightly plastic	Friable	Slightly hard	Very few small shell and very weak effervescence with HCl	

(continued)

Table 23.1 (continued)

Profile no.	Site	Depth (cm)	Soil description: Color: Moist	Color: Dry	Texture-class[a]	Structure	Soil consistencies: Wet	Soil consistencies: Moist	Soil consistencies: Dry	General features	Soil CLASSIFI-CATION
		120–150	Light olive gray 5Y 6/2	Light gray 5Y 7/1	SiC	Massive	Slightly sticky and slightly plastic	Firm	Slightly hard	Very few dead roots, few small shell fragments, and weak effervescence with HCl	
P2	El-Banawan village, El-Mahalla El-Kubra district, El-Gharbia Governorate	0–120	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	SiC	Massive	Sticky and plastic	Firm	Hard	Level land, cultivated for cotton crop, fine and medium roots diffused in the surface cracks (>10 cm deep and 1 cm wide), slight to moderate effervescence with HCl. The soil profile is homogeneous. Upper layers show clear morphological features	Typic Torrifluvents

P3	Kafr Dukhmeis village, El-Mahall El-Kubra district, El-Gharbia Governorate	0–120	0–120	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	SiC SiCL at 6–90 cm	Massive	Sticky and plastic	Firm	Hard	Level land used for vegetable cultivation. Fine and medium roots diffused in the surface cracks (>10 cm deep and 1 cm wide). Some scattered broken shells occur throughout showing moderate effervescence with HCl. The soil profile is homogeneous. Upper layers show clear morphological features	Typic Torrifluvents

(continued)

Table 23.1 (continued)

Profile no.	Site	Depth (cm)	Soil description: Color – Moist	Color – Dry	Texture-class[a]	Structure	Soil consistencies – Wet	Moist	Dry	General features	Soil CLASSIFICATION
	El-Khadmia village, Kafr El-Sheikh district, Kafr El-Sheikh Governorate	0–20	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	SiC	Massive	Sticky and plastic	Firm	Hard	Level land, cultivated by cotton and vegetable crops. Fine and medium roots diffused in this layer, moderate effervescence with HCl	Typic Fluvaquents
P4		20–80	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	CL	Massive	Slightly sticky and slightly plastic	Firm	Slightly hard	Few fine roots diffused. Few shell fragments and weak to moderately effervescence with HCl	
		80–105	Dark grayish brown 10YR 4/2	Pale brown 10YR 6/3	SiC	Massive	Very sticky and very plastic	Very firm	Hard		

P5	El-Banawan village,	0–120	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	SiC	Massive	Sticky and plastic in all layers and very sticky and very plastic in the deepest layer	Firm in all layers and very firm in the deepest layer	Hard	Level land, cultivated by cotton with some vegetable crops. Fine and medium roots diffused in the surface, slight to moderate effervescence with HCl. The soil profile is homogeneous. Upper layers show clear morpho logical features	Typic Ustifluvents

(continued)

Table 23.1 (continued)

Profile no.	Site	Depth (cm)	Soil description								Soil CLASSIFICATION
			Color		Texture-class[a]	Structure	Soil consistencies			General features	
			Moist	Dry			Wet	Moist	Dry		
P6	Faculty of Agriculture farm. 500 m South Kafr El-Sheikh City	0–160	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	SiC	Strong, coarse to medium, sub-angular blocky	Sticky and plastic	Firm	Hard	Fine and medium roots diffused in the surface, cracks (>20 cm deep and 1 cm wide). Slight to moderate effervescence with HCI The soil profile is homogeneous throughout its layers	Vertic Torrifluvents

[a]Apparent soil texture

Texture – *SiC* silty clay, *SL* sandy loam, *SCL* sandy clay loam, *SiCL* silty clay loam, *CL* clay loam

Table 23.2 Selected physical and chemical characteristics of fluvial soil profiles

Profile no.	Depth (cm)	pHs	ECe (dS m^{-1})	Soluble cations (meq l^{-1})[a] Na	K	Ca	Mg	Soluble anions (meq l^{-1})[a] CO_3	HCO_3	Cl	SO_4	OM (%)	$CaCO_3$ (%)	CEC (cmolc kg^{-1})	ESP	Particle-size distribution (%) VCS	CS	MS	FS+VFS	Sand	Silt	Clay	Texture class
P1	0–20	7.87	0.79	2.6	0.2	2.9	2.5	0.0	3.2	4.0	1.0	1.92	1.6	79	30	0.5	0.4	2.7	8.8	12.4	40.4	47.2	SiC
	20–50	7.87	0.62	2.1	0.1	2.2	2.3	0.0	2.5	3.1	1.1	1.64	1.5	65	28	0.1	0.2	0.2	1.2	1.7	46.5	51.8	SiC
	50–80	7.93	0.56	1.7	0.1	2.1	2.0	0.0	2.5	2.3	1.1	1.23	3.5	69	31	0.1	0.1	0.2	0.8	1.3	46.4	52.3	SiC
	80–120	7.98	0.63	1.7	0.1	2.0	2.7	0.0	1.7	3.4	1.4	0.48	1.1	38	39	1.7	2.8	6.9	57.5	68.9	14.1	17.0	SiC
	120–150	7.96	0.68	1.9	0.1	2.3	2.4	0.0	0.9	3.3	2.5	1.02	2.3	59	29	1.2	2.0	8.4	3.26	44.1	27.3	28.6	SiCL
P2	0–30	8.11	1.56	11.4	0.2	2.3	2.1	1.8	2.7	9.0	2.5	1.67	2.4	44	32	0.2	0.2	0.3	1.7	2.4	50.2	47.4	SiC
	30–60	8.31	1.62	12.3	0.2	2.0	2.4	1.3	2.7	7.2	5.7	1.11	1.8	44	33	0.3	0.1	0.1	2.2	2.7	47.5	49.8	SiC
	60–90	8.39	1.65	12.1	0.2	2.4	2.0	0.8	3.0	6.4	6.5	0.70	2.7	42	34	1.2	0.6	0.2	1.6	3.6	52.2	44.2	SiC
	90–120	8.42	1.61	11.8	0.1	2.0	1.8	0.4	2.0	5.6	7.7	0.90	1.6	43	34	0.4	0.8	0.2	1.5	2.8	48.7	48.5	SiC
P3	0–30	7.92	7.06	45.0	0.6	15.0	11.0	0.8	2.0	39.0	29.8	1.58	4.2	43	33	0.5	0.5	3.2	11.4	15.6	41.9	42.5	SiC
	30–60	7.88	6.77	45.0	0.5	14.0	9.7	0.4	2.6	29.2	37.0	0.97	3.9	44	37	0.4	0.4	2.8	7.6	11.2	44.8	44.0	SiC
	60–90	8.17	5.75	47.5	0.3	6.0	9.9	0.0	2.2	31.8	29.7	0.62	3.1	39	42	0.5	0.5	2.9	9.8	13.7	47.6	38.8	SiCL
	90-120	8.29	4.79	37.5	0.2	4.3	4.7	0.0	2.6	25.8	18.3	0.35	4.7	41	41	0.3	0.4	1.9	6.4	9.0	45.8	45.2	SiC
P4	0–20	8.01	2.00	11.7	0.2	3.7	4.2	1.4	2.2	12.8	3.4	2.00	3.9	41	33	0.4	0.4	2.0	6.5	9.3	40.2	50.5	SiC
	20–50	7.93	1.68	9.1	0.1	4.3	3.3	0.0	3.4	11.2	2.2	1.04	4.8	36	30	0.7	0.8	4.0	15.3	20.8	48.6	30.6	CL
	50–80	8.25	1.93	10.1	0.1	4.7	3.7	0.0	3.0	14.9	0.7	0.62	2.3	34	30	0.7	0.6	2.8	11.7	15.8	47.8	36.4	CL
	80–105	7.89	1.62	8.6	0.2	4.4	2.8	0.0	3.0	11.3	1.7	1.31	0.6	52	38	0.3	0.2	0.3	1.4	2.2	44.9	52.9	SiC
P5	0–30	8.24	1.65	10.9	0.1	3.7	2.7	1.2	3.2	9.6	3.4	2.10	3.7	52	28	0.4	0.6	0.9	1.3	3.2	49.5	47.3	SiC
	30–60	8.04	2.23	14.4	0.2	4.0	3.2	0.6	2.5	12.4	6.3	1.24	3.4	47	28	0.2	0.1	0.3	1.2	1.7	53.8	44.5	SiC
	60–90	8.19	1.25	8.5	0.1	2.3	1.7	0.0	3.4	6.8	2.4	0.82	1.6	57	31	0.2	0.2	0.4	1.1	1.8	50.0	48.2	SiC
	90–120	8.35	1.21	8.8	0.2	1.8	1.4	0.5	2.9	6.8	2.0	0.82	1.2	59	34	0.1	0.1	0.1	0.4	0.7	48.5	50.8	SiC

(continued)

Table 23.2 (continued)

Profile no.	Depth (cm)	pHs	ECe (dS m^{-1})	Soluble cations (meq l^{-1})[a] Na	K	Ca	Mg	Soluble anions (meq l^{-1})[a] CO_3	HCO_3	Cl	SO_4	OM (%)	$CaCO_3$ (%)	CEC (cmolc kg^{-1})	ESP	Particle-size distribution (%) VCS	CS	MS	FS+VFS	Sand	Silt	Clay	Texture class
P6	0–30	8.93	4.00	25.7	0.4	6.1	7.9	0.0	4.2	30.2	5.7	2.22	3.1	57	58	0.7	0.8	0.9	3.2	5.5	49.2	45.2	SiC
	30–60	8.81	5.10	37.2	0.4	4.2	10.1	0.0	2.1	35.1	14.6	1.07	2.3	58	57	0.4	0.7	0.7	2.2	4.1	50.3	45.6	SiC
	60–90	9.14	5.10	37.9	0.3	4.9	10.9	0.0	1.8	40.0	12.2	1.02	2.2	52	51	0.3	0.4	0.4	1.6	2.8	47.7	57.5	SiC
	90–120	9.07	6.00	45.0	0.3	6.0	11.8	0.0	1.5	45.2	16.4	0.95	2.3	52	60	0.2	0.3	0.3	1.9	2.8	49.2	48.0	SiC
	120–140	8.86	6.90	52.2	0.4	8.4	12.7	0.0	1.6	50.0	22.4	0.91	1.4	59	61	0.1	0.2	0.2	0.7	1.1	48.8	50.1	SiC
	140–160	8.70	8.00	67.6	0.4	9.3	16.7	0.0	2.8	54.9	36.3	0.91	1.8	63	60	0.1	2.0	0.2	0.7	1.1	49.8	49.1	SiC

[a]In soil saturation extract

ECe EC of soil saturation extract, *VCS* very coarse sand, *CS* coarse sand, *MS* medium sand, *FS* fine sand, *VFS* very fine sand. Texture class – *SiC* silty clay, *SiCL* silty clay loam, *CL* clay loam, *CEC* cation-exchange capacity, *OM* organic matter, *pHs* pH of saturated soil paste, *ESP* exchangeable sodium percentage

23.3.2 *Lacustrine Soils*

23.3.2.1 Field Description, Soil Classification, and Physical and Chemical Characteristics

General aspects and soil classification of four lacustrine profiles are presented in Table 23.3. Field description showed very dark grayish brown color in the moist state of most layers in all profiles, while in dry state, the dominant color was dark grayish brown. The structure in all layers of four tested profiles was massive and massive blocky structure except for the surface layer in P1 and P2, where it was coarse to medium blocky structure. The soil consistence was sticky and plastic in surface layers and very sticky, very plastic in the deepest ones in the wet state, firm in moist state, and hard in dry state.

These features are mainly due to the nature of sediment, the increase of clay content, and cemented materials as well as the type of clay minerals. The classifications of all lacustrine profiles were Typic Fluvaquents (P2 and P4) and Typic Xerfluvents (P1 and P3).

Silty clay is the common soil texture, followed by silty clay loam and in one depth (P4), it is clay loam (Table 23.4). Table 23.4 illustrates heavy texture at surface and subsurface layers and also in the deepest layers, while the texture was relatively light in the middle layers in profile nos. 2, 3, and 4. Such variations in soil texture are due to multi-depositional cycles. The clay (21.4–56.3%) and sands (0.98–55.05%) were distributed variably. The fine and very fine sand (250–50 μm) was the dominant fractions. The differences in soil texture, $CaCO_3$ content, and CEC values are closely related to the matter of sedimentation mode and the nature of parent materials.

The ECe is relatively higher at deeper layers due to leaching. The difference is due to type of irrigation water used, clay content, and drainage conditions. Salt distributions throughout the profiles were irregular and differ in profiles. The soil reaction (pHs) ranges between 7.93 and 9.13 (moderately to strongly alkaline reaction), and ECe is generally less than 4 dS m^{-1} (Table 23.4). Water soluble sodium was dominant among cations, other cations trend $Mg^{2+} > Ca^{2+} > K^{+}$, and among anions, Cl^{-} was dominant over others trending $SO_4 > HCO_3$. Lacustrine soils exhibited more soluble Mg^{2+} and K^{+} relative to other soils. Similar trends are reported earlier (Ali 1985).

The organic matter content is low. The relatively higher but insignificant values at surface are due to cultivation and addition of organic manure and plant residues. Surface and subsurface layers (P2, P3, and P4) have high $CaCO_3$ (17.3%), while the deepest layers of P4 have the lowest (0.07%). The high values of $CaCO_3$ are due to the presence of broken and complete shells.

The CEC values vary greatly and have irregular trend due to sedimentation regime, clay, and organic matter contents. The soils (P1 and P2) are sodic where ESP > 15; other profiles are non-sodic (ESP < 15). The sodic soils are to be amended with gypsum based on gypsum requirement to improve properties of these profiles.

Table 23.3 The location, general description, and soil classification of lacustrine soil profiles

Profile no.	Site	Depth (cm)	Soil description: Color		Texture class[a]	Structure	Soil consistencies			General aspects	Soil classification
			Moist	Dry			Wet	Moist	Dry		
P1	Khalej kepli, Mutubis district, Kafr El-Sheikh Governorate	0–120	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	SiC	Coarse to medium blocky in surface layer and massive in deeper layers	Sticky and plastic in all layers, very plastic in the deepest layer	Firm to very firm	Hard	Level land, plowed after Zea mays crops. Fine and medium dead roots in the surface. Scattered shell fragments at surface and strong effervescence with HCl. Few shells and moderate effervescence with HCl in the subsurface layers. Some red mottling in the fluctuating water zone	Typic Xerfluvents
P2	El-Thamaneen village, El-Hamul district Kafr El-Sheikh Governorate	0–120	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/3	SiC all layers SiCL at 60–90 cm	Coarse to medium blocky in surface layer and massive in deeper layers	Sticky and plastic in all layers and very plastic in the deepest layer	Firm to very firm	Hard	Level land, plowed after Citrullus sp. crops. Fine and medium dead roots in the surface. Scattered shell fragments in all layers except the deepest one showing strong effervescence with HCl in all layers, except the deepest one. Red mottling in the fluctuating water table zone due to oxidation of iron	Typic Fluvaqents

P3	El-Khasha, 500 m to the east of Burulus lake, 7 km to the west of Baltim-El-Hamul road	0–27	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	SiC	Massive	Sticky and slightly plastic	Firm	Slightly hard	Scattered shell fragments band of broken and non-broken shells, few fine roots, strong effervescence with HCl	Typic Torrifluvents
		27–37	Very dark grayish brown 10YR 3/2	Dark brown 10YR 4/3	SiC	Massive	Sticky and plastic	Firm	Hard	Scattered shell fragments, very fine roots, strong effervescence with HCl	
		37–60	Very dark grayish brown 10YR 3/2	Dark brown 10YR 4/3	SiC	Massive	Sticky and plastic	Firm	Hard	Few scattered shell fragments, very fine roots, weak effervescence with HCl	
		60–70	Dark grayish brown 10YR 4/2	Pale brown 10YR 6/3	SiCL	Massive	Slightly sticky and slightly plastic	Slightly firm	Slightly hard	Many scattered shell fragments, strong effervescence with HCl	

(continued)

Table 23.3 (continued)

Profile no.	Site	Depth (cm)	Soil description								
			Color		Texture class[a]	Structure	Soil consistencies			General aspects	Soil classification
			Moist	Dry			Wet	Moist	Dry		
		70–90	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	SiCL	Massive	Sticky and plastic	Firm	Hard	Very few scattered shell fragments, weak effervescence with HCl. Some red mottling observed	
		90–110	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	SiC	Massive	Vey plastic and very sticky	Very firm	Very hard	This layer reveals the fluctuating water table zone. Very few shells and very weak effervescence with HCl	
P4	2 km to the south of Balitim city, 500 m to the east of Burulus lake, 7 km to the west of Baltim-El-Hamul road	0–20	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	SiCL	Massive and blocky	Sticky and slightly plastic	Firm	Slightly hard	Scattered shell fragments, very fine roots, cracks (10 cm deep and 0.5 cm wide), strong effervescence with HCl	Typic Torrifluvents

20–30	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	SiCL	Massive and blocky	Sticky and plastic	Friable	Hard	Scattered shell fragments, band of broken and non broken shells, very fine roots, strong effervescence with HCl
30–72	Dark grayish brown 10YR 4/2	Pale brown 10YR 6/3	SCL	Massive and blocky	Slightly sticky and slightly plastic	Firm to very firm	Hard	Very few scattered shell fragments, very fine roots weak effervescence HCl
72–90	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	SiCL	Massive and blocky	Sticky and slightly plastic	firm	Slightly hard	Scattered shell fragments, very fine roots, cracks (10 cm deep and 0.5 cm wide) strong effervescence with HCl

[a]Apparent soil texture – *SiC* silty clay, *SiCL* silty clay loam, *SCL* sandy clay loam

Table 23.4 Selected physical and chemical characteristics of lacustrine soil profiles

Profile no.	Depth (cm)	pHs	ECe (dS m^{-1})	Soluble cations (meq l^{-1})[a] Na	K	Ca	Mg	Soluble anions (meq l^{-1})[a] CO_3	HCO_3	Cl	SO_4	OM (%)	$CaCO_3$ (%)	CEC (cmolc kg^{-1})	ESP	Particle-size distribution (%) VCS	CS	MS	FS + VFS	Sand	Silt	Clay	Texture class
P1	0–30	8.06	1.96	9.4	0.3	2.9	6.6	0.8	2.8	11.6	4.0	2.68	8.60	64	30	0.3	0.2	0.4	2.0	2.9	44.3	47.2	SiC
	30–60	8.66	2.06	15.1	0.4	1.9	3.7	0.7	1.8	14.0	4.5	1.04	3.90	60	14	0.2	0.2	0.3	0.4	1.0	44.4	51.8	SiC
	60–90	8.68	1.99	14.1	0.4	1.7	3.4	0.7	1.7	14.0	3.3	1.04	2.90	69	24	0.1	0.2	0.2	0.4	1.0	42.7	52.3	SiC
	90–120	8.91	2.41	18.9	0.3	1.9	3.9	0.8	1.9	16.3	6.0	0.83	6.50	60	38	0.4	0.4	0.7	v3.3	4.89	44.3	17.0	SiC
P2	0–30	8.16	2.81	19.9	0.3	3.3	3.6	1.6	3.6	20.5	1.7	1.79	7.80	51	30	0.3	0.2	0.3	0.4	1.2	55.1	47.4	SiC
	30–60	8.18	4.77	35.5	0.7	3.9	8.1	0.4	2.9	31.6	13.3	1.17	5.70	56	34	0.2	0.2	0.4	0.2	1.0	53.2	49.8	SiC
	60–90	8.11	7.88	60.0	1.2	5.3	9.7	0.4	2.1	57.4	16.3	0.97	7.20	51	25	0.9	1.9	2.8	9.9	15.4	45.3	44.2	SiCL
	90–120	7.99	11.20	90.5	1.7	6.6	17.4	0.0	2.0	83.8	30.4	0.97	1.20	48	35	0.1	0.2	0.7	0.8	1.9	55.3	48.5	SiC
P3	0–27	8.12	2.23	13.5	0.3	4.3	5.3	0.8	3.2	14.8	4.6	1.45	17.30	45	7	0.4	0.4	1.8	3.1	5.7	48.0	46.3	SiC
	27–37	8.02	2.59	14.7	0.5	5.3	4.3	0.0	2.4	17.9	4.4	0.62	6.60	50	8	0.3	0.4	0.9	0.7	2.1	48.9	49.0	SiC
	37–60	8.00	2.59	14.7	0.7	3.9	4.9	0.0	2.2	17.9	4.1	1.24	3.40	54	8	0.1	0.2	0.3	1.0	1.6	46.6	51.8	SiC
	60–70	8.21	3.14	16.4	0.8	4.3	8.1	0.0	1.5	23.0	5.1	0.90	6.80	34	8	0.9	1.9	2.9	12.3	17.9	46.0	36.1	SiCL
	70–90	7.93	2.98	17.3	0.9	3.6	9.4	0.0	0.9	21.3	9.0	0.76	0.60	36	7	0.7	1.5	2.7	6.3	11.5	48.7	39.8	SiCL
	90–110	8.11	3.10	15.6	1.0	4.0	9.4	0.0	1.3	22.7	6.0	1.11	0.70	37	8	0.8	1.5	3.2	5.2	10.7	48.3	41.0	SiC
P4	0–20	8.24	3.30	20.8	0.7	3.5	8.5	0.0	1.5	15.2	16.8	1.75	9.31	53	5	1.5	1.8	2.0	6.9	12.2	50.1	37.7	SiCL
	20–30	8.04	2.80	20.9	0.8	2.4	6.6	0.6	3.4	17.5	9.8	1.38	9.85	45	5	1.4	2.1	2.8	8.5	14.8	46.7	38.5	SiCL
	30–72	8.19	2.70	16.7	1.2	2.3	7.2	0.0	2.1	14.9	10.4	0.41	0.94	24	6	2.7	4.2	5.1	43.2	55.0	23.6	21.4	SiCL
	72–wt	8.35	2.40	20.0	0.8	1.8	4.2	0.0	3.0	16.2	7.6	1.08	0.09	46	10	0.0	0.1	0.1	1.4	34.6	25.3	40.1	CL
	wt	8.93	2.50	22.7	0.8	1.9	4.1	0.0	4.2	14.8	10.5	0.84	0.07	44	9	0.0	0.1	0.2	2.6	2.8	58.4	38.8	SiCL

[a]In soil saturation extract

ECe EC of soil saturation extract, *VCS* very coarse sand, *CS* coarse sand, *MS* medium sand, *FS* fine sand, *VFS* very fine sand; Texture class – *SiC* silty clay, *SiCL* silty clay loam, *CL* clay loam, *CEC* cation-exchange capacity, *OM* organic matter, *pHs* pH of saturated soil paste, *ESP* exchangeable sodium percentage, *wt* water table

23.3.3 Marine Soils

23.3.3.1 Field Description, Soil Classification, and Physical and Chemical Characteristics

Table 23.5 presents soil properties and classification. The color is variable dominantly light yellowish brown (dry) and light olive brown (moist). The dominance of light color, structureless, nonsticky, nonplastic and friable properties, and in depth difference in sand, silt, and clay are due to the nature of sandy sediments. The soil classification is Typic Xerpsamments (P1) and Typic Psammiaquents (P1 and P3). Sand is the texture in all profiles at all depths, very fine and fine sands together dominate in sand subfractions, other fraction ranges in their mean values as 2.0–4.6 (silt) and 4.23–5.5 (clay).

Table 23.6 presents physical and chemical characteristics, revealing generally organic matter and $CaCO_3$ (<1%); CEC ranges between 3.1 (P3) and 10 cmol kg^{-1} (P1), and ESP is lowest 6.3 in P3 and the highest 62.9 in P1. The ECe is very low (<0.73 dS m^{-1}) in P1, <3.2 dS m^{-1} in P2, and <7 dS m^{-1} in P3. This shows that P1 and P2 are sodic and P3 is saline at subsurface (below 30 cm). Such a development is due to the use of irrigation water and high drainage conditions in sandy texture that leached the salts.

Soluble Na and chlorides dominate among other cations and anions, respectively. The pH is in the range of moderately to strongly alkaline (P1 and P2) and very strongly alkaline (P3). The pH is above the optimum range (pH 6.6–7.3) where most of the plant nutrients become available to plants. It is not clear why the pH in P1 and P2 is lower than P3, the former are sodic profiles, which usually give pHs > 9.00 (Richards 1954).

23.3.4 Sandy and Fluvio-Sandy Soils

23.3.4.1 Field Description, Soil Classification, and Physical and Chemical Characteristics

Variable color, structure, and consistence observed during profile description (Table 23.7). Table 23.8 shows sandy (P1) and variable texture (clay loam, loam, and sandy loam) in P2. Sand being dominant over silt and clay in both profiles. Profile 2 represents the zone between fluvial and sandy deposits, and there is large difference in texture due to multi-depositional regime. Similar findings were reported by El-Shahawi (1994). The difference in color and other characteristics is due to type of sediment and the management of these soils. The $CaCO_3$ is low (less than 3%), organic matter (<1%), soil reaction (pHs) is very strongly alkaline in all layers of both profiles, except upper layer of P2 (strongly alkaline), and hence will restrict nutrient availability to plants. The CEC is relatively lower in P1 than P2, this is due to high clay content and perhaps type of clay minerals in P2. Soluble Na and

Table 23.5 The location, general description, and soil classification of marine soil profiles

Profile no.	Site	Depth (cm)	Soil description: Color – Moist	Color – Dry	Texture class	Structure	Soil consistencies – Wet	Moist	Dry	General aspects	Soil classification
P1	Khaleg Bahary, Mutubis district, Kafr El-Sheikh Governorate	0–120	Brownish yellow 10YR 6/8	Yellow 10YR 7/6	Sandy	Structureless	Nonsticky and non-plastic	Very friable	Loose	Level soil, cultivated by peach trees. Prolonged application of organic fertilizers turned the surface darker than below. The profile is homogeneous	Typic Xerpsamments
P2	Ezbet Hammad, Baltim district, Kafr El-Sheikh Governorate	0–90	Light olive brown 2.5Y 5/3	Light yellowish brown 2.5Y 6/4	Sandy	Structureless	Nonsticky and non-plastic	Very friable	Loose	Level cultivated land (cotton, vegetable, and trees). The profile is homogeneous. Thin roots observed at 0–60 cm. Decayed palm roots found in the water table fluctuating zone. Few shell fragments and weak effervescent with HCl	Typic Psammiaquents

P3	0.5 km to the south of Mediterranean Sea. El-Sheikh Mubarak village	0–90	Light olive brown 2.5Y 5/3	Light yellowish brown 2.5Y 6/4	Sandy	Structureless	Nonsticky and non-plastic	Very friable	Slightly hard	The profile is homogeneous. Thin roots observed at 0–60 cm. Decayed palm roots found in the water table fluctuating zone. Few shell fragments and weak effervescent with HCl	Typic Psammiaquents

Table 23.6 Selected physical and chemical characteristics of marine soil profiles

Profile no.	Depth (cm)	pHs	ECe (dS m^{-1}	Soluble cations (meq l^{-1})[a] Na	K	Ca	Mg	Soluble anions (meq l^{-1})[a] CO_3	HCO_3	Cl	SO_4	OM (%)	$CaCO_3$ (%)	CEC (cmolc kg^{-1})	ESP	Particle-size distribution (%) VCS	CS	MS	FS + VFS	Sand	Silt	Clay	Texture class
P1	0–30	8.36	0.73	4.3	0.3	1.4	1.9	0.0	2.1	3.9	1.9	0.15	0.6	10.0	59	0.5	0.9	22.8	62.1	86.2	6.2	7.6	S
	30–60	8.63	0.66	3.4	0.4	1.0	1.6	0.0	1.5	3.4	2.1	0.07	0.3	8.5	57	0.4	0.8	21.8	66.6	89.6	5.2	5.2	S
	60–90	8.74	0.50	2.8	0.4	0.9	1.4	0.0	1.0	2.9	1.6	0.04	0.2	7.5	62	0.3	0.9	20.5	70.0	91.6	4.1	4.3	S
	90–120	8.78	0.99	4.9	0.3	2.0	2.9	0.0	0.9	5.6	3.6	0.03	0.2	70	63	0.3	1.0	23.6	68.1	82.9	3.1	4.1	S
P2	0–30	8.25	2.67	13.9	0.5	5.3	5.7	0.0	0.6	16.3	8.5	0.42	0.6	9.4	39	0.4	0.9	18.4	69.0	88.6	4.6	6.8	S
	30–60	8.58	3.16	20.0	0.6	4.4	6.9	0.0	2.9	27.4	1.6	0.21	0.4	7.5	38	0.3	0.8	19.9	69.5	90.4	4.7	4.9	S
	60–90	8.49	2.95	18.1	0.5	4.3	5.8	0.0	3.1	22.1	3.5	0.16	0.3	7.9	45	0.3	1.0	21.8	68.7	91.7	3.5	4.8	S
P3	0–30	9.15	2.80	20.4	0.7	2.2	5.9	0.0	5.1	21.9	2.3	0.57	1.10	5.4	7	0.2	0.6	21.9	1.6	91.8	3.5	4.7	S
	30–60	9.29	6.40	59.0	0.9	5.7	7.8	0.0	3.0	50.2	20.2	0.24	0.90	3.1	7	0.0	0.7	31.5	0.6	95.0	1.2	3.8	S
	60–90	9.26	6.90	60.7	0.8	5.8	9.7	0.0	3.5	55.0	18.6	0.25	0.50	4.9	6	0.0	0.4	33.6	0.6	94.5	1.3	4.2	S

[a]In soil saturation extract

ECe EC of soil saturation extract, *VCS* very coarse sand, *CS* coarse sand, *MS* medium sand, *FS* fine sand, *VFS* very fine sand; Texture class – *S* sand, *CEC* cation-exchange capacity, *OM* organic matter, *pH*s pH of saturated soil paste, *ESP* exchangeable sodium percentage

Table 23.7 The location, general description, and soil classification of sandy and fluvio-sandy soil profiles

			Soil description								
			Color				Soil consistencies				
Profile no.	Site	Depth (cm)	Moist	Dry	Texture class	Structurewet	Wet	Moist	Dry	General aspects	Soil classification
P1 Sandy	South El-Tahreer, El-Beheira Governorate	0–30	Brown	Yellow 10YR 7/5	S	Structure less	Nonsticky and non plastic	Very friable	Loose	Prolonged use of organic fertilizers converted the surface as back. The profile is homogeneous	Typic Xerpsamments
P2 Fluvio-sandy	El-Zapharany village Kom Hamada, city El-Beheira Governorate	0–36	Very dark grayish brown 10YR 3/2	Grayish brown 10YR 5/2	SCL	Massive and blocky	Slightly sticky and plastic	Firm	Hard	Few fine roots of *Zea mays*, some very fine shell fragments and weak effervescence with HCl	Typic Psammiaquents
		36–61	Olive brown 2.5Y 4/4	Light olive brown 2.5Y 5/6	LS	Massive and blocky	Nonsticky and nonplastic	Friable	Slightlyhard	Tongue of clay through the layer	
		61–88	Olive yellow 2.5Y 6/6	Yellow 2.5Y 7/6	S	Structure less	Nonsticky and nonplastic	Very friable	Loose	Tongue of decayed OM observed	
		88-water table	Very dark grayish brown 10YR 3/2	Dark grayish brown 10YR 4/2	CL	Massive	Very sticky and very plastic	Very firm	Veryhard	This layer reveals fluvial nature so it has dark color	

Texture class – *S* sandy, *SCL* sandy clay loam, *LS* loamy sand, *CL* clay loam

Table 23.8 Selected physical and chemical characteristics of sandy and fluvio-sandy soil profiles

Profile no.	Depth (cm)	pHs	ECe (dS m^{-1})	Soluble cations (meq l^{-1})[a]				Soluble anions (meq l^{-1})[a]				OM (%)	$CaCO_3$ (%)	CEC (cmolc kg^{-1})	ESP	Particle-size distribution (%)							Texture class
				Na	K	Ca	Mg	CO_3	HCO_3	Cl	SO_4					VCS	CS	MS	FS + VFS	Sand	Silt	Clay	
P1 Sandy	0–30	9.30	1.2	5.7	0.1	1.7	1.8	0.0	2.3	9.8	0.2	0.15	2.1	3.6	5	5.9	14.9	19.7	54.9	95.4	2.5	2.1	S
	30–60	9.25	1.3	9.6	0.1	2.0	1.8	0.0	2.2	11.0	0.3	0.14	2.4	3.0	5	7.8	13.6	20.7	54.8	97.0	1.6	1.4	S
	60–90	9.14	2.4	15.5	0.3	3.6	5.4	0.0	2.0	19.2	3.5	0.12	2.0	3.6	4	6.2	16.8	23.6	49.1	95.7	3.1	1.2	S
P2 Fluvio-sandy	0–30	8.86	4.1	8.9	0.4	4.5	6.5	0.0	4.5	13.5	2.3	1.62	3.3	22.7	3	3.6	5.8	6.2	51.4	37.3	23.7	39.0	CL
	30–60	9.33	3.6	11.8	0.4	4.2	6.3	0.0	2.2	15.0	5.5	0.42	1.6	17.0	4	5.7	9.7	17.6	51.7	49.2	27.8	23.0	SCL
	60–90	9.16	3.6	17.6	0.3	4.0	3.0	0.0	3.1	14.5	7.3	0.41	1.5	14.7	7	7.1	11.4	15.9	61.0	56.8	29.0	14.1	SL
	8–wt	9.17	2.1	20.8	0.3	4.1	4.5	0.0	4.5	16.6	8.6	0.29	2.6	16.3	7	1.0	4.5	3.8	27.2	46.6	32.9	20.5	L
	Wt	9.06	2.1	10.7	0.2	2.0	5.2	0.0	4.2	12.4	1.5	0.30	2.5	18.2	9	0.8	1.9	2.9	21.1	42.5	28.7	28.8	CL

[a]In soil saturation extract

ECe EC of soil saturation extract, *VCS* very coarse sand, *CS* coarse sand, *MS* medium sand, *FS* fine sand, *VFS* very fine sand; Texture class – *S* sand, *CL* clay loam, *SCL* sandy clay loam, *L* loam, *CEC* cation-exchange capacity, *OM* organic matter, *pH*s pH of saturated soil paste, *ESP* exchangeable sodium percentage, *wt* water table chlorides dominate among other cations and anions, respectively. All layers (P1 and P2) are nonsaline and non-sodic (ECe < 4 dS m^{-1} and ESP < 15), except upper surface in P2 which is saline. Profiles are classified as Typic Quartzipsamments (P1) and Typic Torripsamments (P2). In a previous study, Shaheen (1999) has reported similar results.

23.3.5 Calcareous Soils

23.3.5.1 Field Description, Soil Classification, and Physical and Chemical Characteristics

Variable color, texture, and consistence observed during profile description (Table 23.9). Table 23.10 shows silty loam being the dominant texture (P1 and P2) and variety of textures in P3. Compared to all other profiles investigated, these soils are heavier in soil texture, and silt being dominant. The trend of primary particles is silt > clay > sand. This can be attributed to the type of parent material developed under marine and lagoonal conditions high in carbonate contents (Moustafa 1987).

The difference in color and other characteristics is due to type of sediment and the management of these soils. All profiles are highly calcareous, and the $CaCO_3$ is relatively higher in P1 compared to other two profiles. The high-$CaCO_3$ contents correspond to high silt content (El-Gamal 1992). The organic matter in general is <1%, and at surface of all profiles, it is present up to 1.61%. Soil reaction (pH) is strongly alkaline in all layers (P1 and P2) and very strongly alkaline (P3), and hence will restrict nutrient availability to plants. The mean CEC is higher (11.5–17.8 cmolc kg^{-1}) due to high clay content. The entire profiles (P1, P2, P3) are nonsaline and non-sodic (ECe < 4 dS m^{-1} and ESP < 15). All profiles are classified as Typic Haplocalcids. The trend of soluble cations (Na > Ca > K) and soluble anions is same (Cl > SO_4 > HCO_3) as for other profiles.

23.4 Sesquioxides in the Tested Profiles

Table 23.11 reveals sequioxides of profiles, showing the dominance of total Fe and Al when expressed on g kg^{-1} basis. Total Fe being the lowest in marine soils (6.1 g kg^{-1}), and the highest in lacustrine soils (58.4 g kg^{-1}). Total aluminum follows same trend as for total Fe (lowest 5.9 g kg^{-1} in marine and highest 64.9 g kg^{-1} in lacustrine soils). The general trend of citrate-bicarbonate-dithionite extractable Fe, Mn, Al, Si, and Ca is found as Ca dominates over the others, Mn being the lowest, whereas Fe and Al codominate over other ammonium oxalate extractable contents (Mn, Si, Ca). The variations of sequioxides with respect to profiles developed from different sediments can be seen in Table 23.11.

Table 23.9 The location, general description, and soil classification of calcareous soil profiles

Profile no.	Site	Depth (cm)	Description: Color Moist	Color Dry	Texture class	Structure wet	Soil consistencies: Wet	Moist	Dry	General aspects	Soil classification
P1	Mariut at about 1.5 km to the west of the km 30 of Alexandria-Cairo desert road	Yellowish brown 10YR 6/4	Very pale brown 10YR 7/4	SiL, L and CL	Massive and blocky		Firm	Hard to very hard	The soil profile is homog-enous. The profile is deep where water table was not observed	Typic Haplocalcids	
P2	Mariut at about 1 km to the west of the km 30 of Alexandria Cairo desert road		Yellowish brown 10YR 6/4	Very pale brown 10YR 7/4	Silt loam, and clay loam	Massive and blocky		Firm	Hard to very hard	The soil profile is homogenous	Typic Haplocalcids

P3	Ezbet El-Adlia 1 km to the north of Nubaria canal. Abo El-Matameir, El-Beheira Governorate	0–28	Dark brown 10YR 5/3	Brown 10YR 5/3	Clay loam	Massive and blocky	Sticky and plastic	Firm	Hard	This layer has relatively dark color as a result of mixing with clay fraction, few fine fibrous roots and strong effervescence with HCl	Typic Haplocalcids
		28–50	Strong brown 7.5YR 5/8	Reddish yellow 7.5YR 6/6	Sandy Clay loam	Massive and blocky	Slightly sticky and slightly plastic	Very firm	Very hard	Few fine roots, few white soft lime nodules, and very strong effervescence with HCl	

(continued)

Table 23.9 (continued)

Profile no.	Site	Depth (cm)	Description								
			Color		Texture class	Structure wet	Soil consistencies			General aspects	Soil classification
			Moist	Dry			Wet	Moist	Dry		
		50–80	Yellowish brown 10YR 6/4	Very pale brown 10YR 7/4	Sandy loam	Massive and blocky	Slightly sticky and slightly plastic	Firm	Very hard	Very few and very fine roots, white soft lime nodules, common white lime nodules and concretions, and very strong effervescence with HCl	
		80–wt	Dark brown 10YR 4/4	Brown 10YR 5/3	Loam	Massive and blocky	Slightly sticky and slightly plastic	Firm	Very hard	Common black hard gravels and concretions, very strong effervescence with HCl	

Table 23.10 Selected physical and chemical characteristics of calcareous soil profiles

Profile no.	Depth (cm)	pHs	ECe (dS m^{-1})	Soluble cations (meq l^{-1})[a] Na	K	Ca	Mg	Soluble anions (meq l^{-1})[a] CO_3	HCO_3	Cl	SO_4	OM (%)	$CaCO_3$ (%)	CEC (cmolc kg^{-1})	ESP	Particle-size distribution (%) VCS	CS	MS	FS + VFS	Sand	Silt	Clay	Texture class
P1	0–30	8.53	5.2	33.5	0.8	8.2	10.0	0.0	4.5	26.5	21.8	1.61	33.3	13.0	4.3	1.6	2.7	5.2	23.7	33.2	39.5	27.3	CL
	30–60	8.75	3.0	20.8	0.5	4.6	4.4	0.0	2.0	17.1	11.2	0.51	48.6	10.8	4.3	1.1	1.9	4.6	13.1	20.8	58.1	21.1	SiL
	60–90	8.80	2.9	20.4	0.5	4.4	4.2	0.0	2.1	15.5	11.9	0.43	55.6	9.6	2.9	1.6	2.2	4.8	16.1	24.7	54.3	21.0	SiL
	90–120	8.89	2.5	19.0	0.5	3.8	2.8	0.0	2.3	15.0	8.9	0.50	40.3	12.4	4.1	1.5	2.4	6.2	16.6	26.7	50.6	22.7	SiL
	120–150	8.94	2.3	18.5	0.4	2.2	3.0	0.0	2.4	13.8	7.9	0.49	39.2	11.6	5.2	1.5	2.9	5.4	20.0	29.9	45.3	24.8	L
P2	0–30	8.75	2.9	13.4	0.7	6.2	9.0	0.0	3.5	12.5	3.3	1.03	32.7	9.8	2.4	1.4	2.4	5.5	24.9	34.2	38.5	27.3	CL
	30–60	8.78	2.9	11.9	0.5	6.2	10.3	0.0	3.3	20.0	5.6	0.37	34.5	18.4	3.3	1.6	1.8	4.4	14.3	22.2	57.0	20.8	SiL
	60–90	8.49	2.7	12.1	0.5	5.1	9.3	0.0	3.4	20.0	3.6	0.52	37.0	18.0	2.8	1.8	2.2	4.2	18.8	26.9	50.6	22.5	SiL
	90–120	8.58	2.3	12.8	0.4	4.2	6.4	1.3	3.8	15.0	3.7	0.37	35.1	16.6	2.3	1.7	2.6	6.5	17.8	28.6	50.3	21.1	SiL
P3	0–28	8.86	4.1	28.9	0.6	7.2	8.1	0.0	3.5	23.0	18.3	1.60	20.7	22.7	3.1	1.4	3.4	1.2	31.2	37.3	23.7	39.0	CL
	28–50	9.33	3.6	27.9	0.2	5.6	4.4	0.0	3.3	18.5	16.3	0.42	32.2	17.0	5.1	2.9	3.8	5.0	38.4	49.2	27.8	23.0	SCL
	50–80	9.16	3.6	25.8	0.1	5.9	8.1	0.0	2.3	18.4	19.2	0.41	49.5	14.7	5.4	5.8	3.4	4.7	4.29	56.8	29.0	14.1	SL
	80–wt	9.17	2.1	16.4	0.2	4.0	3.2	0.0	2.5	15.0	6.3	0.29	36.7	16.3	7.3	2.9	2.8	5.2	35.8	46.6	32.9	20.4	L
	uwt	9.06	2.1	15.4	0.3	4.0	2.3	0.0	2.4	14.3	5.3	0.30	27.8	18.2	4.5	1.8	4.8	2.9	33.0	42.5	28.7	28.8	CL

[a]In soil saturation extract

ECe EC of soil saturation extract, *VCS* very coarse sand, *CS* coarse sand, *MS* medium sand, *FS* fine sand, *VFS* very fine sand, Texture class – *CL* clay loam, *SCL* sandy clay loam, *L* loam, *SiL* silt loam, *CEC* cation-exchange capacity, *OM* organic matter, *pHs* pH of saturated soil paste, *ESP* exchangeable sodium percentage, *wt* water table, *uwt* under water table

Table 23.11 Amounts of sesquioxides in the surface layers of tested soil profiles

Profile no.	Depth (cm)	Soil classification	Fe_t	Fe_d	Fe_o	Mn_t	Mn_d	Mn_o	Al_t	Al_d	Al_o	Si_d	Si_o	Ca_d	Ca_o
Fluvial soils		g kg-1 soil													
P1	0–20	Typic Torrifluvents	57.8	10.3	2.49	1.05	0.75	0.52	51.7	0.79	2.02	1.12	1.01	13.5	0.016
P2	0–30	Typic Torrifluvents	63.2	7.9	2.02	0.85	0.69	0.48	69.9	1.03	2.09	1.79	0.83	16.4	0.025
P3	0–30	Typic Torrifluvents	47.9	6.2	1.72	0.74	0.51	0.33	47.1	0.70	1.72	1.28	0.81	17.1	0.014
P4	0–30	Typic Fluvaquents	59.7	9.0	3.35	0.81	0.59	0.41	61.4	0.96	2.48	0.89	1.05	13.0	0.016
P5	0–30	Typic Ustifluvents	62.0	7.6	1.85	1.04	0.67	0.44	69.2	1.07	2.54	1.28	0.90	20.0	0.015
P6	0–30	Vertic Torrifluvents	58.1	5.9	2.03	0.94	0.64	0.46	55.8	0.64	2.15	1.33	0.94	20.5	0.018
Lacustrine soils															
P1	0–30	Typic Xerofluvents	61.9	7.4	3.94	1.00	0.63	0.47	72.0	1.19	3.06	1.37	1.42	26.1	0.012
P2	0–30	Typic Fluvaquents	61.7	6.6	3.76	1.19	0.89	0.62	67.4	0.86	2.15	1.59	0.98	27.8	0.015
P3	0–30	Typic Xerofluvents	62.4	8.2	4.86	0.94	0.63	0.49	71.0	0.78	2.16	1.51	1.14	26.8	0.019
P4	0–30	Typic Fluvaquents	47.8	6.0	3.50	0.65	0.39	0.29	49.1	0.54	1.84	1.23	1.00	26.6	0.023
Marine soils															
P1	0–30	Typic Xeropsamments	7.9	0.9	0.31	0.13	0.07	0.05	6.9	0.29	0.27	0.24	0.20	2.1	0.026
P2	0–30	Typic Psammiaquents	4.6	0.6	0.22	0.13	0.11	0.07	4.9	0.23	0.24	0.30	0.17	3.8	0.025
P3	0–30	Typic Psammiaquents	6.6	0.7	0.26	0.15	0.08	0.06	6.0	0.19	0.27	0.27	0.23	9.0	0.022
Sandy and fluvio-sandy soils															
P1	0–30	Typic Quartzipsamments	3.6	0.7	0.11	0.08	0.10	0.06	4.1	0.32	0.30	0.10	0.14	5.2	0.016
P2	0–30	Typic Torripsamments	25.2	3.2	1.23	0.41	0.31	0.21	27.8	0.60	0.87	0.57	0.54	18.1	0.031
Calcareous soils															
P1	0–30	Typic Haplocalcids	18.3	4.1	1.06	0.34	0.26	0.14	23.3	0.50	0.90	0.22	0.36	37.7	0.025
P2	0–30	Typic Haplocalcids	22.0	5.0	1.48	0.39	0.26	0.14	32.1	0.53	1.02	0.23	0.40	48.5	0.007
P3	0–30	Typic Haplocalcids	22.7	3.9	1.14	0.41	0.33	0.21	28.6	0.54	0.98	0.45	0.52	43.0	0.009

Fe_t, Al_t, and Mn_t = Total Fe, Mn, and Al; Fe_d, Al_d, Mn_d, Si_d, and Ca_d = Citrate-bicarbonate-dithionate extractable (Fe, Al, Mn, Si, Ca); Fe_o, Al_o, Mn_o, Si_o, and CaO = Ammonium oxalate extractable (Fe, Mn, Al, Si, and Ca)

23.5 Conclusions and Recommendations

The classification of profiles and their basic properties are investigated. The profiles vary considerably in physical and chemical properties depending on the geological nature of the deposits (fluvial, lacustrine, marine, calcareous, sandy, and fluvio-sandy). The fluvial, lacustrine, marine, and sandy and fluvio-sandy soils are classified as entisols, whereas calcareous soils as aridisols. The soils exhibited quite different physical and chemical properties. The pH is above optimum range of nutrient availability; therefore, the soil needs careful management to improve nutrient efficiency in soil. The sodic soils need to be amended by gypsum application to reduce sodicity. The diverse geological nature of these deposits is reflected in the wide variation of clay content, carbonates content, and in the form of Fe, Al, Si, and Mn oxides.

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