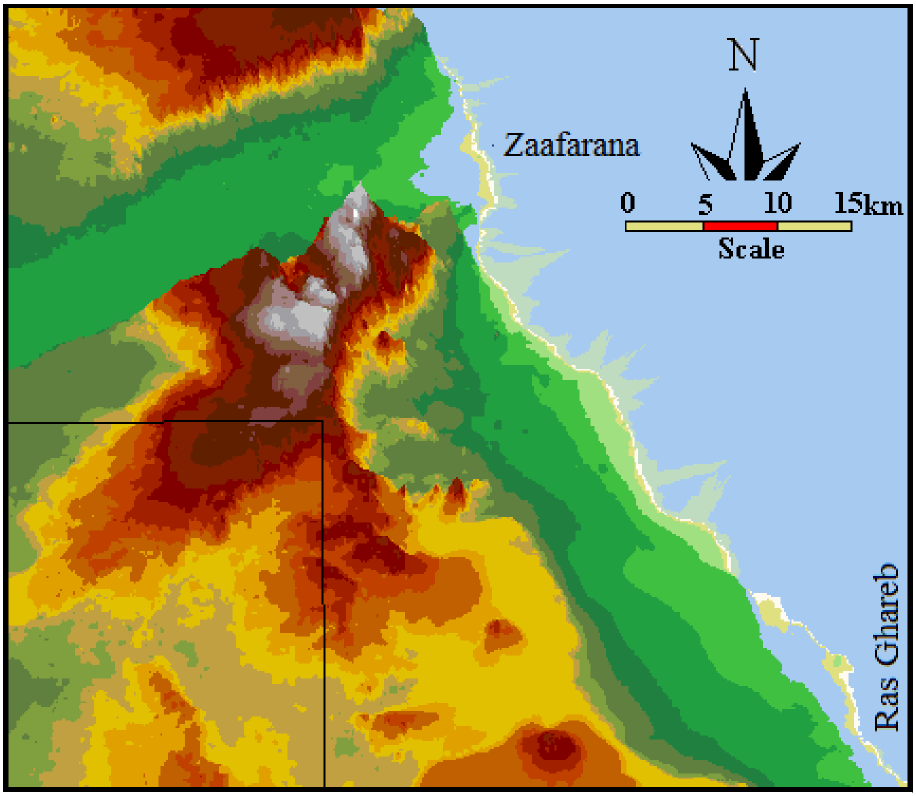
4. RESULTS AND DISCUSSION

4.1 Digital Elevation Model (DEM)

Digital Elevation Model is a data file that contains the elevations of the study area over specified points at fixed grid intervals over the bare earth. The intervals between each of the grid points were referenced to some geographical coordinate system. The closer together the grid points with low differences, the more information be obtained. A DEM produced for the study area as a raster type to be a GIS layout, representing the area as a regular arrangement of locations. In this DEM, each cell has a value corresponding to its elevation. The regularly arranged locations permit the raster GIS to infer many interesting associations among locations as, which cells are upstream from other cells, which locations are visible from a given point and where are the steep slopes. Adding synthetic shaded relief images, contour lines, surfaces for 3-dimentional (3d) visualization, and editable break lines formulated the details of the peaks in the highlands and wadis in the lowlands as modeled with the specified grid spacing intervals. By such DEM (Figure 12), the study area is well illustrated as a satisfactory overall view that serves as a basis for earthwork and grading studies. The map reader can see the relationship between certain terrain and the required land utilization types. On the other hand, such DEM is a beneficial layout for understanding the terrain mode by converting the terrain data into useful representations that can be used in GIS and the 3d modeling formats. In addition, this DEM is interesting as it can be transformed into other forms of data that are useful for many applications such as slope calculation, shaded relief that makes the terrain model graphically more informative and contours being useful and applicable gradients. Probably the most efficient ways to terrain information out of GIS and into a 3d modeling package is as a triangulated surface.

By the aid of DEM, the slope shaded and the profile graph showing the different altitudes values along a specified transect



Legend of the elevation gradient by meters

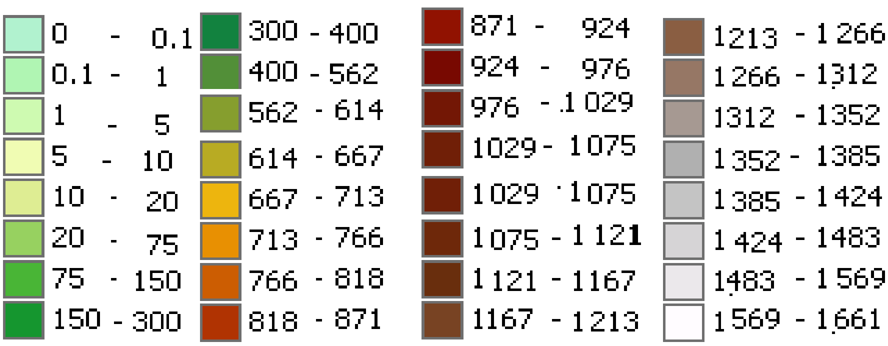


Figure 12 Digital Elevation Model (DEM) of the study area

were produced. The displayed layers of the EegyptSat-1 (raster) and the physiographic features (vector) that intersect the DEM gave a good view to extract the study area as being more promising for agriculture use. The promising study area was reproduced including the physiographic units displayed on top of DEM. Accordingly, the mapping units can further be characterized with respect to physiography and altitude. Also, there is a possibility of displaying the map on top of rectified Egyptsat-1 image. These alternatives of layer displays within the GIS can help in detailed mapping units and soil boundaries drawing on image reflectance variations and other relevant bases.

4.2 Physiographic units

Physiography could identify a certain physiographic processes, which in turn, provide an important element clue for delineating soil patterns after predicting some certain soil properties (Goosen 1967). In the study area, identification in terms of physiographic units was generally based on specifying some geomorphic units, which reflect most of the landscape forms and their genesis. As these units were described and grouped by remote sensing data interpretation, the map legend of physiography replaced geomorphology. The physiographic features of the study area covering 832514.1ha (hactares) or 1982044.4 f (feddans). They are characterized by the spectral signatures of the remote sensing data in Figure 13. They include (1) dissected highland (2) piedmonts (3) bajada (4) alluvial terraces (5) wadis (6) deltaic plains and (7) marine sediments.

4.2.1 Dissected highlands of elevated mountains:

These physiographic units cove 346568.5 ha (825162.9 f).They is situated aligning the study areas consisting of an intricate high and rugged parent rocks. In wadi Araba study area, the northern and southern sides (Gabal El Galala El Bahariayh and Gabal El Galala El Kebliayh, respectively) are characterized by dissected limestone parent rock and dendritic drainage pattern. In Ras Ghareb area, these units are situated aligning the western

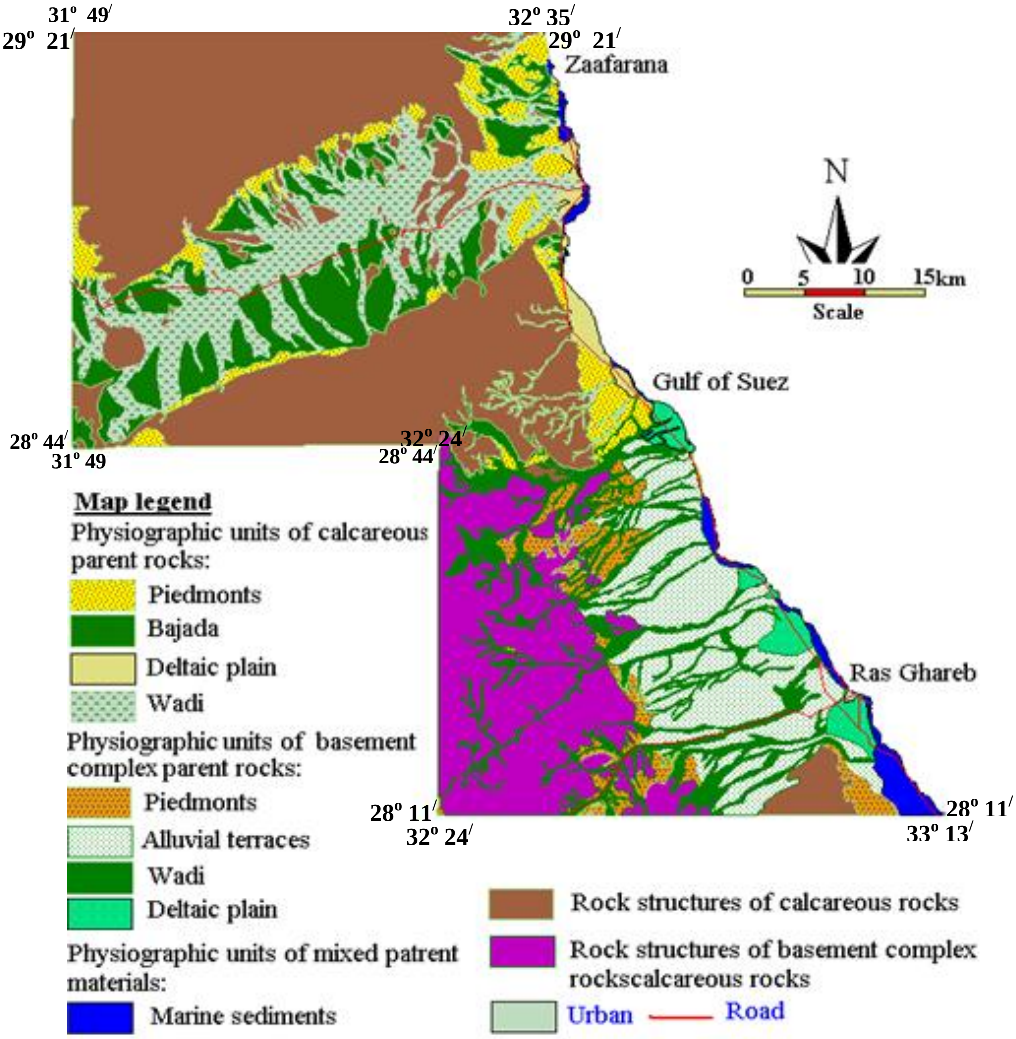


Figure 13 Physiographic units of the study area

border of the lowlands dominated by dissected basement complex parent rocks by sub parallel drainage pattern.

4.2.2 Piedmonts

Piedmont [Piedmonts; etymology: Latin "*piede*" = foot + "*mont*"= mountain] refers to a region in northern Italy named *Piemonte*. The piedmonts cover 77077.9 ha (183516.7 f). They are formed near the foot of the mountains, lying at the base of a mountain range. They occur along both sides of the wadis in the highland or terminating the sides of high rock lands. They are in the areas of sloping surfaces having sediments close to the highlands and partly including areas of pediments [pediments; etymology: Greek "pedon" = ground]. These pediments are the resultants of physical weathering that act on rocky surfaces, giving coarse soils underlain by the parent rock.

4.2.3 Bajadas

Bajada [Bajada; etymology: Spanish = descending slope] . Bajada is a depositional broad slope of debris spread along the lower slopes of mountains by descending streams that form several alluvial fans in coalescing patterns. Bajada cover 92448.7 ha (220116.0 f) in the study area, have gently sloping gullied and gravelly surfaces. They are prominent feature in Araba area where the mountain stream runs to a flatter surface at the front of a mountain system. They extend from the highlands "limestone parent rock" following dip slopes of the mountain bases (Gebal El Galala El Bahariayh and Gebal El Galala El Qebliayh respectively). They were transported and deposited when the runoff loads lose their kinetic energy during the flow on less sloping areas forming series of confluent alluvial fans in a lateral coalescence.

4.2.4 Alluvial terraces

Alluvial terraces are widely distributed in the lowlands as derived from the highlands of the basement complex parent rocks. Afify et al (2007) attributed the parent materials of these terraces to the old sediments of the paleodrainage actions. During rather fluvial periods in relatively recent eras, these terraces represent sites which were most probably left out after regional erosion processes as a result of other later fluvial era. The resultant was dissected surfaces by channels and gullies that follow the general slopes. In the current study, alluvial terraces cover 90804.9 ha (216202.4 f). The relatively more recent streams had partly eroded these sediments leaving remnants of older surfaces along the sides of the running streams. Being the older surfaces with a long-standing isolation from stream erosion, they were preserved out from erosion to be left for pedogenic development.

4.2.5 Wadis

Wadi [Wadis; etymology: Arabic = a channel of a watercourse that is dry except during periods of rainfall]. Wadis are almost flat, partly vegetated with very open zerophytic herbaceous natural vegetation on well-drained soils. They are the resultant of dissection action of the surrounding landscape involving erosional and depositional processes in the fluvial periods. In the study area, Wadis covet 194520.5 ha (232271.1 f), with a dry appearance (being in a drought environment). They receive seasonal flush flooding running through different directions in the study area within two regions of wadis of sedimentary parent rocks and wadis of igneous and metamorphic parent rocks.

4.2.5.1 Wadis that have their alluvium from sedimentary parent rocks.

These wadis initiated and running over highlands of limestone parent rocks linking to watersheds cutting through highlands of limestone watershed areas. They start with relatively shorter channels with more branches forming a dendritic drainage pattern that flows southwards and northwards from El-Galalaa El Bahariayh and El Galalaa El Qibliayah mountains. The dendritic drainage links sediments in the main wadi of braided system (Wadi Araba) of eastward dip slopes. This main wadi runs between the highlands, draining the seasonal loads into the sea water of the Gulf of Suez.

4.2.5.2 Wadis that have their alluvium from igneous and metamorphic (basement complex) parent rocks.

These wadis are draining from igneous and metamorphic parent rocks within watershed areas. Such areas are of sub parallel drainage pattern flowing along the highlands eastwards as narrow gorges of high vertical cliffs of basement complex rocks. They generally run from west to east joining many secondary wadis in the lowlands, and finally link the sediments in main wadis of braided systems. These braided wadis flow towards the Gulf of Suez crossing terraced landscape, deltaic plains and marine sediments.

4.2.6 Deltaica plains.

Delta is the fourth letter of the Greek alphabet, which is shaped like a triangle " Δ". Huggett (2007) stated that, deltas are formed by deposition when rivers run into the sea. So long as the deposition rate surpasses the erosion rate, a delta will grow. Deltas are found in the range of coastal environments. Some deltas form in low-energy coasts with low tidal ranges and weak waves. Others form in high-energy coasts with large tidal ranges and powerful waves. As deltas come in multiplicity, their precise shape depends upon the ability of waves to rework and redistribute the incoming rush of river-borne sediment. According to Chorley et al. (1985), deltas are formed where sediment-laden rivers flow into standing bodies of water. The greater the water discharge, the larger is the drainage basin and therefore, greater sediments and larger deltas are formed.

In the study area, these deltaic plains cover 17720.0 ha (42190.5 f.). They are distributed along the shoreline with curved fronts having almost flat surfaces, but locally separated from that shoreline by marine sediments. The deltaic plains which are derived from limestone parent rocks are relatively small areas covered by whitish fragments compared with those derived from basement complex parent rocks which are larger areas and covered with black fragments.

4.2.7 Marine sediments.

Marine sediments are mainly deposited by sea water through wind, waves and currents. They cover 13018.9 ha (30997.4 f.) in a complex pattern along the shoreline including vegetated areas with *halophytic* communities. The sediments are localized by lagoons and mud flats connected to the tidal level, while are dominated by chalk concretions, which were most probably derived from the coral reefs. According to Van dorser (1984), coral reefs in tropical region were built up by colonies of coral polyps with lime skeletal, which remain after corals die, chalk derived from calcareous algae forms lime concretion which are transported to the coast.

4.3 Soil Taxonomy.

Soil characteristics (taxa) are classes at any categorical level in the multi-categorical system. Soil Taxonomy is a system of standard reference formulated by the USDA for soil classification (USDA 1975). It is used in organizing and communicating knowledge about soils to provide means for understanding relationships among soils within a given area.

4.3.1 Categorization to the family level.

According to the USDA Soil Taxonomy (USDA 1975) based on climatic data of Egypt, the moisture regime of the study area is *"torric"* and the temperature regime is *"hyperthermic"*. Soil characteristics of the study area are classified in the two orders of *Aridisols* and *Entisols* to the soil family level to be associated within the topo-sequence of the physiographic units in the study area. Soil Taxonomy of the physiographic units along the topo-sequence are shown in Table 2 to 4. Detailed soil analyses are included in Tables 5 to 13, while the field morphological description of the soil profiles is shown in appendix 1.

Table 2 Soil Taxonomy within the topo-sequence in the physiographic units from limestone parent rocks

Physiographic unit	Profile No.	Soil Taxonomy				
		Order	Sub Order	Great Group	Sub Group	Family
Piedmonts	26	*Aridisols*	*Calcids*	*Haplocalcids*	*Lithic Haplocalcids*	*Sandy skeletal, carbonatic, hyperthermic*
Bajada	3,6, 28 and 29				*Typic Haplocalcids*	*Loamy skeletal, mixed , hyperthermic*
	30					*Sandy skeletal, mixed, hyperthermic.*
Wadi	1, 4, 5 and 31	*Entisols*	*Fluvents*	*Torrifluvents*	*Typic Torrifluvents*	*Loamy skeletal, mixed (calcareous), hyperthermic*
	2					*Coarse loamy, mixed (calcareous), hyperthermic*
	25		*Orthents*	*Torriorthents*	*Typic Torriorthents*	*Sandy skeletal, mixed, hyperthermic.*
Deltaic plain	27, 32, 33 and 34	*Aridisols*	*Calcids*	*Haplocalcids*	*Sodic Haplocalcids*	*Coarse loamy, carbonatic, hyperthermic.*
	35					*Coarse loamy, hyperthermic*

Table 3 Soil Taxonomy within the topo sequence in the physiographic units of basement parent rocks

Physiographic units	Profile No.	Soil Taxonomy				
		Order	Sub Order	Great Group	Sub Group	Family
Piedmonts	11	*Entisols*	*Orthents*	*Torriorthents*	*Lithic Torriorthents*	*Sandy skeletal, mixed, hyperthermic*
	36					*Fragmental, hyperthermic*
Alluvial Terraces	20, 22, 23 and 24	*Aridisols*	*Gypsids*	*Calcigypsids*	*Typic Calcigypsids*	*Loamy skeletal, mixed, hyperthermic*
	16		*Calcids*	*Haplocalcids*	*Typic Haplocalcids*	*Coarse loamy, mixed, hyperthermic*
Wadi	10	*Entisols*	*Orthents*	*Torrioerthents*	*Typic Torriorthents*	*Sandy skeletal, mixed, hyperthermic*
	8 and 9		*Fluvents*	*Torrifluvents*	*Typic Torrirfluvents*	*Loamy skeletal , mixed, hyperthermic*
	15, 37 and 38					*Coarse loamy, mixed, hyperthermic*
Deltaic plain	7, 17 and19		*Orthents*	*Torrioerthents*	*Typic Torriorthents*	*Coarse loamy, mixed, hyperthermic*

Table 4 Soil Taxonomy within the topo-sequence in the physiographic units of mixed parent materials (fluvio-marine sediments)

Physiographic units	Profile No.	Soil Taxonomy				
		Order	Sub Order	Great Group	Sub Group	Family
Marine sediments	12, 18, 39, 40 and 41	*Aridisols*	*Salids*	*Aquisalids*	*Calcic Aquisalids*	*Sandy, carbonatic, hyperthermic*
	21					*Sandy, mixed hyperthermic*
	13				*Gypsic Aquisalids*	*Fine loamy, mixed, hyperthermic*

Table 5 Physical properties of the soils in the physiographic units of limestone parent rocks.

Physiographic unit	Profile No.	Horizon	Depth (cm.)	Gravel % (v/v)	Particle size distribution %							Modified texture class	$CaCO_3$ g/kg	Gypsum g/kg	OM g/kg
					Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay				
Piedmonts	26	A	0-10	60	19.1	19.6	36.6	4.5	3.6	8.7	7.9	EGLCoS	476.0	39.0	0.80
		ABk	10-45	65	22.5	23.7	27.5	6.4	2.7	9.1	8.1	EGLCoS	589.4	43.9	0.90
		2R	45-	Lithic contact of limestone parent rocks											
Bajada	3	ABk	0-20	15	7.5	11.8	17.3	23.9	6.6	14.3	18.5	GSL	344.0	49.0	5.50
		Bk1	20-50	20	17.7	19.8	22.6	14.3	5.1	10.5	10.1	GCoSL	353.4	44.8	4.41
		Bk2	50-90	45	26.5	21.6	17.5	9.3	2.5	11.2	11.4	VGCoSL	232.0	24.3	5.50
		Bk3	90-150	35	18.4	11.2	12.8	11.6	3.1	19.5	23.4	VGSCL	107.0	26.0	1.70
	6	ABk	0-25	20	4.4	9.1	16.2	39.8	7.7	10.5	12.3	GSL	387.1	11.0	1.50
		Bk1	25-55	35	13.9	13.4	20.5	20.2	9.5	12.7	9.8	VGCoSL	347.2	8.3	3.20
		Bk2	55-90	35	21.5	24.9	19.9	6.8	4.4	12.6	9.9	VGCoSL	368.7	55.0	1.70
		C	90-150	40	9.0	20.1	21.0	17.5	7.8	10.6	14.1	VGCoSL	252.1	10.8	0.08
	28	ABk	0-30	25	5.4	9.7	18.2	30.4	7.7	14.8	13.8	GSL	305.0	12.0	3.80
		Bk1	30-70	40	14.3	18.5	2.0	29.2	11.6	12.6	11.9	VGCoSL	273.6	9.0	2.90
		Bk2	70-100	50	23.5	24.2	12.2	8.6	6.2	13.2	12.1	VGCoSL	326.5	23.0	1.50
		C	100-15(	60	9.9	22.1	25.7	15.7	4.9	11.4	10.3	EGCoSL	294.9	8.0	0.80
	29	ABk	0-25	15	8.5	9.8	17.3	33.4	6.9	11.9	12.1	GSL	263.4	11.0	2.50
		Bk1	25-65	35	15.6	19.8	22.9	5.3	9.1	13.4	14.0	VGCoSL	295.5	9.0	1.40
		Bk2	65-90	40	21.4	21.6	17.8	10.2	3.5	12.3	13.2	VGCoSL	276.3	8.0	1.80
		Bk3	90-150	45	20.4	22.6	19.8	12.1	5.6	10.1	9.4	VGCoSL	376.0	7.1	0.90
	30	ABk	0-15	20	8.5	13.8	23.8	23.8	11.7	9.6	8.8	GLS	306.8	39.0	1.80
		Bk1	15-45	40	11.6	10.8	14.3	37.3	10.5	8.4	7.1	VGLS	311.2	14.8	1.70
		Bk2	45-90	35	20.4	19.5	27.2	9.3	5.5	8.7	9.4	VGCoLS	254.3	24.3	0.90
		C	90-150	35	10.3	18.0	19.8	20.8	9.1	11.5	10.5	VGCoSL	149.0	16.0	0.60
Wadi	1	C1	0-10	40	3.2	17.4	43.8	5.8	12.4	9.2	8.2	VGLS	224.5	6.3	7.50
		C2	10-40	35	5.5	12.2	33.4	3.8	24.9	10.3	9.9	VGSL	253.1	21.5	2.00
		C3	40-70	40	20.0	18.0	21.9	8.5	6.7	10.4	14.5	VGCoSL	249.3	5.2	0.90
		C4	70-100	45	16.0	24.3	24.0	8.1	2.4	9.7	15.5	VGCoSL	181.5	7.9	0.60
		C5	100-15(	35	10.4	16.1	23.2	10.3	6.5	12.3	21.1	VGSCL	215.5	31.0	2.20
	4	C1	0-20	20	7.4	8.2	8.4	51.6	8.7	6.8	8.9	GLFS	371.6	7.1	3.20
		C2	20-50	35	34.8	24.7	3.9	12.8	4.3	10.4	9.1	VGLCoS	352.2	13.3	1.80
		C3	50-90	35	8.9	18.1	18.3	22.3	11.6	10.6	10.3	VGCoSL	325.1	11.2	2.80
		C4	90-150	40	12.1	15.9	8.3	24.8	7.5	15.3	16.2	VGCoSL	228.4	7.4	0.50
	5	C1	0-20	35	20.3	23.0	17.5	10.8	5.6	10.6	12.2	VGSL	358.1	21.0	4.50
		C2	20-50	45	28.8	22.2	22.6	5.8	0.2	10.4	10.1	VGSL	307.7	6.6	3.30
		C3	50-80	50	16.3	24.5	19.7	8.1	6.7	13.2	11.6	VGSL	312.4	5.1	1.82
		C4	80-150	35	23.5	33.9	15.5	5.1	2.0	10.3	9.7	VGLS	241.8	14.5	1.50

A, B, C and R = master horizons, k = accumulation of calcium carbonates, EG = extremely gravelly, VG=very gravelly , G=gravelly, LCoS=loamy coarse sand, LS=loamy sand, CoSL= coarse sandy loam , SL=sandy loamsandy loam ,

Table 5 cont.

Physiographic unit	Profile No.	Horizon	Depth (cm.)	Gravel % (v/v)	Particle size distribution %							Modified texture class	CaCO3 g/kg	Gypsum g/kg	OM g/kg
					Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay				
Wadi	31	C1	0-20	15	10.4	21.3	9.3	11.8	5.9	19.6	21.7	GSCL	229.0	8.3	9.50
		C2	20-50	40	29.0	11.2	24.6	6.8	1.9	12.7	13.8	VGSL	325.6	12.6	7.60
		C3	50-80	35	19.3	28.5	2.2	11.1	6.7	15.5	16.8	VGCoSL	198.5	4.1	1.90
		C4	80-150	45	11.9	30.9	18.9	6.1	2.1	15.7	14.4	VGCoSL	319.3	16.3	0.80
	2	C1	0-20	25	0.2	4.0	17.1	36.3	12.5	13.3	16.5	GFSL	378.0	9.2	4.70
		C2	20-60	30	0.2	7.2	36.8	25.3	9.7	10.5	10.3	GSL	225.1	7.3	3.40
		C3	60-90	35	0.3	2.0	5.5	63.5	7.1	10.2	11.4	GFSL	341.0	6.4	0.90
		C4	90-150	25	0.1	1.3	7.3	30.7	18.3	18.9	23.4	GSCL	29.2	5.2	0.80
	25	A	0-30	30	11.3	13.6	44.3	13.8	4.9	6.5	5.6	GS	339.0	31.1	2.90
		C1	30-60	35	20.0	29.9	20.5	10.2	2.7	8.8	7.9	VGLCoS	376.4	21.7	1.90
		C2	60-90	35	8.8	25.6	19.9	23.1	4.9	9.4	8.3	VGLCoS	382.0	17.3	1.60
		C3	90-150	25	9.5	37.1	34.9	7.5	0.7	4.9	5.4	GCoS	377.5	27.3	1.10
Deltaic plain	27	ABk	0-30	30	12.3	18.9	27.1	14.0	6.3	10.1	11.3	GCoSL	453.8	26.7	1.80
		Bk	30-70	25	14.8	20.3	19.4	15.5	7.1	12.7	10.2	GCoSL	598.0	7.7	1.20
		C	70-150	40	15.6	23.3	16.5	16.9	9.3	8.6	9.8	VGLCoS	525.3	43.6	1.20
	32	ABk	0-25	15	8.1	16.4	24.6	16.5	7.1	11.9	15.4	GSL	391.8	10.6	2.60
		Bk	25-65	25	6.5	12.3	31.7	19.3	6.9	10.5	12.8	GSL	383.7	55.2	1.70
		C	65-150	10	3.6	11.5	38.1	18.6	8.6	9.8	9.8	GLS	482.0	56.0	0.80
	33	A	0-25	5	6.1	12.4	24.9	12.5	6.1	15.3	22.7	SGSCL	282.0	12.0	1.50
		Bk	25-60	10	5.6	10.3	24.1	17.3	7.8	19.4	15.5	SGSL	404.0	41.5	0.60
		C1	60-90	10	3.7	11.4	40.4	16.6	8.9	9.6	9.4	SGLS	387.0	15.2	0.40
		C2	90-150	10	3.7	11.4	24.4	16.6	8.9	18.9	16.1	SGSL	396.9	18.0	0.20
	34	A	0-20	5	10.1	16.4	20.4	16.5	5.7	14.5	16.4	SGSCL	383.0	22.3	0.90
		Bk1	20-65	10	10.1	13.5	34.9	12.7	7.1	10.5	11.2	SGSL	395.0	15.2	0.50
		Bk2	65-85	10	11.6	13.3	31.3	15.6	10.2	8.6	9.4	SGLS	371.8	28.9	0.50
		C	85-150	15	3.6	11.5	36.0	17.6	8.1	12.7	10.5	GSL	195.0	9.9	0.40
	35	A	0-15	5	11.1	15.9	34.9	15.5	4.6	8.9	9.1	SGLCoS	203.1	12.0	1.50
		Bk1	15-45	5	13.0	20.3	11.9	16.8	6.1	17.4	14.5	SGCoSL	285.0	14.7	0.90
		Bk2	45-100	10	15.2	19.6	8.1	19.6	9.2	11.5	16.8	SGCoSL	214.1	8.3	0.60
		C	100-150	5.0	4.6	11.5	37.4	19.7	8.8	9.6	8.4	SGLS	325.3	16.5	0.60

A, B, C and R = master horizons, k = accumulation of calcium carbonates, EG = extremely gravelly,
VG=very gravelly ,G=gravelly, SG= slightly gravelly, LCoS=loamy coarse sand, LS=loamy sand, ,
CoSL= coarse sandy loam , SL=sandy loam , SCL= sandy clay loam

Table 6 Physical properties of the soils in the in the physiographic units of basement complex parent rocks.

Physiographic unit	Profile No.	Horizon	Depth (cm.)	Gravel % (v/v)	Particle size distribution %							Modified texture class	$CaCO_3$ g/kg	Gypsum g/kg	OM g/kg
					Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay				
Piedmonts	11	C1	0-20	60	17.5	27.7	24.5	12.1	3.1	7.1	8.1	EGLCoS	57.0	6.5	0.70
		C2	20-40	65	13.1	21.4	21.1	20.8	8.2	6.2	9.2	EGLCoS	61.0	10.4	1.30
		2R	40-	Lithic contact of basement complex parent rocks											
	36	C	0-35	95	Not sampled										
		2R	35-	Lithic contact of basement complex parent rocks											
Alluvial Terraces	20	ABk	0-20	15	16.7	12.4	21.5	18.6	5.3	14.1	11.4	GCoSL	212.0	8.2	1.10
		Bk	20-40	40	12.6	11.5	19.4	22.7	7.5	12.5	13.8	VGSL	181.0	27.5	2.30
		Bky1	40-70	35	14.5	13.8	16.7	16.4	6.5	21.6	10.5	VGCoSL	146.0	67.3	1.20
		Bky2	70-150	40	15.9	14.6	18.4	12.3	7.8	20.6	10.8	VGCoSL	249.0	51.5	1.70
	22	ABk	0-20	25	15.6	20.8	21.6	12.3	6.7	11.6	11.4	GCoSL	284.0	17.6	1.30
		Bky	20-60	35	8.6	13.8	21.7	19.4	9.2	16.6	10.7	VGSL	218.0	64.4	1.80
		Bk	60-150	40	3.5	7.3	20.5	38.7	6.8	13.3	9.9	VGSL	327.0	42.8	0.40
	23	ABky	0-30	20	6.6	12.7	20.0	30.9	4.0	10.3	15.4	GSL	312.0	79.7	2.70
		Bky1	30-60	40	19.7	21.5	14.7	21.4	1.0	11.5	10.2	VGCoSL	256.0	161.9	2.30
		Bky2	60-150	35	20.5	15.5	23.4	17.9	0.4	10.2	12.1	VGCoSL	203.0	192.0	1.10
	24	ABk	0-20	25	13.1	16.5	21.4	16.5	7.7	13.5	11.3	GCoSL	362.0	25.6	1.80
		Bky	20-50	40	19.0	15.3	15.5	10.0	5.8	17.6	16.8	VGCoSL	327.0	66.8	0.70
		Bk	50-150	40	22.9	18.6	14.6	9.6	6.4	13.3	14.7	VGCoSL	379.0	6.7	3.10
	16	ABk	0-20	20	8.5	11.6	41.7	14.9	5.2	9.4	8.7	GLS	353.0	16.5	1.20
		Bk1	20-70	15	16.7	13.5	15.8	15.2	6.5	19.6	12.7	GCoSL	146.0	23.3	2.20
		Bk2	70-150	15	17.9	14.3	16.5	10.4	6.5	19.6	14.8	GCoSL	137.0	18.0	1.20

A, B, C and R = master horizons, k = accumulation of calcium carbonates, EG = extremely gravelly VG=very gravelly , G=gravelly, LCoS=loamy coarse sand, LS=loamy sand, CoSL= coarse sandy loam , SL=sandy loam.

Table 6 cont.

Physiographic unit	Profile No.	Horizon	Depth (cm.)	Gravel % (v/v)	Particle size distribution % Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Modified texture class	CaCO3 g/kg	Gypsum g/kg	OM g/kg
Wadi	10	A	0-25	35	14.1	23.9	27.5	12.9	3.3	8.7	9.6	VGLCoS	99.5	17.9	4.30
		C1	25-100	45	11.2	20.0	33.8	16.7	0.5	8.9	8.8	VGLS	89.3	15.7	3.70
		C2	25-150	40	10.3	25.0	30.2	15.7	1.2	8.5	9.1	VGLCoS	78.4	14.7	0.90
	8	C1	0-25	35	23.7	18.9	22.9	10.7	3.0	9.9	10.8	VGCoSL	100.0	11.0	12.30
		C2	25-60	50	20.9	26.8	20.4	10.2	3.4	9.4	8.9	VGLCoS	94.0	11.0	7.60
		C3	60-150	35	10.1	22.6	32.3	11.9	2.5	10.2	10.4	VGCoSL	86.0	8.9	1.50
	9	C1	0-20	25	21.7	25.0	20.3	9.6	6.5	7.6	9.3	GLCoS	86.0	2.0	2.60
		C2	20-50	40	23.8	24.3	23.1	8.0	2.9	7.9	10.1	VGLCoS	77.0	6.7	1.80
		C3	50-90	45	13.4	32.5	21.7	6.2	1.8	10.3	14.2	VGCoSL	100.6	5.6	1.20
		C4	90-150	50	42.7	23.4	10.3	2.7	0.7	10.1	10.2	VGCoSL	99.1	18.1	0.80
	15	C1	0-25	10	8.9	9.5	27.6	23.7	7.5	9.9	12.9	SGSL	106.0	15.7	5.20
		C2	25-75	15	1.5	3.4	26.9	30.8	11.6	10.1	15.6	GSL	93.0	14.3	4.60
		C3	75-150	10	0.3	0.4	2.5	32.4	19.5	23.6	21.4	SGSCL	88.9	34.9	20.80
	37	C1	0-15	10	12.9	7.1	27.9	20.7	8.4	10.1	12.9	SGSL	76.0	11.0	6.00
		C2	15-70	15	2.4	4.4	22.9	32.8	10.6	11.3	15.6	SGSL	77.9	9.0	3.50
		C3	70-100	10	1.5	1.3	8.9	35.5	20.5	13.5	18.8	SGFSL	85.0	8.0	4.70
		C4	100-15(	5	1.9	3.3	1.8	30.5	19.2	20.6	22.7	SGSCL	79.0	18.0	3.50
	38	C1	0-25	5	10.1	6.2	32.5	20.7	8.4	11.3	10.8	SGSL	89.9	16.0	4.50
		C2	25-65	10	3.2	3.6	27.3	32.8	10.6	10.7	11.8	SGFSL	82.0	5.0	5.60
		C3	65-150	10	1.2	2.3	3.3	33.5	19.5	19.9	20.3	SGSCL	69.0	7.0	4.80
Deltaic plain	7	A	0-10	20	10.4	13.0	30.6	24.8	4.8	6.1	10.4	GLS	129.0	12.0	0.60
		C1	10-30	25	11.9	12.2	31.1	15.7	4.5	12.4	12.2	GSL	86.0	17.0	0.50
		C2	30-50	15	15.6	29.2	16.4	11.3	2.6	14.8	10.1	GCoSL	60.0	16.0	0.80
		C3	50-150	30	25.2	25.5	24.9	7.2	1.4	12.5	15.8	GCoSL	51.0	4.0	4.40
	17	A	0-20	10	0.6	0.9	35.5	26.6	8.1	13.8	14.5	SGSL	302.0	13.5	6.50
		C1	20-50	15	9.7	14.6	31.7	9.9	6.3	12.4	15.3	GSL	103.0	16.2	1.20
		C1	50-80	15	14.2	32.9	20.1	6.7	2.5	13.2	10.4	GCoSL	83.0	16.1	1.80
		C2	80-150	10	13.2	33.6	19.3	7.6	2.7	12.1	11.5	GCoSL	94.0	21.0	0.64
	19	A	0-20	15	8.7	10.4	37.7	12.3	4.5	11.5	14.9	GSL	301.0	23.2	3.90
		C1	20-60	15	28.6	27.4	15.2	8.5	2.7	10.2	7.4	GLCoS	112.0	16.9	3.50
		C2	60-150	20	30.5	29.3	11.8	6.2	1.9	10.1	10.2	GCoSL	68.0	12.5	1.50

A and C = master horizons, VG=very gravelly, G=gravelly, SG=slightly gravelly, LCoS=loamy coarse sand, LS=loamy sand , CoSL= coarse sandy loam, SL=sandy loam, FSL= fine sandy loam, SCL=sandy clay loam

Table 7 Physical properties of the soils in physiographic units of mixed parent materials.

Physiographic unit	Profile No.	Horizon	Depth (cm.)	Gravel % (v/v)	Particle size distribution %							Modified texture class	CaCO3 g/kg	Gypsum g/kg	OM g/kg
					Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay				
Marine sediments	12	ABkz	0-20	>5	5.5	8.0	42.9	27.0	5.2	5.3	6.2	LS	390.8	47.7	6.6
		Bkz	20-35	>5	4.8	8.4	31.1	38.0	2.4	8.1	7.2	LS	396.0	18.5	8.7
		Bgkz	35-55	>5	1.5	1.9	31.8	51.1	1.4	5.2	7.1	LFS	439.0	34.2	11.2
	18	ABkz	0-25	>5	27.5	11.7	22.6	12.8	1.7	12.2	11.5	CoSL	354.8	45.5	4.8
		Bgkz	25-90	>5	5.8	8.6	21.9	44.7	2.9	8.7	7.4	LS	380.9	22.2	6.0
	39	Az	0-15	>5	1.5	4.7	23.8	30.2	21.8	9.4	8.6	LS	379.0	36.0	9.6
		Bkz	15-55	>5	0.9	5.2	30.9	20.7	25.4	7.8	9.1	LS	405.0	22.2	7.4
		Cgz	55-90	>5	2.7	6.1	17.3	19.7	37.5	8.9	7.8	LS	505.0	28.0	6.5
	40	ABkz	0-15	>5	4.7	3.8	20.1	25.6	29.0	9.2	7.6	LS	405.0	12.2	8.6
		Bkz	15-45	>5	3.9	2.9	19.3	30.5	26.2	8.7	8.5	LS	607.3	12.6	8.5
		Bkgz	45-70	>5	2.1	5.2	9.4	29.9	35.8	7.8	9.8	LFS	359.9	48.8	5.8
	41	Az	0-15	>5	6.1	8.2	39.6	19.5	6.7	10.2	9.7	LS	171.0	36.0	9.8
		Bkz	15-55	>5	5.8	9.1	32.6	26.7	7.4	8.9	9.5	LS	381.6	19.0	7.6
		Cgz	55-65	>5	3.7	3.2	40.3	24.8	4.1	11.4	12.5	SL	374.0	27.0	7.8
	21	ABkz	0-25	>5	13.7	14.8	20.8	23.0	9.9	9.3	8.5	LCoS	293.0	20.3	7.1
		Bgkz	25-50	>5	15.2	11.7	14.5	18.6	20.7	9.5	9.8	LCoS	189.0	46.8	8.2
	13	AByz	0-35	>5	12.6	9.7	10.4	11.7	7.7	14.3	33.6	SCL	189.0	79.8	6.5
		Byz	35-50	>5	3.8	6.6	9.8	15.7	9.6	20.2	34.3	SCL	224.0	73.0	2.8
		Cg	50-70	>5	3.2	7.4	8.5	18.7	14.8	19.8	27.6	SCL	241.0	22.9	4.6

A B C = master horizons, z = soluble salts accumulation, K = calcium carbonates accumulation, y = gypsum accumulation, g = redoxmorphic features, LCoS=loamy coarse sand, LS=loamy sand, LFS= loamy fine sand, SL =sandy loam,
SL =sandy loam, SCL=sandy clay loam

Table 8 Chemical properties of the soils in the physiographic units of limestone parent rocks

Physiographic unit	Profile No.	Horizon	Depth (cm.)	pH in soil paste	EC (dS/m) in soil saturated extract	EC (dS/m) in soil extract 1:1	Soluble ions in saturated extract ($mmol_c$/L)						
							Cations				Anions		
							Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	$HCO3^{-}$	$SO4^{--}$
Piedmonts	26	A	0-10	7.54	10.9	3.8	40.5	20.5	58.7	1.1	41	2.2	77.6
		ABk	10-45	7.58	12.2	4.5	48.7	18.3	69.1	1.3	51	1.6	84.8
		2R	45-	Lithic contact of limestone parent rocks									
Bajada	3	ABk	0-20	7.6	13.6	5.6	60.9	28.8	58.3	0.9	100	1.6	47.8
		Bk1	20-50	7.7	4.4	1.9	21.7	17.5	5.4	0.4	6.8	1.8	36.4
		Bk2	50-90	7.6	14.2	5.4	78.2	35.8	80	0.5	155	1.8	37.6
		Bk3	90-150	7.5	20.4	8.1	69.9	29.2	151	0.1	229	1.2	20.0
	6	ABk	0-20	7.8	6.11	2.46	15.8	10.8	34.9	1.2	18	2.2	43.0
		Bk1	20-50	7.9	6.5	1.38	14.4	11.2	41.1	0.7	20	1.8	45.6
		Bk2	50-90	7.7	14.8	3.14	46.9	31.9	80.2	1.3	66	1.8	93.0
		C	90-150	7.7	20.5	6.14	74.3	57.7	103	0.9	113	2	121.1
	28	ABk	0-30	7.8	10.2	3.8	40.6	29.7	38	1.1	59	1.2	48.9
		Bk1	30-70	7.5	13.7	4.9	70.4	40.6	40	0.9	71	1.4	80.0
		Bk2	70-100	7.8	10.4	4.1	55.7	25.8	30	0.8	49	1.2	61.8
		C	100-150	7.9	15.9	6.9	65.3	55.6	45	1.2	89	1.2	77.3
	29	ABk	0-25	7.7	7.8	3.4	40.2	35.8	26.2	0.7	49	2	52.0
		Bk1	25-65	7.8	7.4	2.8	24.5	20.1	30.5	0.8	45	2.4	28.9
		Bk2	65-90	7.9	6.2	2.1	20.6	18.3	25.4	0.8	39	2.2	24.1
		Bk3	90-150	7.8	6.7	2	26.4	16.6	24.7	0.6	33	1.8	33.8
	30	Abk	0-15	7.5	8.6	4.1	20.5	12.8	50.6	0.5	55.7	2	26.7
		Bk1	15-45	7.6	7.26	3.5	19.7	10.9	47.5	0.4	55	2.2	21.5
		Bk2	45-90	7.7	9.2	3.9	24.9	13.9	56.1	0.9	61	1.8	33.3
		C4	90-150	7.5	6.9	2.8	23.7	14.8	33.9	1.1	42	1.6	29.8
Wadi	1	C1	0-10	7.58	3.9	1.2	20.2	5.4	13.9	0.8	16	2.6	21.3
		C2	10-40	7.64	3.8	1.3	19.9	3.4	14.5	0.6	23	2.4	12.7
		C3	40-70	8.15	1.2	0.8	2.5	3.1	6.7	0.3	4.9	2.4	5.3
		C4	70-100	8.1	1.9	0.9	8.2	5.6	6.7	0.3	4.9	1.2	14.7
		C5	100-150	7.72	3.2	1.2	16.8	8.4	7.5	0.3	4.9	1.2	26.9
	4	C1	0-20	7.51	3.32	1.3	15.3	7.96	9.5	1	12	2.8	19.2
		C2	20-50	7.84	1.22	0.5	4.72	2.8	4.1	0.7	9.1	2.2	1.0
		C3	50-90	7.73	1.3	0.6	4.72	2.7	4.8	0.8	5.1	2	5.9
		C4	90-150	7.96	1.45	0.6	5.5	3.5	5.6	0.3	6.2	1.8	6.9
	5	C1	0-20	7.46	7.4	2.2	30.9	4.9	40.6	1.5	62	1.6	13.9
		C2	20-50	7.68	13.85	4.9	55.4	27.3	75.6	0.9	135	1.6	23.1
		C3	50-80	7.82	15.54	5.9	67.8	36.5	92.1	0.8	142	1.4	53.5
		C4	80-150	8.07	12.58	4.8	37.7	10.1	114	0.5	92	2	69.0

Table 8 cont.

Physiographic unit	Profile No.	Horizon	Depth (cm.)	pH in soil paste	EC (dS/m) in soil saturated extract	EC (dS/m) in soil extract 1:1	Soluble ions in saturated extract ($mmol_c$/L)						
							Cations				Anions		
							Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	SO_4^{--}
Wadi	31	C1	0-20	7.8	6.40	1.70	18.5	14.8	33.4	0.4	45.8	1.4	19.9
		C2	20-50	7.6	5.20	1.30	14.8	12.9	25.8	0.8	36.7	1.6	16.0
		C3	50-80	7.9	3.80	1.10	10.6	9.8	17.7	0.6	25.6	1.2	11.9
		C4	80-150	7.8	5.10	2.10	15.7	12.2	26.4	0.4	37.1	1.8	15.8
	2	C1	0-20	7.7	1.80	0.50	9.9	3.9	5.8	1.3	5.9	2.8	12.2
		C2	20-60	8.2	0.72	0.30	3.6	1.1	2.1	0.5	1.9	3.6	1.8
		C3	60-90	8.3	0.50	0.30	2.4	0.9	1.5	0.2	1.5	2.2	1.3
		C4	90-150	8.1	0.58	0.20	2.9	0.6	2.3	0.1	2.9	2.2	0.8
	25	A	0-30	7.5	19.00	5.99	108.5	36.9	69.5	1.2	150.0	1.8	64.3
		C1	30-60	7.7	8.80	3.14	37.1	23.6	37.3	1.1	45.0	1.8	52.3
		C2	60-90	7.2	9.10	4.01	38.2	23.5	45.8	1.4	42.0	2.0	64.8
		C3	90-150	7.8	8.94	2.35	39.8	41.4	20.5	0.7	10.0	2.6	89.8
Deltaic plain	27	ABk	0-30	7.5	38.20	10.74	74.8	51.6	380.5	0.9	315.0	2.2	190.6
		Bk	30-70	7.9	12.75	4.83	34.9	26.3	103.2	0.5	72.0	2.0	90.9
		C	70-150	7.9	19.70	5.87	52.7	61.4	174.6	1.1	115.0	2.2	172.6
	32	ABk	0-25	7.3	28.80	11.26	54.9	29.8	290.8	0.6	310.6	2.2	63.3
		Bk	25-65	7.7	14.50	5.63	45.8	23.7	96.2	0.4	120.5	2.2	43.4
		C	65-150	7.7	18.70	6.52	57.7	30.7	178.6	0.8	210.0	1.8	56.0
	33	A	0-25	7.8	16.70	5.80	44.8	38.6	89.7	0.7	129.8	2.2	41.8
		Bk	25-60	7.9	7.20	3.10	16.6	10.4	47.7	0.4	56.5	2.4	16.2
		C1	60-90	8.1	8.10	3,6	17.7	11.5	55.3	0.5	64.9	2.8	17.3
		C2	90-150	7.8	5.80	2.10	10.8	7.9	39.7	0.6	30.6	2.2	26.2
	34	A	0-20	7.9	14.20	4.90	32.6	26.7	119.5	1.0	120.8	2.4	56.6
		Bk1	20-65	8.1	8.50	3.10	10.2	7.4	70.4	0.8	73.7	2.6	12.5
		Bk2	65-85	7.9	10.30	3.80	20.9	11.5	80.6	1.1	89.6	2.8	21.7
		C	85-150	7.9	9.60	3.50	14.2	8.7	75.8	0.8	79.9	1.8	17.8
	35	A	0-15	7.5	9.20	3.80	22.8	6.8	74.7	0.7	81.7	2.2	21.1
		Bk1	15-45	7.3	7.50	2.90	19.5	7.4	50.6	0.6	60.6	1.8	15.7
		Bk2	45-100	7.2	8.90	3.10	21.2	9.8	63.8	0.9	70.7	1.6	23.4
		C	100-15(	8	7.60	2.90	18.7	10.9	50.2	0.8	56.8	2.4	21.4

Table 9 Chemical properties of the soils in Physiographic units of basement complex parent rocks

Physiographic unit	Profile No.	Horizon	Depth (cm.)	pH in soil paste	EC (dS/m) in soil saturated extract	EC (dS/m) in soil extract 1:1	Soluble ions in saturated extract (mmol$_c$/L)						
							Cations				Anions		
							Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	$HCO3^{-}$	$SO4^{--}$
Piedmonts	11	C1	0-20	8.3	0.8	0.3	1.2	0.7	5.8	0.3	2.0	2.2	9.36
		C2	20-40	7.8	1.2	0.34	2.1	0.9	7.9	0.4	2.0	1.8	8.11
		2R	40--	Lithic contact of basement complex parent rocks									
	36	C	0-35	Not sampled									
		2R	35--	Lithic contact of basement complex parent rocks									
Alluvial terraces	20	ABk	0-20	7.7	32.8	10.7	99.8	79.1	308.0	7.9	265.0	1.2	228.6
		Bk	20-40	7.6	74.3	18.4	121	105	960.8	15.5	845.0	2.2	354.9
		Bky1	40-70	7.7	55.3	12.5	85	88.2	600.4	14.0	490.0	1.6	296.1
		Bky2	70-150	7.6	32.8	7.9	82	86.5	310.5	15.8	300.0	1.8	193
	22	ABk	0-20	7.7	11.2	2.8	37.2	28.3	72.1	1.1	50.0	1.0	87.7
		Bky	20-60	7.8	9.2	1.8	32.5	27.3	49.7	1.6	36.0	1.2	73.9
		Bk	60-150	7.7	66.2	10.3	95.5	121	780.8	5.5	60.0	1.4	940.9
	23	ABky	0-30	7.4	63	23.2	262	209	464	12.6	525.0	2.8	419.2
		Bky1	30-60	7.5	64	22.2	228	111	498	12.4	625.0	3	220.5
		Bky2	60-150	7.5	75	26	223	241	636	9.4	675.0	1	433.3
	24	ABk	0-20	7.7	59	20	161	151	550.7	0.9	622	3	238.6
		Bky	20-50	7.2	43.6	16.8	150	89.8	388.8	1.4	200	2.2	427.7
		Bk	50-150	7.5	60.5	20.3	183	158	529.7	0.7	709	2.2	159.6
	16	ABk	0-20	7.9	12.7	8.1	32.5	27.8	101.5	4.3	110.0	1.4	54.8
		Bk1	20-70	7.9	9.5	2.5	15.5	23.8	65.7	1.8	60.0	1.2	45.7
		Bk2	70-150	8.0	12.3	3.5	14.2	18.2	110.0	4.3	80.0	1.6	65.1

A B C = master horizons, k = calcium carbonates accumulation

Table 9 cont.

Physiographic unit	Profile No.	Horizon	Depth (cm.)	pH in soil paste	EC (dS/m) in soil saturated extract	EC (dS/m) in soil extract 1:1	Soluble ions in saturated extract ($mmol_c$/L)						
							Cations				Anions		
							Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	$HCO3^{-}$	$SO4^{--}$
Wadi	10	A	0-25	7.5	1.75	0.7	8.2	4.3	5.1	0.7	2.5	2.0	13.8
		C1	25-100	7.7	1.78	0.3	5.5	5.0	6.2	0.8	1.5	2.2	13.8
		C2	100-150	7.6	1.9	0.4	5.4	4.9	5.9	0.8	1.4	2.2	13.4
	8	C1	0-25	7.6	2.83	0.15	14.5	5.4	11.2	0.9	5.0	1.4	25.6
		C2	25-60	7.8	2.61	0.4	13.5	3.3	11.2	0.4	7.0	1.2	20.2
		C3	60-150	8.5	0.75	0.1	3.1	1.9	2.7	0.3	1.0	2.0	5.0
	9	C1	0-20	7.7	1.95	0.15	7.3	5.4	7.1	0.8	2.0	2.0	16.6
		C2	20-50	7.9	1.32	0.22	4.4	3.3	5.4	0.7	1.5	1.8	10.5
		C3	50-90	8.2	0.44	0.2	1.7	0.9	1.7	0.3	0.5	2.2	1.9
		C4	90-150	8.4	0.72	0.22	2.7	1.8	2.4	0.4	1.0	2.2	4.1
	15	C1	0-25	7.4	48.1	2.8	70.5	114.8	450.6	6.8	455.0	1.8	185.9
		C2	25-75	7.4	57.7	10.2	72.8	99.5	671.5	18.2	610.0	1.6	250.4
		C3	75-150	7.8	28.5	6.2	36.3	142.5	281.4	4.4	111.5	1.2	351.9
	37	C1	0-15	7.5	4.7	1.8	19.7	11.9	16.6	0.3	28.6	1.4	18.5
		C2	15-70	7.4	7.5	2.7	36.7	19.3	20.1	0.4	33.3	1.2	42.0
		C3	70-100	7.7	5.8	1.6	22.7	16.9	19.8	0.3	29.6	1.8	28.3
		C4	100-150	7.5	6.9	2.3	25.9	16.5	26.9	0.6	34.1	2.0	33.8
	38	C1	0-25	7.8	7.1	2.7	28.1	20.6	21.8	0.2	38.8	1.6	30.3
		C2	25-65	7.6	5.7	1.9	23.1	19.4	15.5	0.7	29.5	1.8	27.4
		C3	65-150	7.8	4.9	1.1	19.5	15.7	14.2	0.8	20.8	1.2	28.2
Deltaic plain	7	A	0-10	7.8	5.9	2.2	15.4	9.1	34.2	1.4	18.5	1.8	39.8
		C1	10-30	7.55	11.45	2.42	34.1	30.7	70.4	1.8	51	2.2	83.8
		C2	30-50	7.91	6.41	1.86	15.2	12.1	40.2	1	35	1.4	32.1
		C3	50-150	7.45	12.47	6.6	37.3	33.6	76.4	0.8	70	2.2	75.9
	17	A	0-20	7.6	24.3	7.1	79.5	70.65	211.6	7.2	230	1.6	137.35
		C1	20-50	7.55	32.5	9.3	134	160.7	255.4	12.6	305	1	256.7
		C2	50-80	7.71	20.2	3.6	77.8	80.4	176.7	1.2	165	1.2	169.9
		C3	80-150	7.6	18.5	3.1	50.2	71.6	150.5	2.6	170	1.8	103.1
	19	A	0-20	7.46	72.5	18.2	131.6	301.9	582.8	0.7	550	1.4	465.7
		C1	20-60	7.46	45.81	11.1	155.1	116.6	378.2	0.5	360	1.8	288.7
		C2	60-150	7.55	50.93	12.4	162.6	110.6	427.8	0.6	340	1.4	360.2

Table 10 Chemical properties of the soils in physiographic units of mixed parent materials.

Physiographic unit	Profile No.	Horizon	Depth (cm.)	pH in soil paste	EC (dS/m) in soil saturated extract	EC (dS/m) in soil extract 1:1	Soluble ions in saturated extract ($mmol_c$ /L)						
							Cations				Anions		
							Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	$HCO3^{-}$	$SO4^{--}$
Marine sediments	12	ABkz	0-20	7.8	91.80	38.50	80.5	289.5	1220.0	25.5	755.0	1.4	859.1
		Bkz	20-35	7.9	80.30	31.50	99.5	178.5	1007.1	17.1	500.0	2.4	799.8
		Bgkz	35-55	7.9	78.40	30.90	82.5	251.2	988.5	21.4	700.0	2.2	641.4
	18	ABkz	0-25	7.2	129.00	48.50	209.2	237.8	1190.7	24.9	1480.7	2.4	179.5
		Bgkz	25-90	7.5	80.90	32.40	98.5	180.5	998.1	19.1	805.0	2.4	488.8
	39	Az	0-15	7.4	101.80	39.80	287.6	210.2	989.4	18.5	1201.2	2.8	301.7
		Bkz	15-55	7.2	88.40	30.70	202.8	175.6	790.8	11.8	970.5	2.0	208.5
		Cgz	55-90	7.8	79.30	30.50	167.5	125.3	697.2	8.9	804.3	2.4	192.2
	40	ABkz	0-15	7.2	95.70	38.70	189.4	167.6	830.8	19.1	1010.8	1.8	194.3
		Bkz	15-45	7.8	120.80	40.30	213.2	230.8	1200.7	25.4	1405.7	2.2	262.2
		Bkgz	45-70	7.1	87.20	32.60	174.8	131.3	863.5	20.1	980.6	2.6	206.5
	41	Az	0-15	7.3	128.70	40.70	290.8	197.5	1120.6	71.7	1200.8	2.0	477.8
		Bkz	15-55	7.4	112.45	35.90	270.1	187.4	1200.4	79.3	1180.8	1.8	554.6
		Cgz	55-65	7.2	60.50	20.80	192.6	150.2	580.4	44.3	600.9	2.2	364.4
	21	ABkz	0-25	6.5	158.70	63.50	381.8	105.7	1101.2	16.8	1246.8	1.1	357.6
		Bgkz	25-50	6.4	154.45	60.10	360.3	99.5	1490.1	30.5	1408.6	2.8	569.0
	13	AByz	0-35	7.5	81.80	30.90	86.6	296.3	793.5	25.7	801.4	2.4	398.2
		Byz	35-50	7.7	85.40	32.70	94.6	360.5	1009.5	30.5	1198.2	2.6	294.3
		Cg	50-70	7.7	33.60	10.50	37.4	122.4	323.7	18.9	390.3	2.8	109.3

Table 11 Cation exchange capacity and exchangeable cations of the soils in the physiographic units of limestone parent rock

Physiographic unit	Profile No.	Horizon	Depth (cm.)	C.E.C (cmol$_c$/kg soil)	Exchangeable cations (cmol$_c$/ kg soil)				ESP
					Ca^{++}	Mg^{++}	K^{+}	Na^{+}	
Piedmonts	26	A	0-10	3.9	2.15	1.13	0.12	0.45	11.6
		ABk	10-45	3.2	2.40	0.25	0.12	0.47	14.5
Bajada	3	ABk	0-20	13.8	6.20	5.99	0.18	1.43	10.4
		Bk1	20-50	7.4	3.30	3.15	0.40	0.56	7.5
		Bk2	50-90	8.8	4.20	3.23	0.25	1.10	12.6
		Bk3	90-150	12.3	4.80	5.58	0.12	1.80	14.6
	6	ABk	0-25	7.9	5.10	1.82	0.08	0.90	11.4
		Bk1	25-55	6.5	4.30	0.17	1.10	0.88	13.6
		Bk2	55-90	7.4	4.90	1.17	0.19	1.10	14.9
		C	90-150	9.8	5.20	2.95	0.20	1.45	14.8
	28	ABk	0-30	12.7	5.65	5.43	0.38	1.24	9.8
		Bk1	30-70	7.5	4.08	2.56	0.24	0.62	8.2
		Bk2	70-100	9.6	3.96	4.68	0.34	0.62	6.5
		C	100-15(	8.4	5.10	2.10	0.50	0.70	8.4
	29	ABk	0-25	7.9	2.46	4.81	0.25	0.38	4.8
		Bk1	25-65	7.8	3.62	3.06	0.52	0.60	7.6
		Bk2	65-90	8.4	2.28	5.33	0.22	0.57	6.7
		Bk3	90-150	12.6	4.35	6.80	0.54	0.91	7.2
	30	ABk	0-15	7.8	3.86	1.97	0.84	1.13	14.5
		Bk1	15-45	8.3	6.24	0.71	0.32	1.03	12.4
		Bk2	45-90	12.2	6.12	3.92	0.34	1.82	14.9
		C	90-150	6.8	5.46	0.29	0.42	0.63	9.2
Wadi	1	C1	0-10	4.5	3.12	1.02	0.08	0.23	5.3
		C2	10-40	4.9	2.14	1.68	0.84	0.23	4.7
		C3	40-70	7.0	4.67	1.85	0.13	0.31	4.4
		C4	70-100	6.1	3.58	2.24	0.09	0.21	3.4
		C5	100-15(	10.6	5.89	4.39	0.09	0.19	1.8
	4	C1	0-20	4.9	2.34	2.15	0.24	0.13	2.8
		C2	20-50	6.1	2.10	3.74	0.09	0.17	2.8
		C3	50-90	6.3	4.60	1.20	0.18	0.27	4.3
		C4	90-150	9.8	5.80	3.54	0.08	0.34	3.5
	5	C1	0-20	8.8	4.20	3.99	0.18	0.40	4.6
		C2	20-50	7.1	2.60	4.19	0.08	0.27	3.8
		C3	50-80	8.3	3.80	3.56	0.34	0.60	9.9
		C4	80-150	6.2	1.90	3.60	0.19	0.51	8.1

A, B, C and R = master horizons, k = accumulation of calcium carbonates CEC = Cation Exchange Capacity ESP = Exchangable Sodium Percentage

Table 11 cont.

Physiographic unit	Profile No.	Horizon	Depth (cm.)	C.E.C cmol$_c$ / kg soil	Exchangeable cations (cmol$_c$/ kg soil)				ESP
					Ca^{++}	Mg^{++}	K^{+}	Na^{+}	
Wadi	31	C1	0-20	12.7	8.54	2.69	0.24	1.23	9.7
		C2	20-50	7.5	5.84	0.83	0.18	0.65	8.7
		C3	50-80	9.6	6.30	2.37	0.32	0.61	6.4
		C4	80-150	8.4	5.10	2.29	0.32	0.69	8.2
	2	C1	0-20	8.6	5.48	2.34	0.43	0.33	3.8
		C2	20-60	5.4	2.34	1.98	0.87	0.16	3.0
		C3	60-90	5.2	3.12	1.83	0.09	0.20	3.8
		C4	90-150	10.9	6.34	3.73	0.12	0.70	6.4
	25	A	0-30	2.2	1.56	0.31	0.13	0.18	8.1
		C1	30-60	3.5	1.85	1.33	0.09	0.21	5.9
		C2	60-90	4.8	2.70	1.56	0.18	0.36	7.4
		C3	90-150	2.7	1.20	1.21	0.08	0.24	8.9
Deltaic plain	27	ABk	0-30	7.7	2.62	3.07	0.09	1.90	24.7
		Bk	30-70	7.0	3.25	1.18	1.10	1.45	20.8
		C	70-150	6.3	2.60	1.92	0.65	1.11	17.6
	32	ABk	0-25	7.1	2.22	2.25	1.02	1.61	22.7
		Bk	25-65	5.2	2.64	0.65	0.95	0.97	18.6
		C	65-150	4.5	1.15	1.89	0.26	1.20	26.7
	33	A	0-25	13.8	7.48	3.24	0.86	2.22	16.1
		Bk	25-60	7.6	3.55	2.38	0.52	1.15	15.2
		C1	60-90	5.7	2.74	1.37	0.64	0.95	16.7
		C2	90-150	7.9	3.70	2.28	0.72	1.20	15.2
	34	A	0-20	9.3	4.86	1.99	0.24	2.21	23.7
		Bk1	20-65	7.2	3.66	1.50	0.22	1.82	25.2
		Bk2	65-85	5.1	1.94	1.88	0.16	1.12	22.0
		C	85-150	6.4	4.54	0.04	0.28	1.54	24.1
	35	A	0-15	6.2	4.20	0.74	0.12	1.14	18.4
		Bk1	15-45	8.7	3.70	2.88	0.90	1.22	14.0
		Bk2	45-100	9.3	6.20	1.51	0.08	1.51	16.2
		C	100-150	4.2	1.7	1.25	0.7	0.55	13.0

A ,B and C= master horizons, z= soluble salts accumulation, k = calcium carbonates

Table 12 Cation exchange capacity and exchangeable cations of the soils in the physiographic of basement complex parent rocks.

Physiographic unit	Profile No.	Horizon	Depth (cm.)	C.E.C (cmol /kg soil)	Exchangeable cations ($cmol_c$ /kg soil)				ESP
					Ca^{++}	Mg^{++}	K^{+}	Na^{+}	
Piedmonts	11	C1	0-20	4.3	2.76	1.11	0.09	0.29	6.8
		C2	20-40	4.0	2.35	1.31	0.04	0.28	7.1
		2R	40--	Lithic contact					
	36	C	0-35	Not sampled					
		2R	35--	Lithic contact					
Alluvial Terraces	20	ABk	0-20	6.7	3.23	1.26	0.49	1.67	25.1
		Bk	20-40	7.0	1.35	2.52	0.82	2.29	32.8
		Bky1	40-70	5.5	2.65	1.10	0.04	1.66	30.5
		Bky2	70-150	4.8	1.98	1.19	0.34	1.25	26.3
	22	ABk	0-20	7.1	3.45	2.50	0.12	1.05	14.8
		Bky	20-60	7.3	4.87	1.62	0.06	0.79	10.8
		Bk	60-150	6.3	1.25	2.31	0.65	2.04	32.6
	23	ABky	0-30	9.9	3.12	2.65	1.12	2.98	30.2
		Bky1	30-60	6.4	1.65	1.90	0.54	2.26	35.6
		Bky2	60-150	6.7	1.67	1.91	0.62	2.54	37.6
	24	ABk	0-20	6.2	3.14	1.13	0.12	1.83	29.4
		Bky	20-50	8.6	4.93	1.87	0.08	1.68	19.6
		Bk	50-150	7.1	3.25	2.33	0.09	1.45	20.4
	16	ABk	0-20	4.2	2.44	0.69	0.10	0.95	22.8
		Bk1	20-70	6.3	2.52	2.55	0.12	1.11	17.6
		Bk2	70-150	7.2	3.81	1.86	0.07	1.46	20.3

A ,B, C and R= master horizons, k = accumulation of calcium carbonates, y = accumulation of gypsum. CEC = Cation Exchange Capacity

ESP = Exchangable Sodium Percentage

Table 12 cont.

Physiographic unit	Profile No.	Horizon	Depth (cm.)	C.E.C (cmol$_c$/ kg soil)	Exchangeable cations (cmol$_c$/ kg soil)				ESP
					Ca^{++}	Mg^{++}	K^+	Na^+	
Wadi	10	A	0-25	6.78	4.94	1.55	0.11	0.18	2.7
		C1	25-100	5.34	3.05	1.87	0.23	0.19	3.7
		C2	100-150	4.67	3.40	0.96	0.15	0.16	3.5
	8	C1	0-25	5.37	3.44	1.12	0.55	0.26	4.8
		C2	25-60	4.24	2.48	0.97	0.65	0.14	3.2
		C3	60-150	4.12	1.97	1.99	0.07	0.09	2.2
	9	C1	0-20	7.34	4.13	2.18	0.75	0.28	3.8
		C2	20-50	6.45	3.54	2.49	0.18	0.24	3.7
		C3	50-90	7.98	4.56	3.18	0.09	0.15	1.9
		C4	90-150	7.44	4.45	2.76	0.06	0.17	2.3
	15	C1	0-25	8.55	4.58	2.14	0.76	1.07	12.5
		C2	25-75	8.98	5.33	1.84	0.56	1.25	13.9
		C3	75-150	12.58	6.64	4.32	0.14	1.48	11.8
	37	C1	0-15	9.30	4.36	4.33	0.18	0.43	4.7
		C2	15-70	10.20	4.34	5.32	0.12	0.42	4.2
		C3	70-100	11.80	4.85	6.28	0.08	0.59	5.0
		C4	100-150	16.10	6.06	8.90	0.04	1.10	6.8
	38	C1	0-25	7.80	4.03	3.12	0.26	0.39	5.0
		C2	25-65	6.90	1.79	4.65	0.21	0.25	3.6
		C3	65-150	12.80	4.44	7.85	0.05	0.46	3.6
Deltaic plain	7	A	0-10	6.95	3.14	2.66	0.27	0.88	12.6
		C1	10-30	7.18	3.16	2.32	0.64	1.06	14.8
		C2	30-50	7.90	2.49	4.26	0.13	1.02	12.9
		C3	50-150	8.12	3.76	3.03	0.11	1.22	15.0
	17	A	0-20	6.58	3.29	0.90	0.70	1.69	25.8
		C1	20-50	7.98	3.55	2.54	0.06	1.83	22.9
		C1	50-80	5.35	2.44	1.65	0.09	1.17	21.9
		C2	80-150	5.84	3.11	1.34	0.14	1.25	21.4
	19	A	0-20	6.88	3.4	1.6	0.4	1.41	20.5
		C1	20-60	3.04	0.3	1.0	0.9	0.87	28.6
		C2	60-150	4.82	1.9	1.3	0.1	1.44	29.9

A,C = master horizons, CEC = Cation Exchange Capacity
ESP = Exchangable Sodium Percentage

Table 13 Cation exchange capacity and exchangeable cations of the soils in physiographic units of mixed parent materials

Physiographic unit	Profile No.	Horizon	Depth (cm.)	C.E.C ($cmol_c$ / kg soil)	Exchangeable cations ($cmol_c$ /kg				ESP
					Ca^{++}	Mg^{++}	K^+	Na^+	
Marine sediments	12	ABkz	0-20	2.9	0.15	1.02	0.28	1.49	50.7
		Bkz	20-35	3.1	0.08	1.24	0.19	1.61	51.5
		Bgkz	35-55	2.8	0.25	0.85	0.35	1.37	48.7
	18	ABkz	0-25	4.7	0.73	1.02	0.66	2.33	49.1
		Bgkz	25-90	1.1	0.39	0.22	0.08	0.45	39.8
	39	Az	0-15	4.8	0.50	2.02	0.12	2.13	44.7
		Bkz	15-55	5.3	0.67	2.10	0.38	2.15	40.6
		Cgz	55-90	3.9	0.86	1.25	0.17	1.62	41.6
	40	ABkz	0-15	3.2	0.65	0.45	0.54	1.54	48.5
		Bkz	15-45	4.1	0.25	0.89	0.82	2.16	52.4
		Bkgz	45-70	5.7	0.65	2.02	0.10	2.93	51.4
	41	Az	0-15	7.1	1.25	2.30	0.74	2.81	39.6
		Bkz	15-55	6.8	2.07	1.93	0.08	2.72	40.0
		Cgz	55-65	8.9	2.19	3.15	0.08	3.48	39.1
	21	ABkz	0-25	3.2	0.32	0.87	0.43	1.56	49.1
		Bgkz	25-50	3.9	0.69	0.75	0.19	2.29	58.5
	13	AByz	0-35	14.8	3.45	4.67	0.22	6.41	43.4
		Byz	35-50	13.0	2.60	3.55	0.54	6.26	48.3
		Cg	50-70	12.9	2.83	4.92	0.84	4.28	33.3

A, B ,C= master horizons, z= soluble salts accumulation, K = calcium carbonates accumulation, y= gypsum accumulation,g = redoxmorphic features,

4.3.1.1 *Aridisols.*

Arid from Latin "*aridus*" = dry. *Aridisols* are developed under an aridic moisture regime and a *hyperthermic* temperature regime. They include one or more of the diagnostic horizons as salic, gypsic and calcic. Aridisols of the study area include the following ten families:

i-*Gypsic Aquisalids, fine loamy, mixed, hyperthermic.*

These *Aquisalids* occur in the almost flat marine sediments of mixed parent materials. They are waterlogged, being permanently saturated with water in any layer within 100 cm of the soil surface with redoxmorphic features and underlain by ground water table at 70 cm. The soils have salic horizons (EC of 81.8 to 85.4 dS/m in the soil paste or 30.9 to 32.7 dSm^{-1} in 1:1 soil water extract). These salic horizons are associated with gypsic horizons, which have gypsum contents of 73.0 to 79.8 g/kg and 10 to 20 % by volume as secondary visible gypsum "Byz". The soil control section of the soil profile is dominated by sandy clay loams (profile 13)

ii-*Calcic Aquisalids, sandy, carbonatic, hyperthermic.*

These *Aquisalids* occur in the almost flat marine sediments of mixed parent materials, underlained by ground water table at the depth of 55 to 90 cm. The soils have salic horizons expressed as EC from 78.4 to 129.0 dS/m in the soil paste or 30.5 to 48.5 dS/m in 1:1 soil water extract. These salic horizons are associated with calcic horizons that have $CaCO_3$ contents of 334.8 to 607.3 g/kg and 10 to 20 % by volume as secondary visible lime "Bkz". As the control section is dominated by loamy sands, it was described as sandy. The mineralogical class is carbonatic as the soil layers include more than 40 % by weight $CaCO_3$ plus gypsum (400.3 to 619.9 g/kg) and the carbonates are more than 65 % of the sum of carbonates and gypsum (profiles 12, 18, 39, 40 and 41).

iii-*Calcic Aquisalids, sandy, mixed, hyperthermic.*

These *Aquisalids* occur in almost flat marine sediments of mixed parent materials. They are underlain by ground water table at a depth of 50 cm. from the surface. The soils have salic horizons expressed as EC of 154.4 to 158.7 dS/m in the soil paste extract or 35.9 to 40.7 dSm^{-1} in 1:1 soil water extract. These salic horizons are associated with calcic horizons that have $CaCO_3$ contents of 189.0 to 293.0 g/kg and 10 to 20 % by volume as secondary visible lime “Bkz". As the soil control section is dominated by loamy sand, the soil family was described as sandy (profile 21).

iv-*Typic Clacigypsids, loamy skeletal, mixed, hyperthermic.*

These *Clacigypcids* developed in the alluvial terraces that were derived from the basement complex parent rocks. The soils have gypsic horizon “By” including gypsum contents from 51.5 to 192 g/kg and 10 to 30 % by volume as secondary visible gypsum. Calcic horizons also developed in these soils separately “Bk” or associated with the gypsic horizon "Bky" including $CaCO_3$ contents of 146.0 to 379.0 g/kg and 5 to 15 % by volume identifiable lime. These *Clacigypsids* are "*Typic*", being representing the central concept of the great group. Since these soils have very gravelly sandy loams, they are *loamy skeletal* (Profiles 20, 22, 23 and 24).

v-*Sodic Haplocalcids, coarse loamy, carbonatic, hypothermic.*

These *Haplocalcids* occur in the deltaic plains that were derived from the limestone parent rocks. They have calcic horizons "ABk” and “Bk” including $CaCO_3$ contents of 371.8 to 598 g /kg and 5 to 10 % by volume as secondary visible lime. The soils are *Sodic* since they have in horizons within 100cm from the surface , Exchangeable Sodium Percent (ESP) values that range from 15.2 to 26.7 (i. e. exceeding than 15). Because the soil control section is dominated by gravelly sandy loams, they are coarse loamy. Also they are dominated by gravelly and slightly gravelly sandy loam; they were categorized as coarse loamy. The mineralogical class is carbonatic as the soil layers include more than 40 % by weight calcium carbonate plus gypsum (400.7 to 605.7 g/kg) and the carbonates are more than 65 % of the sum of carbonates and gypsum (profiles 27, 32, 33 and 34).

vi-*Sodic Haplocalcids, coarse loamy, mixed, hyperthermic.*

These *Haplocalcids* occur in the deltaic plains that were derived from the limestone parent rocks. The soils have calcic horizons "ABk" and "Bk" which have $CaCO_3$ contents of 203 to 325 g/kg and 5 to 10 % by volume as secondary visible lime. The soils are sodic since they have ESP values exceeding 15 (15 to 16.2). As the soil control section is dominated by slightly gravelly sandy loams, they are coarse loamy (profile 35).

vii-*Typic Haplocalcids, coarse loamy, mixed, hyperthermic.*

These *Haplocalcids* occurred in the alluvial terraces. The soils have calcic horizons "ABk" and "Bk" with $CaCO_3$ contents of 137 to 353 g./kg and 5 to 10 % by volume as secondary visible lime. Since the soil control section is dominated by gravelly coarse sandy loams, they are coarse loamy (profile 16).

viii-*Typic Haplocalcids, loamy skeletal, mixed, hyperthermic.*

These *Haplocalcids* occur in Bajada. The soils have calcic horizons "ABk" and "Bk" have $CaCO_3$ contents of 107 to 387 g./kg and 5 to 10 % by volume as secondary visible lime. Since the soil control section is dominated by very gravelly sandy loams, they are *loamy skeletal* (profiles 3, 6, 28 and 29).

ix-*Typic Haplocalcids, sandy skeletal, mixed, hyperthermic.*

These *Haplocalcids* occurred in bajada. The soils have calcic horizons "ABk" and "Bk" including $CaCO_3$ of 149 to 311.2 g/kg and 5 to 10 % by volume as secondary visible lime. As the soil control section is dominated by very gravelly loamy sands, they are *Loamy skeletal* (profile 30).

x-*Lithic Haplocalcids, sandy skeletal, carbonatic, hyperthermic*

These *Haplocalcids* occur in the piedmonts that were derived from the limestone parent rocks. The soils have calcic horizon "BCk" with $CaCO_3$ contents of 476 to 589.4 g/kg and 5 to 10 % by volume as secondary visible lime. As soil depth is limited by the parent rock "2R" at 45 cm, they are *Lithic*. As the soil control section is dominated by extremely gravelly loamy sands, they are sandy *skeletal* (profile 26).

4.3.1.2 *Entisols.*

[Ent. Implying recent, the last 3 letters of the word “recent”]. Smith (1986) considered Entisols as either are losing material rapidly through truncation or receiving additions rapidly for horizons to form. The suborder level is first sorted out according to the reasons as why they had no subsurface diagnostic horizon. Entisols distribution in the study area are related only to the deposition process of the water agent resulting in nine soil families.

i-*Typic Torrifluvents, coarse loamy, mixed (calcareous), hyperthermic.*

Fluvent from Latin “*fluvius*” = river related to *fluere* = to flow. The clues that led to specify *Fluvents,* express the risk of flooding as the soils are located within the drainage network. *Fluvents* must be alluviums, while alluviums should not be *Fluvents* if the soils are not subjected to the flooding. *Fluvents* are recent soils “C” lacking “A” horizon since the epipedons are mostly reworked by seasonal water runoff. This mode of *Fluvents* should be considered to be a precautionary name for soil management and protection. Accordingly, in some cases (like the soils of Nile Delta that have Ap horizon and are not subjected to the flooding, using the term *Fluvents* is most probably a redundant.

In the current study, *Fluvents* occur in wadis which are derived from limestone parent rocks. The soils are stratified reflecting sequential depositions with an irregular decrease in organic matter within depth 25 cm to 125 cm under a *torric* moisture regime “*Torric*”. The soil control section is dominated by gravelly sandy loams, therefore these soils are coarse l*oamy*, effervesces in all parts between 25 to 50 cm to be calcareous (profile 2).

ii-*Typic Torrifluvents, coarse loamy, mixed, hyperthermic.*

These *Torrifluvents* occurred in wadis that were derived from the basement complex parent rocks. Since the soil control section is dominated by slightly gravelly sandy loams, they are *coarse loamy* (profiles 15, 37 and 38).

iii-*Typic Torrifluvents, loamy skeletal, mixed (calcareous), hyperthermic.*

These *Torrifluvents* occur in wadis which are derived from the limestone parent rocks. The soils are *loamy skeletal* as the soil control section is dominated by very gravelly sandy loams (profiles 1, 4, 5 and 31).

iv-*Typic Torrifluvents, loamy skeletal, mixed, hyperthermic.*

These soils occur in wadis which are derived from the basement complex parent rocks. The soils are *loamy skeletal* since soil control section is dominated by very gravelly sandy loams (Profiles 8 and 9).

v- *Typic Torrorthents, coarse loamy, mixed, hyperthermic.*

These *Orthents* are associated or not with *fluvents* but are developed in certain locations that protect them from flooding. They are found in the deltas of basement complex parent rocks. Since the soil control section is dominated by gravelly sandy loams, they are *coarse* l*oamy* (Profiles 7, 17 and 19).

vi-*Typic Torriorthents, sandy skeletal, mixed, hyperthermic.*

These soils occur in wadis which are derived from the limestone parent rocks. The soil control section is dominated by very gravelly sands, thus they are classified as *sandy skeletal* (Profile 25).

vii-*Typic Torriorthents, sandy skeletal, mixed, hyperthermic.*

These soils occurred in wadis which are derived from the basement complex parent rocks parent rocks. The soil control section is dominated by very gravelly loamy sands, thus they are *sandy skeletal* (Profile 10).

viii-*Lithic Torriorthents, sandy skeletal, mixed, hyperthermic*

These soils occurred in the piedmonts that were derived from the basement complex parent rocks parent rocks. As soil depth is limited by the parent rock at 40 cm, they are lithic. The soil control section is dominated by extremely gravelly loamy sands to be *sandy skeletal* (Profile 11).

ix-*Lithic Torriorthents, fragmental, hyperthermic.*

These soils occur in the piedmonts which are derived from the basement complex parent rocks parent rocks, having a fine-earth component of less than 10 percent (including associated medium and fine pores) of the total volume**.** (Profile 36)

4.3.2 Formulating tentative soil series

Soil series are differentiated on all differentials of the higher categories plus those additional and significant characteristics in the soil control section. Some of the characteristics commonly used to differentiate series, are soil thickness, arrangement of horizons and their structure, color, texture, reaction, consistence, content of carbonates and other salts, content of rock fragments, and mineralogical composition.

An official soil series description should include full taxonomic name of the family taxon, description of a typical pedon, a statement that identifies the type location of a representative pedon. The descriptive parts of an official soil series description include the physiographic position, parent material including parent rock, drainage, geography, major use, distribution and the area where the series is proposed, name of the person who prepared and approved the description of the series and references to available laboratory data (USDA, 1993).

In the current study area, identification of soil series was used for naming the predominant soil categories within the limits of their family level, representing the main processes of soil genesis. These soil series are proposed as tentative, being prepared, using essential data required for this purpose

From forty one pedons, eight soil series are defined considering that, the selected pedon taxa must serve a range of characteristics that specifies a certain series range within the family level. The soil taxa , that were not enough for setting up an extra soil series or not adequate for the statement of the ranges of properties within the specified soil series, were processed up to the family level, as taxonomic units of the mapped polygons.

4.3.2.1 Defined soil series within the Order Aridisols "in alphapitical order"

Aridisol soil series identified in the study area are (i) Galala Series, (ii) Shokair Series, (iii) Tinasib Series (iv) Zaafarana Series.

i-Galala Series.

Galala series consists of very deep, well drained soils formed in alluvium which are mainly derived from limestone parent rocks. These soils occur in bajada, having slopes of 1.5 to 2.5 percent.

<u>Taxonomic class</u>: *Loamy skeletal, mixed, hyperthermic, Typic Haplocalcids*

<u>Representative pedon</u>: Galala gravelly sandy loam, gently sloping in bajada- natural vegetation. Colors are for dry soils unless otherwise stated.

ABk– 0 to 20 cm; brownish yellow (10YR 6/8) gravelly sandy loam, brownish yellow (10 YR 6/6) moist; massive; slightly hard, very friable, non sticky and non plastic; about 15 percent by volume fine and medium rounded and sub rounded pebbles; few fine vesicular pores; common calcium carbonate soft accumulations coating pebble; strongly effervescent; moderately saline, slightly alkaline; clear smooth boundary.

Bk1 – 20 to 50 cm; yellow (10YR 7/6) gravelly coarse sandy loam, yellowish brown (10YR 5/6) moist; massive, slightly hard, friable, non sticky and non plastic; about 20 percent by volume fine and medium rounded pebbles; common soft calcium carbonate accumulations and coating pebbles; strongly effervescent, slightly saline; slightly alkaline; clear smooth boundary.

Bk2 – 50 to 90 cm; yellow (10YR 7/8) very gravelly coarse sandy loam, brownish yellow (10 YR 6/6) moist; massive; hard, friable, non sticky and non plastic; about 45 percent by volume fine through course rounded parting to sub rounded pebbles; common calcium carbonate soft accumulations coating pebbles;

strongly effervescent; moderately saline; slightly alkaline; abrupt smooth boundary.

Bk3 – 90 to 150 cm; yellow (10YR 7/8) very gravelly sandy loam, brownish yellow (10 YR 6/6) moist; massive; hard, friable, non sticky and non plastic; about 35 percent by volume medium and coarse rounded and sub rounded pebbles; common calcium carbonate soft and hard nodules and coating pebbles; strongly effervescent; strongly saline, slightly alkaline.

Type location: Al Bahr El Ahmar province, located in latitude of $28^{o}\,56^{/}\,42^{//}$ North and longitude of $32^{o}\,07^{/}\,33^{//}$ East (profile 3).

Geographic setting: Galala soils are on gently sloping straight slopes in bajada at elevations of 90 to 300 meters. The climate is arid.

Use and vegetation: These soils are not used but are terrestrial vegetated areas by sparse herbaceous xerophytes in rills.

Distribution: On the foot slopes south and north of the mountains of El Galala El Bahariayh and El Galala El Qebliayh respectively.

Additional data: Characterization data are on the profiles 3, 6, 28 and 29 in tables 5, 8 and 11.

ii- Shokair Series.

Shokair series consists of moderately deep, poorly drained soils formed in marine sediments of mixed parent materials. The soils occur in flat surfaces having slopes of 0.5 to 1 percent.

Taxonomic class: *Sandy*, *carbonatic*, *hyperthermic*. *Calcic Aquisalids.*

Representative pedon: Shokair loamy sand, flat with 0.5to 0.1 percent slopes in marine sediments. Colors are for dry soils unless otherwise noted.

ABkz – 0 to 20 cm; very bale brown (10YR 8/4) loamy sand, very bale brown (10YR 7/4); massive; soft, very friable non sticky and non plastic; strongly effervescent; many calcium carbonate soft segregations; strongly saline; slightly alkaline; gradual smooth boundary.

Bkz– 20 to 35 cm; brownish yellow (10 YR6/6) loamy sand, yellowish brown (10 YR 5/6) moist; massive; friable; common fine roots; slightly sticky and slightly plastic; common fine vesicular pores; many calcium carbonate soft segregations; strongly saline; moderately alkaline; gradual smooth boundary.

Bgkz – 35 to 55; loamy sand light yellowish brow (10YR 6/4), loamy fine sand, common grayish brown (10YR 5/2) faint mottles; friable; common fine roots; slightly sticky and slightly plastic; many calcium carbonate soft segregations; strongly saline; moderately alkaline.

Type location: Al Bahr El Ahmar, located in latitude of 28 ^{o} 16$^{/}$ 38$^{//}$ North and longitude of 33 ^{o} 06$^{/}$ 55 East (profile 12).

Geographic setting: Shokair soils are on flat marine sediments at elevations of 0.5 to 1 meters. This pattern has scattered salt crust express localities of water logging mode. The climate is arid.

Use and vegetation: These soils are not used for any agricultural activities, but are covered by terrestrial vegetation of very open herbaceous halophytes.

Distribution: Observed along the shoreline of the Gulf of Suez from Zaafarana to Ras Gareb towns.

Additional data: Characterization data are on profiles 12, 18, 39, 40 and 41in tables 7, 10 and 13.

iii-Tinasib Series

Tinasib series consists of very deep, well drained alluvium, derived from igneous and metamorphic parent rocks. These soils occur in alluvial terraces, having slopes of 2 to 4 percent.

Taxonomic class: L*oamy skeletal, mixed, hyperthermic. Typic Calcigypsids.*

Representative pedon: Tinasib gravelly sandy loam, gently sloping (2.0 to 3.5 percent slopes) in alluvial terraces. Colors are for dry soils unless otherwise noted.

ABk – 0 to 20 cm; reddish yellow (7.5YR 7/6) gravelly coarse sandy loam, reddish yellow (7.5YR 6/6) moist; massive; soft, friable, non sticky and non plastic; about 15 percent medium sub rounded pebbles; few fine tubular pores; few fine roots; common calcium carbonate soft segregations; strongly effervescent; strongly saline; slightly alkaline; clear wavy boundary.

Bk – 20 to 40 cm; redish yellow (7.5YR 7/6) very gravelly sandy loam. reddish yellow (7.5YR 6/6) moist; massive; slightly hard, friable, non sticky and non plastic; about 40 percent fine sub rounded pebbles; common calcium carbonate soft segregations and coating; strongly effervescent; strongly saline; slightly alkaline; clear wavy boundary.

Bky1– 40 to 70 cm; light brown (7.5YR 6/4) very gravelly coarse sandy loam, brown (7.5YR 5/4) moist; massive; slightly hard, friable, non sticky and non plastic; about 35 percent by volume fine and medium sub rounded pebbles; few fine tubular pores; few fine roots; common calcium carbonate soft segregations; common gypsum soft and hard nodules; strongly effervescent; strongly saline; slightly alkaline; clear wavy boundary.

Bky2 – 70 to 150 cm; light brown (7.5YR 6/4) very gravelly coarse sandy loam, brown (7.5YR 5/4) moist; massive; hard, firm, non sticky and non plastic; about 40 percent by volume fine to coarse sub rounded pebbles; common calcium carbonate soft segregations and coatings; common gypsum soft and hard nodules; strongly effervescent; strongly saline; slightly alkaline.

Type location: Al Bahr El Ahmar Province, west of Zaafarana Ras Ghareb road. Located in latitude of 28 ^{o} 32$^{/}$ 02$^{//}$ North and longitude of 32 ^{o} 51$^{/}$ 46$^{//}$ East (profile 20).

Use and vegetation: These soils are not used for any agricultural activities. Natural vegetation is very rare as scattered grasses that are restricted in the rills.

Distribution: Observed on the dissected open landscape east of the mountainous area of the igneous and metamorphic rocks.

Additional data: Characterization data are on profiles 20, 22, 23 and 24 in Tables 6, 9 and 12.

iv-Zaafarana Series

Zaafarana series consists of very deep, well drained soils formed in alluvium that was mainly derived from limestone parent rocks. These soils occur in the deltaic plains of 1.0 to 1.5 percent slopes.

Taxonomic Class: *Coarse loamy, carbonatic hyperthermic. Sodic Haplocalcids*

Representative pedon: Zaafarana gravelly coarse sandy loam, nearly level in deltaic plain. Colors are for dry soils unless otherwise noted

ABk - 0 to 30 cm; yellow (10YR7/6) dry, gravelly coarse sandy loam, brownish yellow (10YR 6/6) moist; soft, very friable, slightly sticky and slightly plastic; about 30 percent fine and medium rounded pebbles; few tubular pores; common calcium carbonate soft segregations; strongly effervescent, strongly saline; slightly alkaline; clear wavy boundary.

Bk - 30 to 70 cm; yellow (10YR7/6) gravelly coarse sandy loam, yellowish brown (10YR 5/4) moist; slightly hard, friable, slightly sticky and slightly plastic; about 25 percent fine and medium rounded pebbles;common calcium carbonate soft segregations; strongly effervescent; moderately saline; moderately alkaline; gradual smooth boundary.

C - 70 to 150 cm; light yellowish brown (10YR 6/4) dry, very gravelly loamy coarse sand, yellowish brown (10YR 5/4) moist, hard, friable non sticky and non plastic; strongly effervescent; common calcium carbonate soft segregations; strongly saline; moderately alkaline.

Type location: Al Bahr El Ahmar Province, located in latitude of $28^{o}\,55^{/}\,48^{//}$ North and longitude of $32^{o}\,39^{/}\,17^{//}$ East (profile 27).

Geographic setting: Zaafarana soils are on deltaic plains at elevations of 1.5 to 8 meters. The climate is arid.

Use and vegetation: These soils are locally covered by scattered stations for extracting petroleum.

Distribution: Observed in polygons aligning the shoreline of the Gulf of Suez in the northern part of the study area and are locally separated from the shoreline by the marine sediments.

Additional data: Characterization data are on profiles 27, 32, 33 and 34 in Tables 5, 8 and 11.

4.3.2.2 Defined soil series within the Order *Entisols*

Soil series within the *Entisols* in the study area are (i) Abu Had Series, (ii) Araba Series, (iii) Bakr Series, and (iv) Ras Ghareb Series.

i- Abu Had Series

Abu Had series consist of very deep somewhat excessively well drained alluviums, mainly derived from igneous and metamorphic rocks. These soils occur in wadis, having slopes of 1.5 to 2.0 percent.

Taxonomic Class: *Loamy skeletal*, *mixed*, *hyperthermic*. *Typic Torrifluvents*

Representative pedon: Abu Had gravelly loamy coarse sand, nearly level in wadis-vegetated. Colors are for dry soils unless otherwise noted.

Cl– 0 to 20 cm brownish yellow (10YR6/6) gravelly loamy coarse sand, yellowish brown (10YR 5/6) moist; massive; soft, very friable, non sticky and non plastic; about 25 percent medium sub-rounded pebbles; common fine and medium tubular pores; common fine and medium roots; moderately effervescent; non saline; slightly alkaline; clear smooth boundary.

C2– 20 to 50 cm; brownish yellow (10YR6/6) very gravelly loamy coarse sand, reddish yellowish brown (10YR 5/6) moist; massive; soft, very friable non sticky and non plastic; about 40 percent fine and medium sub rounded and sub angular pebbles; common fine vesicular pores; common fine and medium roots; weak effervescent; very slightly saline; slightly alkaline; clear gradual boundary.

C3– 50 to 90 cm; brownish yellow (10YR6/4) very gravelly coarse sandy loam, yellowish brown (10YR5/6) moist; massive; slightly hard, friable; non sticky and non plastic; about 45 percent by volume fine and medium and sub angular pebbles; common fine tubular pores; few fine roots; weak effervescent; non saline; moderately alkaline; clear smooth boundary.

C4– 90 to 150 cm; light brown (7.5YR 6/4) very gravelly coarse sandy loam dark brown (7.5YR 4/4) moist; massive; slightly hard, friable; non sticky and non plastic; about 50 percent by volume fine to coarse medium and sub angular pebbles; few fine roots; weak effervescent; non saline; moderately alkaline

Type location: Al Bahr El Ahmar Province, located in latitude of $28^{o}\ 16^{/}\ 44^{//}$ North and longitude of $32^{o}\ 42^{/}\ 39^{//}$ East (profile 9).

Geographic setting: Abu Had soils are on smooth surfaces of wadis at elevations of 20 to 200 meters. The climate is arid.

Use and vegetation: These soils are not used for any agricultural activities, but are covered by terrestrial vegetation of very open herbaceous *zerophytes*.

Distribution: Observed along the braided system of Wadi Abu Had in the relatively high parts within the southern part of the study area.

Additional data: Characterization data are on two profiles (8 and 9) in Tables 6, 9 and 12.

ii-Araba series

Araba series consists of very deep well drained alluvium, mainly derived from calcareous sedimentary rocks. These soils occur in wadis, having slopes of 1 to 2 percent.

Taxonomic class: *Loamy skeletal, mixed (calcareous), hyperthermic. Typic Torrifluvents.*

Representative pedon: Araba very gravelly loamy sand, nearly level in wadis-vegetated. Colors are for dry soils unless otherwise noted.

Cl– 0 to 10 cm; yellowish red (5YR 5/6) gravelly loamy sand, yellowish red (5YR 4/6) moist; massive; soft, non sticky and non plastic; about 40 percent medium sub-rounded pebbles; few fine tubular pores; very few fine roots; strongly effervescent; very slightly saline; slightly alkaline; clear smooth boundary.

C2– 10 to 40 cm; reddish yellow (7.5YR 7/6) very gravelly sandy loam, reddish yellow (7.5YR 6/6) moist; massive; soft, non sticky and non plastic; about 35 percent fine and medium sub-rounded pebbles; common fine vesicular pores; few fine roots; strongly effervescent; very slightly saline; slightly alkaline; clear smooth boundary.

C3– 40 to 70 cm; yellowish red (5YR 4/6) very gravelly coarse sandy loam, reddish brown (5YR 4/4) moist; massive; soft, non sticky and non plastic; about 40 percent by volume fine and medium sub-rounded pebbles; common fine tubular pores; few fine roots; strongly effervescent; non saline; moderately alkaline; clear smooth boundary.

C4– 70 to 100; yellowish red (5YR 4/6) brown very gravelly coarse sandy loam, reddish brown (5YR 4/4) moist; massive; slightly hard, non sticky and non plastic; about 45 percent by volume fine to coarse sub-rounded pebbles; few fine tubular pores; few fine roots; strongly effervescent; non saline; moderately alkaline; gradual smooth boundary.

C5– 100 to 150; yellowish red (5YR 5/6) very gravelly sandy clay loam, reddish brown (5YR 4/4) moist; massive; hard, non sticky and non plastic; about 35 percent by volume fine to coarse sub-rounded pebbles; strongly effervescent; very slightly saline; slightly alkaline.

Type location: Al Bahr El Ahmar Province, located in latitude of $28^{o}\ 58^{/}\ 28^{//}$ North and longitude of $32^{o}\ 03^{/}\ 20^{//}$ East (profile 1).

Geographic setting: Araba soils are on smooth surfaces of nearly level topography at elevations of 200 to 300 meters. This pattern has gravelly tops within the tributaries of wadi Araba. The climate is arid.

Use and vegetation: These soils are not used for any agricultural activities. The natural vegetation is terrestrial of very open herbaceous *zerophytes.*

Distribution: Observed along the braided system of Wadi Araba.

Additional Data: Characterization data are on four profiles (1, 4, 5 and 31) in Tables 5, 8 and 11.

iii- Bakr Series

Bakr series consists of very deep, well drained soils formed in alluviums, derived from igneous and metamorphic parent rocks. These soils occur in wadis of nearly level surfaces of 1.0 to 1.5 slopes.

Taxonomic class: *Course loamy, mixed, hyperthermic Typic Torrifluvents.*

Representative pedon: Bakr slightly gravelly sandy loam, nearly level – vegetated rangeland. Colors are for dry soils unless otherwise stated.

C1– 0 to 25 cm; yellow (10YR 7/6), slightly gravelly sandy loam, brownish yellow (10YR 6/6) moist; massive in laminated pattern; soft, very friable, non sticky and non plastic; about 10 percent fine rounded pebbles; common fine tubular pores; few fine roots; weak effervescent; strongly saline; slightly alkaline; abrupt smooth boundary.

C2– 25 to 75 cm; yellow (10YR 7/6), gravelly sandy loam, brownish yellow
(10YR 6/6) moist; massive; soft, very friable, non sticky and non plastic; about 15 percent by volume fine and medium rounded and surrounded pebbles; common fine tubular pores; common fine roots; weak effervescent; strongly saline; slightly alkaline; clear smooth boundary

C3– 75 to 150 cm; brownish yellow (10YR 6/6) slightly gravelly sandy clay loam, Light yellowish brown (10YR 6/4) moist; massive, slightly hard, friable, non sticky and non plastic; about 10 percent by volume fine rounded pebbles; few fine roots; weak effervescent; strongly saline; slightly alkaline.

Type Location: Al Bahr El Ahmar Province located at latitude of 28 ^{o} 23$^{/}$ 38$^{//}$ north and longitude of 32 ^{o} 59$^{/}$ 43$^{//}$ east (profile 15).

Geographic setting: Bakr soils are on a nearly level topography in wadis at elevation of 5 to 50 meters. The climate is arid.

Use and vegetation: The soils are used for range pasture. Native vegetation of very open forbs of herbaceous cover.

Distribution: In the lower parts of drainage pattern that are draining from the highlands of the basement complex rocks. These soils are mostly identified in the mouth of wadis.

Additional data: Characterization data are on three profiles (15, 37 and 38) in Tables 6, 9 and 12.

iv- Ras Ghareb Series.

Ras Ghareb series consists of very deep, well drained soils formed in alluvium, derived from rocks that are mainly composed of igneous and metamorphic parent rocks. These soils occur in deltaic plain of nearly level surface.

Taxonomic class: *Course loamy, mixed, hyperthermic Typic Torriorthents.*

Representative pedon: Ras Ghareb slightly gravelly sandy loam, nearly level. Colors are for dry soils unless otherwise stated

A– 0 to 20 cm; yellow (10YR 7/6), slightly gravelly loamy sand, brownish yellow (10YR 6/6) moist; massive; soft, very friable, non sticky and non plastic; about 20 percent fine rounded pebbles; common fine tubular pores; few fine roots; weak effervescent; strongly saline; slightly alkaline; abrupt smooth boundary.

C1– 20 to 50 cm; light brown (7.5YR 6/4), gravelly sandy loam, brown (7.5YR 5/4), moist; massive; soft, very friable, non sticky and non plastic; about 25 percent fine rounded pebbles; common fine tubular pores; few fine roots; weak effervescent; strongly saline; slightly alkaline; gradual smooth boundary.

C2– 50 to 80 cm; reddish yellow (7.5YR 6/8), gravelly coarse sandy loam, light brown (7.5YR 6/4), moist; massive; soft, very friable, non sticky and non plastic; about 15 percent fine rounded pebbles; common fine tubular pores; few fine roots;

weak effervescent; strongly saline; slightly alkaline; gradual smooth boundary.

C3– 80 to 150 cm; reddish yellow (7.5YR 7/6) , gravelly coarse sandy loam, strong brown (7.5YR 5/8), moist; massive; soft, very friable, non sticky and non plastic; about 30 percent fine rounded pebbles; weak effervescent; strongly saline; slightly alkaline.

Type location: Al Bahr El Ahmar Province, located at latitude of 28 ^{o} 20$^{/}$ 23$^{//}$ north and longitude of 33^{o} 03$^{/}$ 13$^{//}$ east (profile 17).

Geographic setting: Ras Ghareb soils are on a nearly level topography in deltaic plains at elevation of 3 to 10 meters. The climate is arid.

Use and vegetation: These soils are locally covered by scattered stations for extracting petroleum.

Distribution: Observed in the polygons of deltaic plains that are aligning the shoreline of the Gulf of Suez in the southern part of the study area. They are locally separated from the shoreline by the marine sediments.

Additional data: Characterization data are on three profiles (7, 17 and 19) in Tables 6, 9 and 12.

4.4 Spatial distribution of flora habitats within the land cover units.

The presence of *xerophytes* and *halophytes* habitats reflects the possibility of utilizing the potential adaptation of the natural vegetation for certain human needs. Introducing such areas to be under the demand of agricultural land use will be inevitable for producing dry and green crops that can be adapted to grow in this environment for local development. The study area has habitats of national potential resources including many diversities of *zerophytes* and *halophites*, which can be used for food, fiber and medical vegetation as well as introducing saline and sodic soils to be economically under use.

The land cover features of the study area were formulated under a comprehensive hierarchically structured system which based on the Land Cover Classification System (LCCS) 2004. Accordingly, the spatial distributions and their life form were considered within the vegetated areas over the surface aspects. In the non vegetated areas, the surface aspects were directly categorized.

4.4.1 Terrestrial vegetated areas.

These areas are covering at least 4% within at least two months of the year. They are defined as life forms woody (trees, shrubs) or herbaceous (forbs and graminoids) or a combination of them. They also are defined by the spatial distribution (plant dominance and heights) as natural vegetative cover is in balance with the abiotic and biotic forces of its biotope. These vegetated areas are defined as vegetation not planted by humans and do not require human activities to be maintained in the long term. There are two types of communities, *xerophyte* and *halophyte* communities.

4.4.1.1 *Xerophyte* communities.

There are three of these forb communities (i) Very open striped tall forbs (ii) Very open striped medium tall forbs and (iii) Sparse park like patches short forbs.

i- Very open striped (30-50 %) grassland of tall (0.8- 1.5 m) herbaceous forbs.

This habitat is dominated by the plant species of *Zygophyllum coccineum* (Bean-caper) associated with *Zilla spinosa* (Edhress) covering 15-40% and *Suaeda vera* (Sea-blite) covering 15-40 %. This diversity is adapted in wadis of basement complex parent rocks in watershed areas which start as sub parallel drainage pattern within the relatively highlands. In the relatively low wadis of braided system, the species *Suaeda vera* (Sea-blite) become more prominent. The flora habitat is characterized by a recent complex pattern including very gravely soils of *Typic Torriorthents, sandy skeletal, mixed*; *Typic Torrifluvents loamy skeletal, mixed* and *Typic Torrifluvents coarse loamy, mixed.* This habitat is a pattern of Abu Had and Bakr soil series.

ii- Very open (15-30 %) striped grassland medium tall (0.3-0.8 m) herbaceous forbs.

This habitat is dominantly covered by the plant species of *Hyoscysamus muticus* (Egyptian Henbane), which are growing as short forbs (less than 0.3m) herbaceous forbs. The habitat is locally associated with spars (5 %) scattered high (3-5m) shrubs of *Accacia tortilis* (Karamoja). This diversity grows in the Wadi of limestone parent rocks (Wadi Araba) in watershed areas of dendrite drainage pattern that flow southwards and northwards from Jabal El- Galalaa El Bahariayh and El Galalaa El Qibliayah, respectively draining water to the main wadi. The flora habitat is a complex pattern of very recent gravely calcareous soils. They are *Typic Torrifluvents, loamy skeletal, mixed (calcareous); Typic Torrifluvents coarse loamy, mixed (calcareous) and Typic Torriorthents, sandy skeletal, mixed* with a dominancy of *Araba* soil series.

iii- Sparse park like patches (10 %) grassland of short (less than 0.3 m) herbaceous forbs.

This vegetation is dominated by the plant species of *Zygophyllum coccineum*, (Bean-caper) which grow in bajada of descent slopes on gullied and gravelly surfaces. The flora grow over very gravely sandy and loamy soils that include high quantities of lime that developed in the calcic horizon. The soils are *Typic Haplocalcids,loamy skeletal, mixed* and *Typic Haplocalcids sandy skeletal, mixed.*) This habitat is dominated by Galala soil series.

4.4.1.2 *Halophyte* communities.

This is one type of forb community which includes very open (15-20 %) striped grassland of tall (1.0- 1.5 m) herbaceous forbs. This habitat is dominated by the plant species of *Haloxylon saliconicum* (Sandfish), which are in association with sparse park like patches (10 %) grassland of medium tall (0.3-0.8m) herbaceous forbs of *Nitraria retusa* (Salt tree) .This diversity of *halophytic* communities is adapted in almost flat marine sediments of mixed parent materials within a complex pattern along the shoreline. The flora habitat is waterlogged with extremely saline soils and high contents of lime (*Calcic Aquisalids* of *sandy, carbonatic* and *sandy, mixed)*. This habitat includes Shokair soil series. Tables 14 explain the comprehensive terms of the spatial distribution flora diversities in their environmental attributes. They are photographically reported in plates from 1 throughout 8.

Table 14 Spatial distribution of flora diversity in their habitats

Land cover class	Diversity floristic names	Flora habitats	
		Taxonomic units of soil pattern	Soil series
Xerophytes:			
Very open striped tall forbs in wadis of basement complex parent rocks	*Zygophyllum coccineum* *Zilla spinosa* *Suaeda vera*	**Typic Torrifluvents, loamy skeletal, mixed* **Typic Torrifluvents, Coarse loamy, mixed*	Abu Had Bakr
		Typic Torriorthents, sandy skeletal, mixed	-
Very open striped medium - tall forbs with spars scattered high shrubs in wadis of limestone parent rocks	*Hyoscyamus muticus* *Accacia tortilis*	**Typic Torrifluvents, loamy skeletal mixed (calcareous)*	Araba
			-
		Typic Torrifluvents, coarse loamy mixed (calcareous)	-
		Typic Torrorthents, sandy skeletal, mixed	
Spars scattered short forbs in bajada of limestone parent rocks	*Zygophyllum coccineum*	**Typic Haplocalcids, loamy skeletal, mixed* *Typic Haplocalcids, sandy skeletal, mixed*	Galala
Halophytes:			
Very open striped tall forbs in marine sediments of mixed parent materials.	*Haloxylon saliconicum* *Nitraria retusa*	**Calcic Aquisalids, sandy, carbonatic*	Shokair
		Calcic Aquisalids, sandy, mixed	-

*Dominant soils for series formulation

Plate 1 Very open striped tall forbs of Bean-caper *(Zygophyllum coccineum)* in Wadi Abu Had

Plate 2 Very open striped tall forbs of Edhress *(Zilla spinosa)* in Wadi Abu Had

Plate 3 Very open striped tall forbs of Sea-blite *(Suaeda vera)* in Wadi Had

Plate 4 Very open striped medium-tall forbs of Egyptian Henbane (*Hyosysamus muticus*) in Wadi Araba

Plate 5 Spars scattered high shrubs of Karamoja (*Accacia tortilis*) in Wadi Araba

Plate 6 Sparse park like patches short forbs of Bean-caper (Zygophylum *coccineum)* in Bajada

Plate 7 Very open striped tall forbs of Sandfish *(Haloxylon salicornicum)* in Marine sediments

Plate 8 Sparse park like patches medium tall forbs of Salt tree (*Nitraria retusa*) in marine sediments

4.4.2 Terrestrial non vegetated areas

This class includes areas that have a total vegetative cover of less than 4% for more than 10 months of the year as the vegetation is influenced by the edaphic substratum. The attributes of non vegetated areas reflect the reasons of restricting the natural vegetation growth as results of consolidated bed (rock), non water holding capacity as the soils are in relatively higher sites out of water runoff and the areas do not have artificial engineering practices as a result of human activities. There are two types of these non vegetated areas as bare area and artificial surfaces.

4.4.2.1 Bare areas

i-Consolidated areas of bare rocks

These land cover units consisting of intricate high and rugged rocks of Gabal El Galala El Bahariayh and Gabal El Galala El Kebliayh that sided Wadi Araba. They are characterized by dissected limestone parent rocks and dendritic drainage pattern. The other mountainous region is aligning the western border of the lowlands from Zaafarana to Ras Ghareb. They are dominated by dissected basement complex parent rocks and sub-parallel drainage pattern.

ii- Unconsolidated areas of bare soils

- Piedmonts of basement complex parent rocks have soils of *Lithic Torriorthents, sandy skeletal, mixed,* locally *fragmental.*

-Piedmonts of limestone parent rocks have soils of *Lithic Haplocalcids, sandy skeletal, carbonatic.*

- Alluvial Terraces of basement complex parent rocks have soils of *Typic Calcigypsids of loamy skeletal, mixed* and *coarse loamy, mixed; Typic Haplocalcids course loamy, mixed.*

- Deltaic plains of limestone parent rocks have *Sodic Haplocalsids, coarse loamy, carbonatic and Sodic Haplocalcids, course loamy*. The soils of *Typic Torriorthents, coarse loamy, mixed* occurred in the areas of basement complex parent rocks.

4.4.2.2 Artificial surfaces

i-Built up non linear surfaces

These artificial surfaces are characterized by built up non linear areas include the urban settlements and the industrial areas.

ii-Built up linear surfaces

These artificial surfaces are characterized by built up non linear areas include the asphalted roads and non asphalted ones.

Figure 14 formulate the geographic distribution of vegetated and non vegetated areas within the land cover features in the study area.

4.5 Land evaluation

The land units of the study area were evaluated for the irrigated agriculture to satisfy the target of managing certain kinds of land utilization types versus different levels of land qualities. Accordingly, the land suitability classes, based on the system of Sys 1991, were mapped as delineated polygons that are dominated by certain soil taxonomic units. The defined land utilization types can be used as guides for most suitable land use for maximizing land productivity by fitting each of them in certain physiographic unit to be more adapted and promising for agricultural purposes.

Land suitability subclasses were categorized according limitation order that define the suitability. This land evaluation was processed to be valid for irrigation purposes in arid and semi arid regions. This approach was based on the guideline framework for the definition of orders, classes, and subclasses

(FAO 1976). The limitations of land qualities as based on their soil characteristics were matched with the crop requirements in different suitability levels as proposed by Sys et al. (1993). The suitability index (SI) for irrigated agriculture was calculated according to the following formula:

$$SI = a/100*b/100*c/100/*d/100*g/100*n/100*p/100*s/100*x/100*y/100*s/100$$

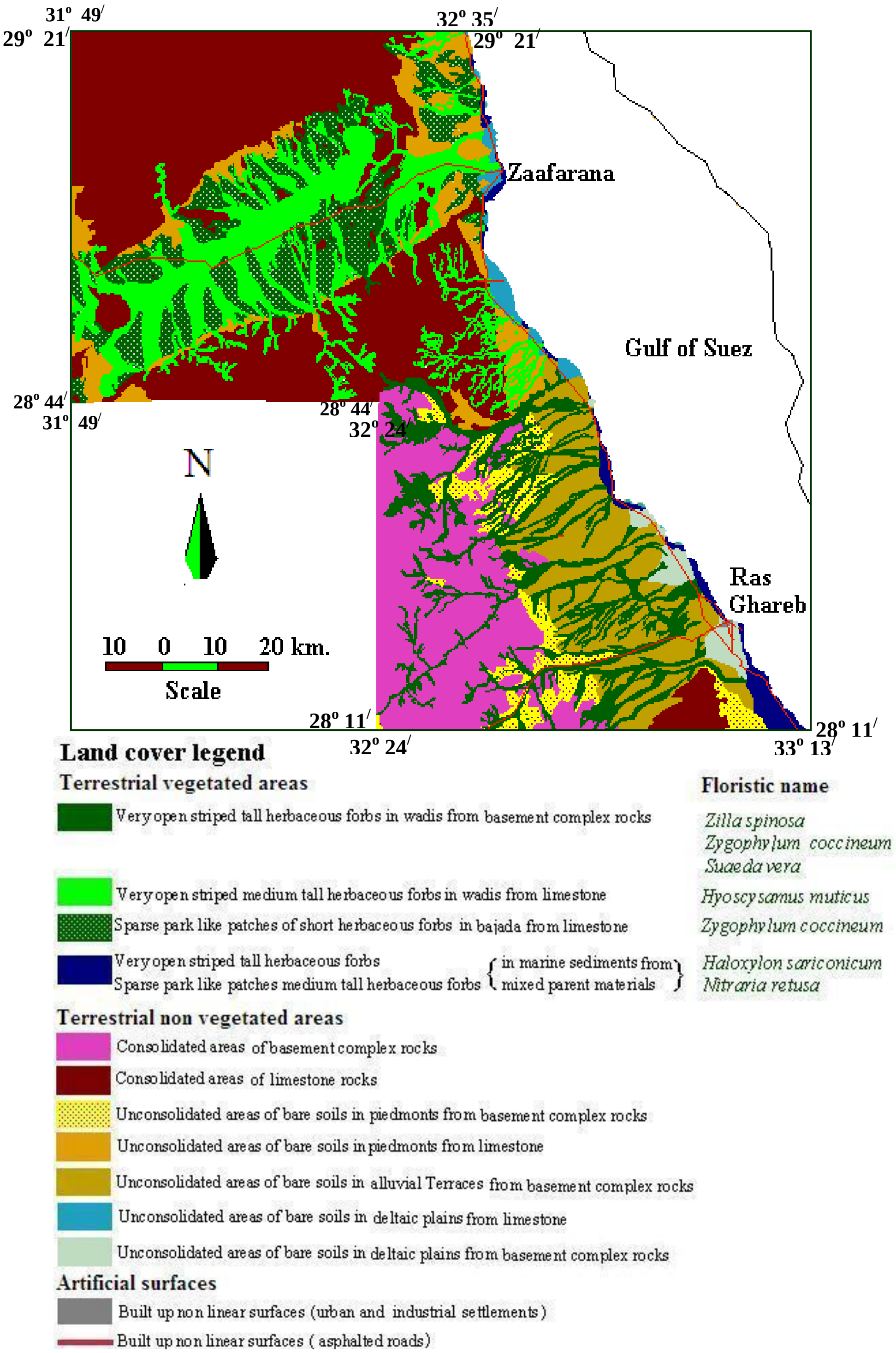


Figure 14 Flora habitats within the land covers units in the study area

Where:

SI = Suitability index

a = Apparent Cation Exchange Capacity (CEC)

b = Base saturation

c = $CaCO_3$ rating

d = Drainage rating

n = Alkalinity rating

p = Depth rating

t = Slope rating

x = Texture rating

s = Salinity rating

y = gypsum rating

Values of suitability index and limitation intensities are used for setting up land suitability as orders of suitable (S) and not suitable (N). Suitable order is sub-categorized as classes of highly suitable (S1) moderately suitable (S2) and marginally suitable (S3). The not suitable order is sub-divided to currently not suitable (N1) and potentially not suitable (N2). Suitability sub-classes that reflect kinds of limitations or main kinds of required improvement are indicated in symbols using lower-case letters indicating such limitations. From the practical point of view, the land suitability sub classes are applied to specify limitations that are in correlation with their physiographic units and can be used as a guide for soil management.

The proposed land utilization types for the study area are designed considering some important crops that can be cultivated. These crops are grain crops (barley and wheat) fodder crop (alfalfa and sorghum); oil seed crops (maize, canola and olives) and some trees like date palm, guava, and grapes were included. These crops are associated with specified mode of irrigation as follows:

(a) Alfalfa, barley, wheat, sorghum and canola using sprinkler irrigation.

(b) Date palm, grapes, guava and, olives using drip irrigation

4.5.1 Gross current land suitability

The study area includes a promising expansion for agricultural development which covers 485591 ha (1156169 f) after excluding rock lands. Current land suitability was defined for the virgin lands by matching the crop requirements with the present land qualities. The case will enable different alternatives for specific utilizations that are adapted to the existing limitations to give maximum output. The gross current land suitability (Table 15) indicates that, the main limiting factors in the study area are calcareousness, texture, stoniness and salinity. These limitations are partly inhibiting the growth of some crops in many of the physiographic units. The most affected crops are alfalfa, barley, maize, sorghum, wheat and date palm. These crops are mostly marginally suitable but are locally moderately or not suitable. At those levels of limitations of the current land suitability, canola, olive and grapes have relatively more tolerance to grow and overcome those limitations. Based on the gross current land suitability, the supreme land suitability (Table 16 and Figure 15) extracted from Table in Appendex 2 can be used for managing the virgin land for alternatives of cultivating specific crop in certain physiographic units. The case will realize a natural adaptation for cultivating this virgin land without major improvements covering about 395494.1 ha (941523f).

Table 15 Gross current land suitability of the different physiographic units for certain crop cultivations

Physiographic unit	Suitability subclass									
	Alfalfa	Sorghum	Barley	Wheat	Maize	Canola	Olive	Date palm	Grapes	Guava
Piedmonts of limestone barent rocks	N1c,g,p,s,x	N1c,g,p,s,x	N1c,g,x	N1c,g,p,s,x	N1c,g,p,s,x	N1g,p,x	N1p,g	N1c,g,p,s,x	N1g, p,x	N1g,n,p,s,x
Bajada of limestone parent rocks	S3g, s	S3c,g,x	S3g, x	N1c,g,s,x	N1c,g,s,x	S1m	S1m	N1c,g,s,x	S3g,s,x	N1g,n,s,x
Wadi of limestone parent rocks	S3c,g,x	S2g, x	S3g, x	S3g,s,x	S3c,g,x	S1m	S1m	N1c,g,s,x	S1m	N1g,x
Deltaic plain of limestone parent rocks	S3c,g,s	S2s, x	S3 c,n,x	N1s,x	N1c,n,s,x	S1m	S1m	N1c,s,x	S3g,n,s	N1g,n,s,x
Piedmonts of basement parent rocks	N1c,g,p,x	N1c,g,p,x	N1g,p,x	N1c,g,p,x	N1c,g,p,x	N1g,p,x	N1g,p,x	N1c,g,p,x	N1g,p,x	N1g,p,x
Alluvial terraces of basement parent rocks	S3c,g, n	S3g,n,x	S3 n,x	N1g,n,s,x	S3c,g,n,x	S2g,n, s	S2n,s	N1c,g,s,x	S3n,s	S3g,n, s
Wadi of basement parent rocks	S3,g,x	N1g,x	S3 g,x	S3g,x	S3g,x	S2s	S1m	S2c,g,x	S1m	S3g,x
Deltaic plain of basement parent rocks	S2g,s	S3g,x	S3 n,x	N1n,s,x	N1c,n,s,x	S2n, s	S1m	N1c,s,x	S2n, s	S2g, s
Marine sediments of mixed parent materials	N1c,d, n,p,s	N1c,d, n,s,x	N1c,d,n, s,x	N1d, n,s,x	N1c,d,n,p,s,x	N1d,n,p,s	N1 n,s, p, d	N1c, d,n,s,x	N1c,d, n,p,s	N1 d,n,s, x

Soil limitations [c : calcium carbonate %, d:drainage, g : gravel %, m: minor limitations, n : ESP, p : soil depth, s : salinity, x : texture] S1: Higly suitable ,
S2 : Moderately suitable, S3: Marginally suitable, N1: Currently not suitable

Table 16 Supreme current land suitability of the study area for the different crop cultivations.

Physiographic unit	Suitability sub class	Crop
Piedmonts of limestone parent rocks	N1c,g,p,s, x	
Bajada of limestone parent rocks	S1m	Canola
	S3g, x	Barley
Wadi of limestone parent rocks	S1m	Canola
	S3g,s,x	Wheat
	S3g, x	Barley
	S3c,g,x	Maize
Deltaic plain of limestone parent rocks	S1m	Canola
	S2s, x	Sorghum
Piedmonts of basement parent rocks	N1c,g,p,x	
Alluvial terraces of basement parent rocks	S2n,s	Olive
	S2g,n, s	Canola
	S3 n,x	Barley
Wadi of basement parent rocks	S1m	Olive
	S2s	Canola
	S2c,g,x	Date palm
	S3 g,x	Barley
Deltaic plain of basement parent rocks	S1m	Olive
	S2n, s	Canola
	S2g,s	
	S3 n,x	
Marine sediments of mixed parent materials	N1c,d,n,sx	

Soil limitations [c : calcium carbonate %, d:drainage, g : gravel %, m: minor limitations, n : ESP, p : soil depth, s : salinity, x : texture] S1: Highly suitable, S2 : Moderately suitable, S3: Marginally suitable, N1: Currently not suitable.

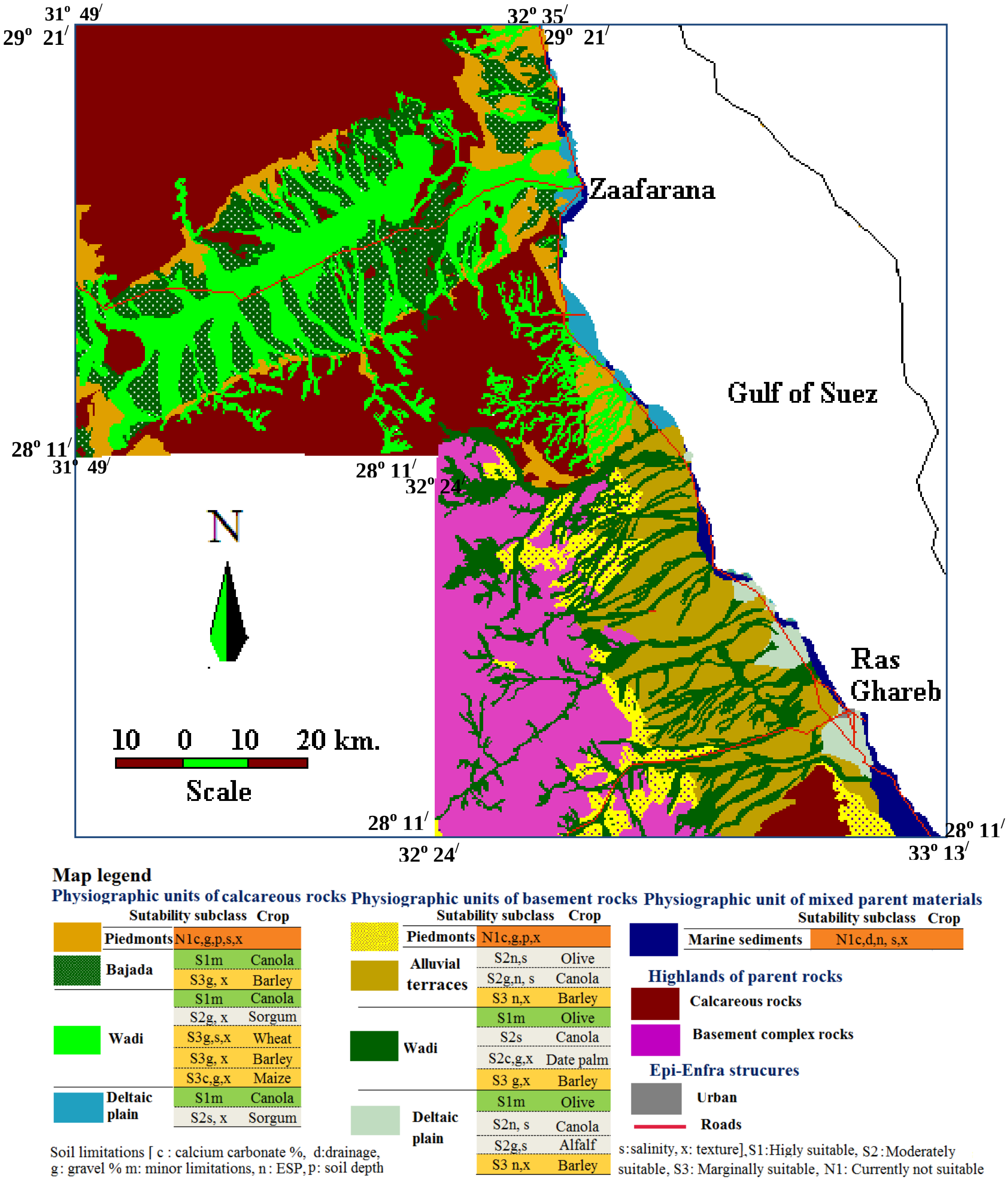


Figure 15 Supreme current land suitability in the study area for different crop cultivation

4.5.2 Gross potential land suitability

The current land suitability for certain cropping patterns can be more profitable and applicable after executing specified major land improvements proposed in the study area based on presence of certain limitations. These major improvements depend on the holders that have high capital intensities and can manage their land under the system of large land tenures, which are highly recommended for developing the current land attributes. Recommended realistic major improvements in the study area are those land qualities relating to salinity and sodicity. They are commonly initiated to be improved under land reclamation process. Once the land is put under cultivation, these land qualities will be improved to release the potentialities of the other good land qualities. Gross potential land suitability of the study area for the different crops is shown in Table 17. It reflects the ability of extra crops to be more adapted with the improved land qualities.

4.5.3 Profitable potential land suitability

Based on the gross potential land suitability, the alternatives of shifting each crop to be adapted with certain physiographic unit made it possible for using the land in the study area as profitable agricultural land use. This level of land suitability by using more selections to give higher production for profitable agriculture cover 408513 ha (972520.4 f.). The alternatives of using certain crops are shown in Table 18 and Figure 16.

4.5.3.1 Highly suitable (S1) adaptations

i- Canola, olives and grapes are highly suitable for all the physiographic units of the area except the marine sediments and piedmonts

ii- Guava is highly suitable for the soils of basement parent rocks (alluvial terraces, wadis and deltaic plains)

iii- Alfalfa is highly suitable for the soils of limestone parent rocks (wadis and deltaic plains).

iv- Maize is highly suitable for the soils of limestone parent rocks (deltaic plains)

4.5.3.2 Moderately suitable (S2) adaptations

i- Sorghum is moderately suitable for the soils in wadis and deltaic plains of the limestone parent rocks and alluvial terraces of basement parent rocks.

ii- Guava is moderately suitable for the soils of limestone parent rocks (bajada, wadis and deltaic plains)

iii- Date palm is moderately suitable for of the wadis of basement parent rocks

4.5.4 Supreme profitable potential land suitability

i- Guava is moderately suitable for the soils of limestone parent rocks (bajada, wadis and deltaic plains)

ii- Date palm is moderately suitable for of the wadis of basement parent rocks

iii- Barley is moderately suitable for the soils of basement parent rocks (alluvial terraces, wadis and deltaic plains)

iv- Maize is moderately suitable for the soils of wadis and deltaic plains of both limestone and basement parent rocks.

The land evaluation assessment for soils of the study area indicates that, the most profitable utilization is to manage the soils for canola and olive cultivation. These two crops have high tolerance for the potential left-out levels of soil limiting factors after the proposed major improvements of salinity and sodicity. The remaining limiting factors which include soil depth, drainage, coarse fragments, calcium carbonates and soil texture all of which inhabit the growth of other crops at different suitability levels. Except for the piedmonts and marine sediments, canola and olive are highly suitable (S1) for other soils. This high suitability is slightly affected by minor limitations but is still profitable as highly suitable (S1m) in the alluvial terraces. In marine sediments, canola is affected by the high levels of lime “c”, poor drainage “d” and coarse texture classes “x” to be

Table 17 Gross potential land suitability of the different physiographic units for certain crop cultivations

Physiographic unit	Suitability subclass									
	Alfalf	Sorghum	Barley	Wheat	Maize	Canola	Olive	Date palm	Graps	Guava
Piedmonts of limestone barent rocks	N2c,g,p,x	N2c,g,p,x	N2g,x	N2c,g,p,x	N2c,g,p,x	N2g,p,x	N2g,p,x	N2c,g,p,x	N2g, p,x	N2g,p,x
Bajada of limestone parent rocks	S3c,g	S3c,g,x	S3g, x	S3c,g,x	S3c,g,x	S1m	S1m	N2c,g,x	S1m	S2g,x
Wadi of limestone parent rocks	S2c,g,x	S2g, x	S3g, x	S3g,x	S2c,g,x	S1m	S1m	N2c,g,x	S1m	S2g,x
Deltaic plain of limestone parent rocks	S1m	S2 x	S3 c,x	S3g,x	S1m	S1	S1	N2c,x	S1	S2g,x
Piedmonts of basement parent rocks	N2c,g,p,x	N2c,g,p,x	N2g,p,x	N2c,g,p,x	N2c,g,p,x	N2g,p,x	N2g,p,x	N2c,g,p,x	N2g,p,x	N2g,p,x
Alluvial terraces of basement parent rocks	S3c,g,n	S2g,x	S2x	S3c,g,x	S3c,g,x	S1m	S1m	,S3c,g,x	S1	S1m
Wadi of basement parent rocks	S3,g,x	S3,x	S2g,x	S3g,x	S2x	S1	S1	,S2c,g,x	S1m	S1m
Deltaic plain of basement parent rocks	S1m	S3g,x	S2x	S3g,x	S2g,x	S1	S1	S3c,g,x	S1	S1m
Marine sediments of mixed parent materials	N2c,d,p	N2c,d,x	S3c,d,x	S3d, x	N2c,d,p,x	S3c,d,x	S3p, d	N2c,d,x	N2c,d,p	S3d,x

Soil limitations [c : calcium carbonate %, d:drainage, g : gravel %, m: minor limitations, n : ESP, p : soil depth, s : salinity, x : texture] S1: Higly suitable , S2 : Moderately suitable, S3: Marginally suitable, N2: Potentially not suitable

Table 18 Profitable potential land suitability in the study area for differen crop cultivations

Physiographic unit	Sutability subclass	Crop		
Piedmonts of limestone parent rocks	N2g,p,x			
Bajada of limestone parent rocks	S1m	Canola	Olive	
	S2g,x	Guava		
Wadi of limestone parent rocks	S1m	Canola	Olive	Grapes
	S2g, x	Sorghum	Guava	
	S2c,g,x	Alfalf	Maize	
Deltaic plain of limestone parent rocks	S1	Canola	Olive	Grapes
	S1m	Alfalf	Maize	
	S2 x	Sorghum		
	S2g,x	Guava		
Piedmonts of basement parent rocks	N2g,p,x			
Alluvial Terraces of basement parent rocks	S1	Graps		
	S1m	Canola	Olive	Guava
	S2x	Barley		
	S2g,x	Sorghum		
Wadi of basement parent rocks	S1	Canola	Olive	
	S1m	Grapes	Guava	
	S2x	Maize		
	S2g,x	Barley		
	S2c,g,x	Date palm		
Deltaic plain of basementparent rocks	S1	Canola	Olive	Grapes
	S1m	Guava		
	S2x	Barley		
	S2g,x	Maize		
Marine sediments of mixed parent materials	S3d,x	Wheat		
	S3p, d	Olive		
	S3c,d,x	Barley	Canola	
	S3c,d,p,x	Guava		

Soil limitations [c : calcium carbonate %, d:drainage , g : gravel %, m: minor limitations, n : ESP, p : soil depth, s : salinity, x : texture] S1: Higly suitable, S2 : Moderately suitable, S3: Marginally suitable, N2 Potentially not suitabale.

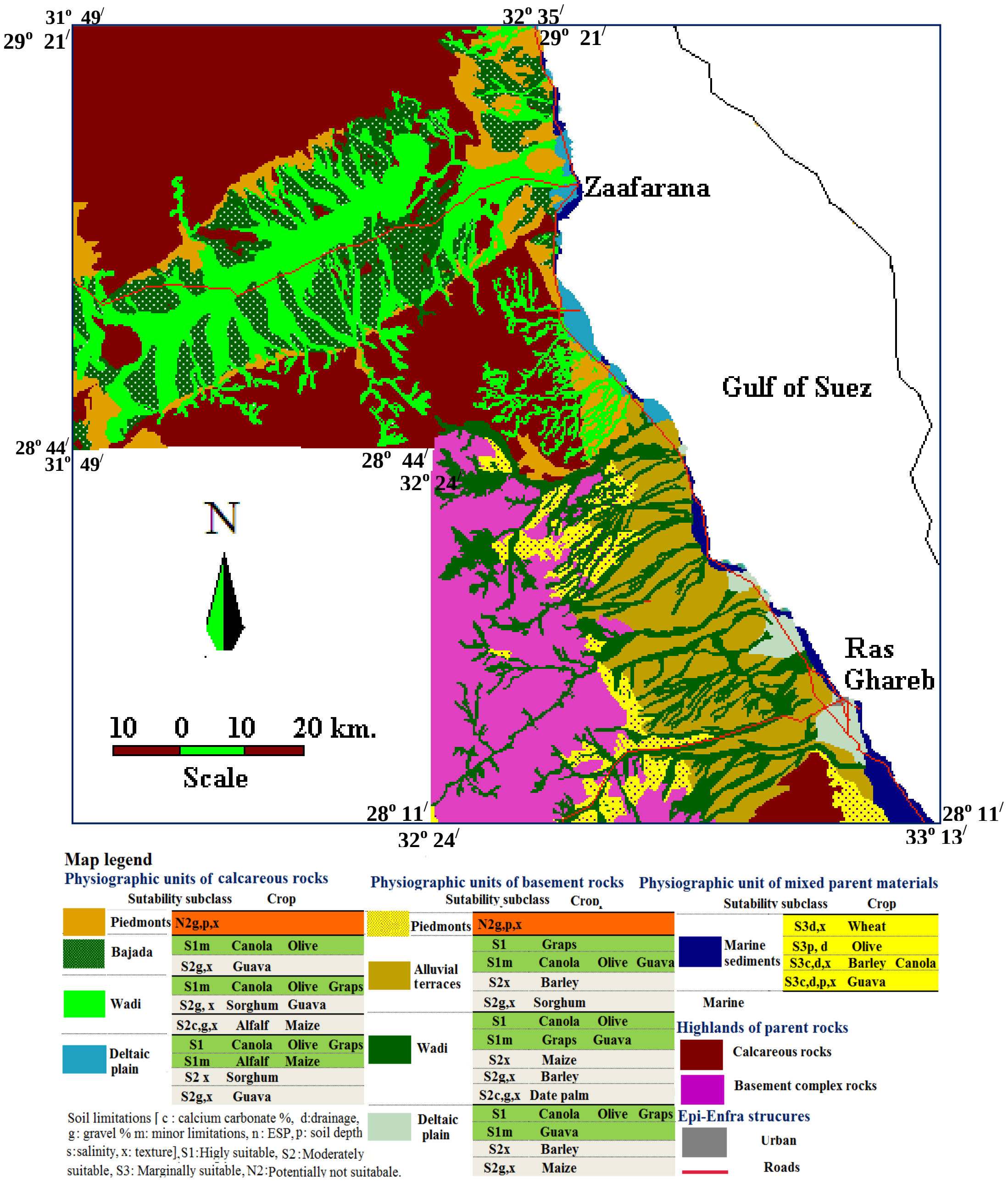


Figure 16 Profitable potential land suitability in the study area for different crop cultivation

marginally suitable (S3c,d,x). In the same sediments , olive is affected by soil depth as limited by saline water table “p” and the poor drainage “d” to be marginally suitable (S3d,p). Accordingly, the study area is highly promising to be introduced as canola and olive cultivation belt which can partly compensate a significant portion of food oil production deficiency in Egypt. This deficiency is currently compensated by importing the food oil products.

According to GAIN 2006, the deficit of food oil production in Egypt is going to be more as the cottonseed meal output decreases. This decrease is related to a drop in cotton area production. The potential land suitability sub classes of canola and olive are covering about 408513.0 ha (972520 f) as distributed in most of the promising areas. (Figure 17).

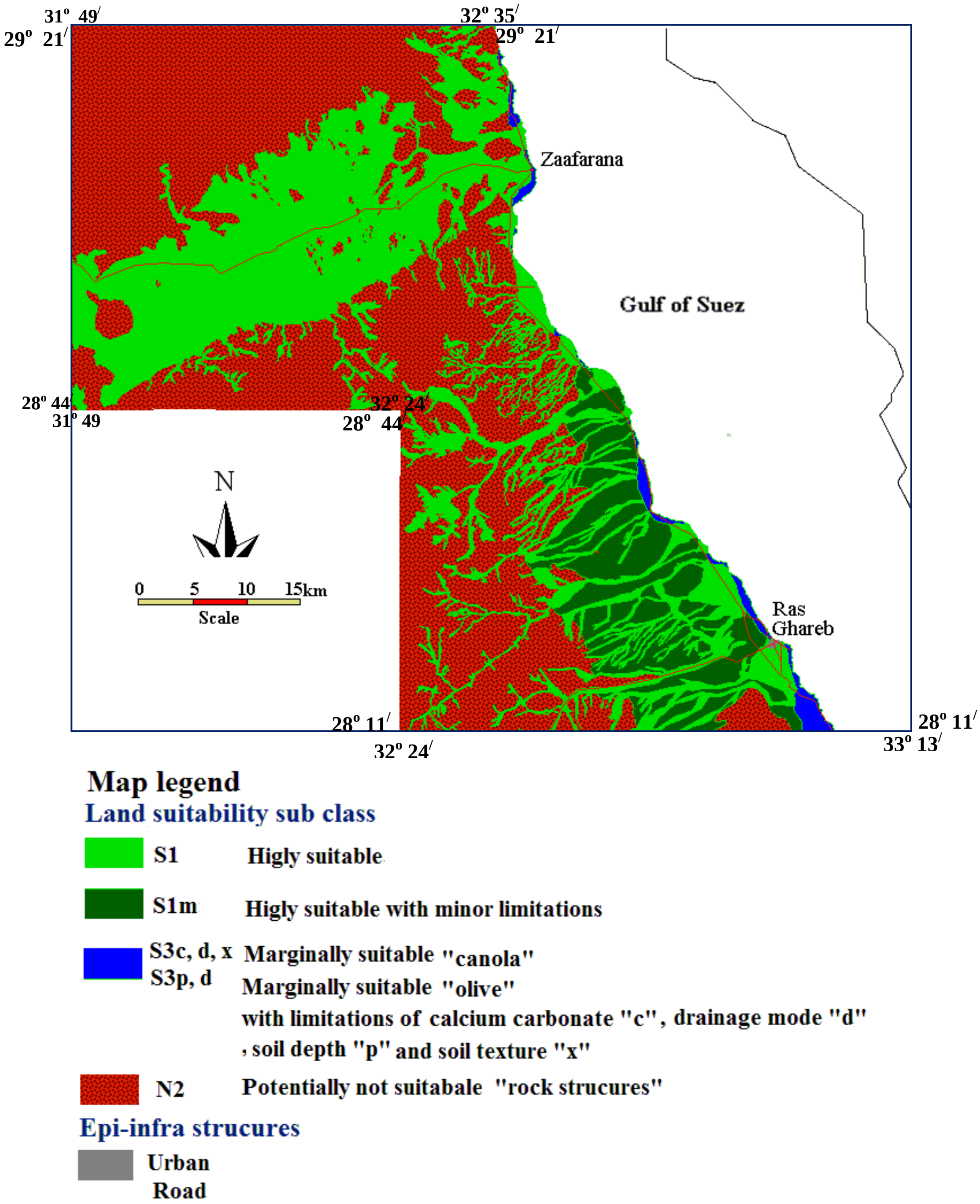


Figure 17 Supreme profitable potential land suitability in the study area for canola and olive belt)