MODIFIED LAND SUITABILITY EVALUATION MODEL FOR IRRIGATED AGRICULTURE

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Abstract

The proposed modification of soil rating was performed to study the comparison between different methods of land evaluation for the irrigated arid and semi-arid regions. Therefore, twenty-two soil profiles were chosen to represent some soils of the main geomorphic units within the Nile Delta and its desert fringes in Egypt. These soil profiles were assessed to identify the suitability classes by using the parametric soil rating of Storie and Sys systems as well as the descriptive FAO and USBR schemes. Data revealed the major differences in suitability classes with respect to their either descriptive or parametric system. The modified soil rating model depends mainly on soil characteristics itself. The principle of land classification in arid and semi-arid regions, the concepts of FAO Framework, Storie and Sys methods, as well as the guidelines for soil profile description and the criteria of soil taxonomic units, were all take into consideration. The soil rating chart includes the more stable characteristics (factor a), the relatively less stable characteristics (factor b); surface characteristics (factor c), and the miscellaneous (factor x) with respect to Suitability index values of (Si) is calculated as:

Si = Factor (a) x factor (b) / 100 x factor (c) / 100 x factor (x) /100

However;

S1 (Si ≥ 80) Highly Suitable S4 (20 – 39) Marginally Suitable
S2 (60 - 79) Suitable SC (10 – 19) Conditionally Suitable
S3 (40 - 59) Moderately Suitable N (Si < 10) Unsuitable

By using the modified rating, the obtained results would become more reliable application and qualitative evaluation of either current or potential suitability classes pertinent the pre-project, reconnaissance and even detailed phase of soil survey.

INTRODUCTION

Land use is a set of biological and technological human activities, engaged for economic and social purposes. These activities are directed towards the management and improvement of land resources. Land resources as such are phenomena of nature which are described in strictly scientific terms; they give no indication themselves of how they could or should be used. Land qualities or ecological land conditions are used as a mean for indicating the direct relations between the land as an ecological complex and the biological and technological activities of land use (Vink, 1975).

For the purpose of judging "land suitability", both for land use and land improvement, a systematic land evaluation system is necessary. Land evaluation is the process of collating and interpreting basic inventories of soil, vegetation, climate, and other aspects of land partly because insufficient quantitative information is available, and partly in order to identify and make a first comparison of promising land use alternatives in simple socio-economic terms (Brinkman and Smyth, 1973). Therefore, land evaluation is an essential tool in land use planning as it is assigned the indispensable task of translating the data on land resources into terms and categories which can be understood and used by all those concerned with land management, land improvement and land development. The qualitative classification is one in which relative suitability is expressed in qualitative terms, without precise calculation of cost and returns. The categories are based mainly on the physical productive potential of the land, with economics only present as a background.

About one-third of the world's land surface suffers from a moisture deficiency which presents a major constraint to agricultural development (Zonn, 1977). Any significant increase in agricultural output from arid and semi-arid regions is dependent upon new irrigation schemes. Such projects are highly expensive and necessitate very careful planning to ensure ultimate economic and social success. A general subjective system of land evaluation for irrigated agriculture has been elaborated by the United States Bureau of Reclamation (USBR, 1953). This system has been applied in many other countries, often after certain modification, but none of these systems has been universally accepted. In view of this, FAO has prepared a manual entitled "Framework for Land Evaluation" (FAO, 1976). This manual which, intended to have world-wide application, is based on the concepts and procedures of land evaluation that have evolved during FAO-assisted development projects.

Land evaluation which is numerically calculated avoids subjective assessments. As described by Beek (1978), parametric methods involve the selection of soil properties which are evaluated and given numerical scores. These scores are subjected to mathematical formulas mostly by multiplied together, so that an overall index of suitability or performance is obtained. An early index was proposed by Clarke (1951) and summarized by Smith and Atkinson (1975). Another widely quoted early methods are by Storie (1954), Olsen (1974), Vink (1975) and Storie (1978). The index is obtained by multiplying scores for selected variable and the results have been applied in many studies, often after some modifications for local conditions. Also, Bowser and Moss (1950) trace the development of soil rating methods relevant to irrigation, the system proposed by Sys and Verheye (1974) gives greater emphasis to soil chemical properties suggested by Bowser and Moss (1950). They state that the suitability of soils for irrigation in arid and semi-arid area is mainly influenced by seven factors, viz texture, soil depth, calcium carbonate content, gypsum status, salinity and alkalinity content, soil drainage and slope. However, with the guidance of FAO Framework for Land Evaluation (FAO, 1976), the parametric simple approach proposed by Sys and Verheye (1978), modified and improved by Sys *et. al.* (1991 and 1993) are widely used to identify suitability categories. Generally, these methods are mainly depending upon the same principles but with some modifications. It is noticed that these methods have differences in their suitability index values.

This work aims to compare the obtained results from application of the most common used methods in some soils of Egypt as arid region, within the proposed modifications of some soil ratings.

MATERIALS AND METHODS

1-Soil data:

According to El-Nahal *et. al.* (1977) and Veenenbos (1963), twenty-two investigated sites were chosen to represent some soils in the main geomorphic units in the Nile Delta and its desert fringes (Fig. 1). The soil profiles in these sites were morphologically described according to the methods undertaken by both FAO (1990) and USDA (1993). Representative soil samples were collected from the different profile layers. for physical and chemical analyses.

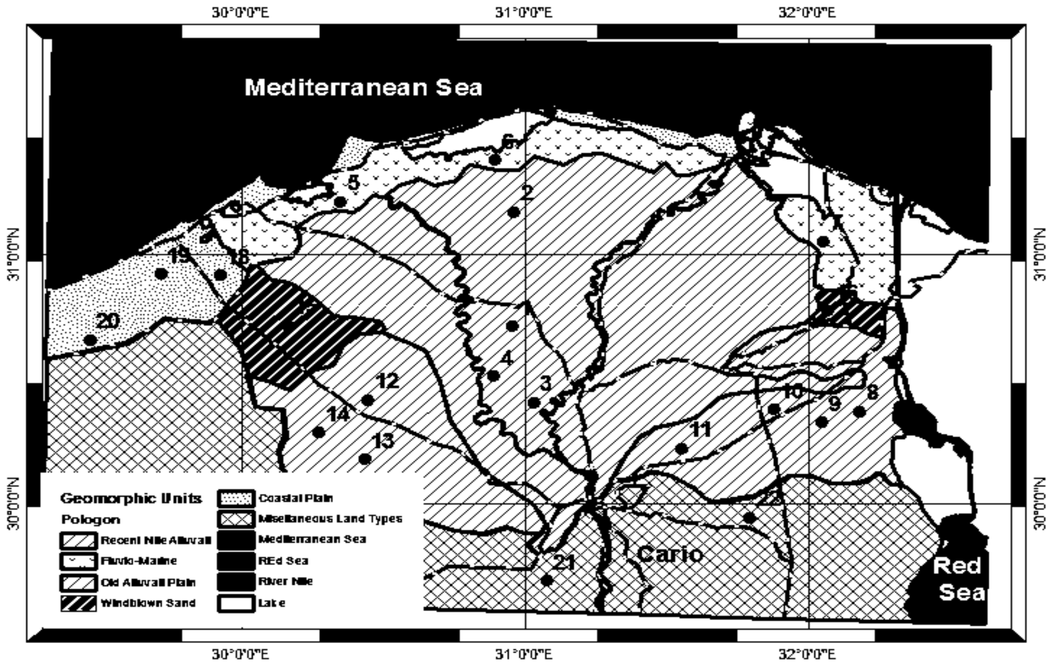

Fig. 1. Main geomorphic units and location of the investigated soil profiles.

According to USDA (2004), the fine earth of soil samples were analyzed for particle size distribution by pipette method; soil reaction (pH) in the saturated soil paste and soil salinity as Electrical Conductivity (ECe) of the saturated soil extract; Cation Exchange Capacity (CEC) and Exchangeable Sodium Percent (ESP) using ammonium chloride solution of pH 8.5; Organic Matter content (OM) using the modified method of Walkley and Black; $CaCO_3$ % by using the Collin's Calcimeter; and gypsum content by precipitation with acetone. The soil profiles were classified to the family level according to the Soil Taxonomy System (USDA, 2014).

2-Land suitability evaluation methods:

Land suitability evaluation for surface irrigation was achieved according to the following systems:

Descriptive methods:

- Suitability evaluation regarding to individual soil characteristics (FAO, 1979).
- Suitability evaluation regarding to land qualities (Sys *et. al.,* 1991).
- The general system of USBR modified by Griffiths (1975).
- USBR system correlated with the FAO land classification (FAO, 1979).

Parametric methods:

- Storie method modified by Nelson (1963).
- Storie Index Soil Rating (1978).
- Sys and Verheye (1974 and 1978) and Sys et al. (1991).

RESULTS AND DISCUSSION

1. Soil characteristics:

The differences in soils are closely associated with variation in its origin that influences the nature of soils, as well as the effect of man through land reclamation. The investigated soils, which extensively mantled with Pleistocene and Holocene epochs, include examples of soils derived from recent Nile alluvial Delta as old cultivated land of Egypt; the old and recent reclaimed soils located in the north along the sea coast and northern lakes as Fluvio-Marine soils; the desert fringes on both sides of the Delta as old alluvial soils; the soils derived from active Aeolian processes as windblown sand soils; the coastal plain soils as depressed Sabkhas and Marine-Lacustrine plain; and Miscellaneous land types. The morphological features, analytical data, and soil taxonomic units characterized the chosen soil profiles were illustrated in Tables 1, 2 and 3, respectively.

2. Suitability evaluation for irrigated agriculture:

The obtained suitability classes by using the investigated methods, which are made on qualitative bases under surface irrigation, are shown in Table (4). Generally, the results indicate different suitability classes between numbers of the examined soil profiles and can be discussed as follows:

a- Descriptive methods:

- The USBR scheme (Griffiths, 1975) is not only concerned with soil conditions but with all the factors which influence the ultimate financial returns once an irrigation schemes is installed. Accordingly, only 3 out of 9 sites that represent the cultivated soil under surface irrigation indicate the same suitability class compared with FAO (1979) method.
- Land suitability regarding to individual soil characteristics (FAO, 1979**)** indicates different classes in 50 % of the examined sites if compared with the land qualities assessment (Sys et al., 1991). There is no clear trend of the more or less grade between the two methods.

Table 1. Morphological features of the investigated soils.

Main Geomorphic unit	**Recent Nile alluvial soils (Nile Delta)**	**Fluvio-Marine soils**	**Old alluvial plain soils**	**Windblown sand soils**	**Coastal plain soils**	**Miscellaneous land types**
Profile No.	1, 2, 3, 4	5, 6, 7	8, 9, 10, 11, 12, 13, 14	15, 16	17, 18, 19, 20	21, 22
Landform elements	Almost flat floodplain (1, 2) or levee (3, 4); 5 to 14 m. above sea level (a.s.l)	Locally lagoons ; < 1.0 m (a.s.l)	Almost flat to undulating old deltaic plain (8), old river terraces (9, 10, 11, 12), valley floor (13), piedmont (14); 30 to 120 m (a.s.l)	Aeolian low sand dunes; 18 to 30 m. (a.s.l)	Depressed sabkha (17) <1.0 m (a.s.l); almost flat to gently undulating marine-lacustrine plain (18, 19, 20), 20 to 28 m. (a.s.l)	Almost flat to gently undulated. denuded rock-land (21) or plateau remnants (22); 150 to 170 m. (a.s.l)
Human influence	Old cultivated, surface irrigation and drainage system.	Relatively old (5,6) or recently cultivated (7), surface irrigation and drainage system	No influence (8,9,11, 12, 13, 14), recently cultivated by sprinkler irrigation (10)	Leveling, surface irrigation (15) or sprinkler irrigation (16)	No influence (17,20), cultivated by sprinkler irrigation (18) or surface irrigation (19)	No influence
Surface characteristics	Wide cracks when dry (1,2,3)	Wide cracks when dry	Few to common gravel (9,10,11,12,13), thin sand sheet (8), few gravel and stones (14)	-	Very few shells (17), common scattered vegetation	Few gravel and stones
Effective soil depth and water table	Very deep; water table >150 cm (1, 3, 4), 120 cm (2).	Moderately deep, water table 65 to 85 cm depth	Very deep, water table >150 cm; moderately deep (14).	Very deep, water table >150 cm.	Moderately deep, water table 60 cm (17); 100cm (19); very deep (18,20).	Moderately deep (21), shallow (22); water table >150 cm.
Surface soil layers, 0-15 to 25 cm	Dark brown clay texture, moderate subangular blocky structure with hard consistence when dry (1, 2, 3), sandy clay loam texture (4)	Very dark grayish brown clay texture, moderate to weak subangular blocky structure with hard consistence when dry.	Yellowish brown to very pale brown, slightly gravel loamy sand to sand texture, massive structure with soft to loose consistence when dry.	Light yellowish brown to brownish yellow sand or loamy sand texture, single grains and loose consistence.	Light yellowish brown sand with few shells (17); yellowish brown sandy loam, massive structure with soft consistence, few lime accum. (18, 19, 20)	Yellowish brown slightly gravel to gravelly sandy loam, massive and soft; few lime accum. (22).
Subsurface layers, 15 to 25 cm up to 100 cm	Dark brown to very dark grayish brown clay, strong angular blocky and clear slickensides up to 60-70 cm.with sticky and plastic when wet (1,2); brown clay loam (3) or sandy loam (4), moderate to weak subangular blocky with slightly sticky and plastic to slightly plastic when wet.	Very dark gray to very dark grayish brown clay with common to abundant mottling, strong angular blocky and clear slickensides up to 55 cm with sticky to very sticky consistence when wet.	Strong brown to yellowish red gravelly to very gravelly loamy sand or sandy loam (8, 9, 10, 11, 14) to sandy clay loam (12, 13); massive structure with soft to hard consistence when dry; few to common lime and gypsum accumulations	Yellow loose sand	Light yellowish gray to brown loose sand with common to many mottling (17); yellowish brown to strong brown sandy clay loam to loam texture with common to many indurated nodules, weak subangular blocky to massive structure, many to common soft lime accumulation.	Dark reddish gray silty clay loam, fine and medium platy structure up to 60 cm over shale clay; common gypsum accum. (21); strong brown sandy loam up to 50 cm over limestone (22).
Substratum > 100 cm depth	As above (1,2,4); yellowish brown sandy loam and weak subangular blocky structure (3)	As above with more stickiness and plasticity and less structure grade.	As above with more coarser texture and less gravel contents; gravelly stony layers (14).	As above	As above with less indurated nodules contents; many gypsum accumulation (20).	Rock

Table 2. Laboratory determinations of the collected soil profile samples.

Prof. No and location	Depth (cm)	Coarse Fragments %	Particle size distribution %				*Texture Class	pH	EC dS/m	O.M %	CEC cmol/Kg soil	ESP	CaCO3 %	Gypsum %
			Coarse sand	Fine sand	Silt	clay								
Recent Nile alluvial soils (Nile Delta)														
1 El-Monofia Gov.	0-20	-	2.7	11.4	32.4	53.5	C	7.9	1.2	1.6	51	4.5	2.4	1.1
	20-60	-	1.9	11.8	30.1	56.2	C	7.8	1.1	1.1	60	3.7	1.4	0.9
	60-150	-	1.8	7.3	33.5	57.4	C	7.7	1.5	1.0	55	5.4	1.7	1.4
2 Kafr Elshikh Gov	0-20	-	1.5	11.9	31.6	55.0	C	7.9	1.3	1.4	55	6.6	2.5	1.2
	20-70	-	0.85	6.55	29.1	63.5	C	7.8	2.09	0.86	81	7.1	2.5	0.7
	70-120	-	0.66	3.84	28.4	67.1	C	7.6	3.26	0.88	68	8.9	1.9	0.8
3 El-Qalubia Gov.	0-20	-	6.5	23.6	25.7	44.2	C	7.8	2.1	1.8	47	3.5	1.5	1.0
	20-50	-	7.1	24.2	33.4	35.3	CL	7.7	1.6	1.1	40	3.5	1.6	0.8
	50-100	-	12.4	26.7	30.1	30.8	CL	7.8	1.5	1.1	36	1.9	2.0	0.8
	100-150	-	22.6	39.6	20.3	17.5	SL	7.5	1.4	0.9	29	1.8	1.9	0.7
4 El-Monofia Gov.	0-25	-	27.3	26.3	20.8	25.6	SCL	7.9	0.9	1.6	32	2.4	1.8	0.9
	25-55	-	45.1	19.5	15.5	17.4	SL	7.8	0.8	0.8	27	2.6	1.5	1.6
	55-150	-	47.6	20.8	21.4	10.2	SL	8.0	0.6	0.7	21	1.6	1.2	0.6
Fluvio-Marine soils														
5 Idkou	0-20	-	1.1	23.0	25.6	50.3	C	7.8	3.7	2.1	44	14.6	4.8	2.2
	20-50	4	2.2	14.5	36.8	46.5	C	8.2	6.3	1.1	51	16.2	3.4	2.9
	50-85	-	0.8	3.8	45.3	50.1	SiC	8.1	5.7	1.1	52	18.1	3.2	1.1
6 Kafr Elshikh Gov	0-20	-	2.5	19.7	33.2	44.6	C	8.0	4.7	1.7	51	11.2	0.6	0.9
	20-55	-	0.6	20.5	31.5	47.4	C	7.9	5.2	1.1	49	13.1	1.7	1.1
	55-80	-	0.8	16.2	29.8	53.2	C	7.9	6.4	0.9	52	14.6	1.1	0.8
7 El-Hasaniya Plain	0-20	-	1.7	11.6	29.3	57.4	C	8.4	15.4	2.3	49	18.1	7.6	0.2
	20-45	-	0.8	4.8	29.2	65.2	C	8.2	5.5	1.4	55	18.0	4.0	0.4
	45-65	-	0.9	5.6	27.4	66.1	C	8.3	7.2	0.9	54	22.3	1.2	0.1
Old alluvial plain soils														
8 Ismaeilya Gov.	0-15	5	56.3	24.4	12.8	6.5	LS	7.9	1.5	0.3	10	1.5	2.2	0.3
	15-60	20	60.4	24.0	6.5	9.1	LS	8.1	5.5	0.4	12	4.1	5.3	0.5
	60-150	8	70.2	12.8	9.5	7.5	LS	8.3	6.1	0.4	9	3.5	3.2	1.2
9 Ismaeilya Gov.	0-15	10	31.3	54.2	8.2	6.3	LS	7.8	13.5	0.4	8	3.8	7.4	0.15
	15-60	45	40.2	50.6	5.1	4.1	S	8.1	11.4	0.2	5	2.5	26.1	0.22
	60-100	30	36.6	45.8	9.2	8.4	LS	7.9	12.8	0.3	9	2.6	19.2	2.3
	100-150	20	37.9	50.7	5.2	6.2	S	8.0	4.4	0.1	4	1.9	15.4	2.8
10 El-Salhia project	0-15	3	40.2	41.9	7.8	10.1	LS	7.9	2.9	1.1	14	6.6	6.5	-
	15-50	10	45.7	37.4	10.4	6.5	LS	8.0	3.1	0.6	9	4.2	7.1	0.6
	50-90	35	33.6	38.6	17.5	10.3	SL	8.1	4.2	0.4	12	5.1	17.2	0.9
	90-150	10	42.3	39.5	8.4	9.8	LS	7.8	2.5	0.5	8	3.8	9.3	0.4

***Texturel class:** (C) clay, (CL) clay loam, (SiC) silty clay, (SCL) sandy clay loam, (SL) sandy loam, (LS) loamy sand, (S) san

Table 2. Cont.

Prof. No. and landform	Depth (cm)	Coarse Fragments %	Particle size distribution %				*Texture Class	pH	EC dS/m	O.M %	CEC cmol/Kg soil	ESP	CaCO3 %	Gypsum %
			Coarse sand	Fine sand	Silt	clay								
Old alluvial plain soils														
11 10th of Ramdan	0-20	5	34.2	49.4	7.1	9.3	LS	7.7	32.3	0.7	8	11.4	3.0	0.1
	20-40	15	62.6	22.0	6.3	9.1	LS	7.6	30.7	0.9	6	9.6	3.5	0.4
	40-80	40	42.3	36.7	5.8	15.2	SL	7.5	39.4	0.4	11	12.1	2.4	0.7
	80-150	15	46.6	42.5	7.5	3.4	S	7.5	16.1	0.2	5	8.2	1.2	2.3
12 El-Sadat City area	0-15	10	31.4	49.9	10.2	8.5	LS	7.7	11.4	0.8	8	8.5	7.3	1.1
	15-45	20	33.2	35.1	18.1	13.6	SL	7.9	20.5	0.5	6	10.4	16.6	2.3
	45-95	42	27.8	31.5	15.4	25.3	SCL	7.8	28.6	0.4	16	12.5	15.4	9.7
	95-150	10	42.4	39.7	12.1	5.8	LS	8.0	21.2	0.2	6	10.6	7.6	1.2
13 Wadi El-Farigh	0-25	30	18.1	51.3	14.2	16.4	Sl	7.8	10.3	0.4	12	5.7	6.1	0.9
	25-80	20	12.3	35.7	21.8	30.2	SCL	7.6	8.6	0.2	18	7.4	3.3	0.4
	80-150	10	20.5	50.3	11.4	17.8	SL	7.7	11.2	0.1	10	8.1	2.4	1.1
14 Wadi El-Farigh	0-20	10	48.3	34.4	8.2	9.1	LS	7.5	17.7	0.1	9	9.2	23.4	1.5
	20-70	40	45.6	29.3	9.8	15.3	SL	7.9	11.3	0.09	13	8.3	16.2	1.7
Windblown sand soils														
15 El-Bostan area	0-20	-	56.7	32.8	3.1	7.4	S	7.9	1.3	1.1	8	6.7	4.1	0.2
	20-60	-	59.6	31.1	3.8	5.5	S	7.8	1.0	0.3	4	5.1	3.5	0.1
	60-150	-	59.8	31.2	3.6	5.4	S	7.8	1.2	0.4	4	5.2	4.4	0.1
16 El-Salhia area	0-15	-	66.7	18.8	5.4	9.1	LS	8.03	3.7	1.05	19	10.1	1.02	0.1
	15-150	-	75.1	16.7	3.3	4.9	S	8.12	1.9	0.54	5	7.4	1.55	-
Coastal plain soils														
17 Kafr Elshikh Gov	0-15	4	30.4	65.1	2.3	2.2	S	7.0	5.6	0.4	3	19.3	0.2	0.6
	15-35	-	33.6	59.9	3.1	3.4	S	7.5	35.5	0.3	4	21.1	0.2	0.5
	35-60	-	35.2	54.9	3.8	6.1	S	7.5	40.8	0.2	4	17.6	0.5	0.4
18 Nubariya Res. Station	0-30	-	40.1	32.1	14.5	13.3	SL	7.7	1.8	0.55	13	2.6	10.4	3.3
	30-70	10	32.4	28.8	16.2	22.6	SCL	8.0	1.9	0.40	18	5.8	16.6	2.1
	70-150	4	28.3	25.2	20.4	26.1	SCL	8.1	2.7	0.40	19	5.3	20.8	2.5
19 Nubariya area	0-25	-	49.6	27.1	12.8	10.5	SL	7.9	3.6	0.65	8	8.4	18.6	1.9
	25-60	5	30.3	51.1	10.2	8.4	LS	7.9	2.5	0.32	5	11.5	20.2	3.6
	60-100	20	35.4	26.2	15.2	23.2	SCL	8.0	4.4	0.24	16	10.1	30.3	4.8
20 South El-Nasr canal	0-15	4	25.4	47.9	14.4	12.3	SL	7.6	7.2	0.3	9	6.6	31.5	0.3
	15-45	20	29.6	33.7	15.1	21.6	SCL	7.6	8.8	0.3	14	7.1	40.2	0.2
	45-80	40	19.2	26.1	32.5	22.2	L	7.6	11.5	0.25	13	7.4	30.1	1.9
	80-150	3	16.2	23.1	35.3	25.4	L	7.7	13.6	0.05	14	7.3	26.3	15.5
Miscellaneous land types														
21 6th of October	0-15	5	44.2	26.1	16.1	13.6	SL	7.7	2.6	0.2	11	7.1	6.3	1.1
	15-60	20	1.6	13.3	48.2	36.9	SiCL	8.3	18.4	0.3	40	14.2	0.9	10.5
22 10th of Ramadan	0-20	20	40.6	32.5	12.6	14.3	SL	7.1	35.4	0.3	13	17.4	3.5	2.3
	20-50	50	48.4	27.7	11.2	12.7	SL	7.2	40.5	0.3	11	19.8	8.8	2.1

***Texturel class:** (C) clay, (CL) clay loam, (SiC) silty clay, (SCL) sandy clay loam, (SL) sandy loam, (LS) loamy sand, (S) sand

Table 3. Soil Taxonomic units of the investigated soil profiles(according to USDA,2014)

Profile No.	Taxonomic unit
Recent Nile alluvial soils (Nile Delta)	
1	Typic Haplotorrerts; fine, smectitic, thermic.
2	Typic Haplotorrerts; very-fine, smectitic, thermic.
3	Typic Torrifluvents; fine-loamy, mixed, superactive, calcareous, thermic.
4	Typic Torrifluvents; coarse-loamy, mixed, superactive, calcareous, thermic.
Fluvio-Marine soils	
5	Sodic Endoaquerts; fine, smectitic, thermic.
6	Typic Endoaquerts; fine, smectitic, thermic.
7	Sodic Endoaquerts; very-fine, smectitic, thermic.
Old alluvial soils	
8	Typic Torriorthents; sandy, mixed, hyperthermic.
9	Typic Haplocalcids; sandy-skeletal, mixed, hyperthermic .
10	Typic Haplocalcids; loamy-skeletal, mixed, superactive, thermic.
11	Typic Torriorthents; loamy-skeletal, mixed, superactive, calcareous, thermic.
12	Typic Calcigypsids; loamy-skeletal, mixed, superactive, thermic .
13	Typic Torriorthents; fine-loamy, mixed, superactive, calcareous, thermic.
14	Typic Haplocalcids; loamy-skeletal over fragmental, mixed, superactive, thermic.
Windblown sand soils	
15	Typic Torripsamments; siliceous, thermic.
16	Typic Torripsamments; siliceous, thermic.
Coastal plain soils	
17	Sodic Psammaquents; siliceous, thermic.
18	Typic Haplocalcids; fine-loamy, mixed, superactive, thermic.
19	Typic Haplocalcids; sandy over loamy, mixed, superactive, thermic.
20	Typic Calcigypsids; fine-loamy, carbonatic, thermic.
Miscellaneous land types	
21	Typic Haplogypsids; fine-loamy, mixed, superactive, hyperthermic.
22	Lithic Torriorthents; loamy-skeletal, superactive, calcareous, thermic.

Table 4. Suitability classes of soil profiles by using the investigated methods.

Profile No.	Descriptive methods				Parametric methods									
	FAO		USBR		Storie				Sys and Verheye				Sys et al.	
	(1979)	Sys et al. (1991)	Griffiths (1975)	FAO (1979)	Nelson (1963)		(1978)		(1974)		(1978)		(1991)	
					Ci	Class	Ci	Class	Ci	Class	Ci	Class	Ci	Class
Recent Nile alluvial soils (Nile Delta)														
1	S2	S2	Class 2	Class 2	71.9	B	68.4	2	76.0	II	70.7	S2	62.9	S2
2	S3	S3	Class 3	Class 3	64.3	C	57.8	3	59.9	III	52.6	S3	44.5	S3
3	S1	S1	Class 1	Class 1	81.9	B	80.0	1	95.0	I	86.3	S1	84.2	S1
4	S1	S2	Class 1	Class 1	84.6	A	100.0	1	71.3	II	75.0	S1	60.0	S2
Fluvio – Marine soils														
5	S3	S3	Class 3	Class 3	42.0	D	47.6	3	39.4	IV	48.5	S3	37.9	S3
6	S2	S3	Class 3	Class 2	42.0	D	51.0	3	45.2	III	46.0	S3	36.3	S3
7	S3	N1	Class 3	Class 3	37.3	D	44.8	3	27.3	V	32.1	S3	22.9	N1
Old alluvial plain soils														
8	S3	S3	Class 3	Class 3	59.4	C	72.2	2	47.2	III	42.4	S3	34.8	S3
9	S3	S3	Class 3	Class 3	40.9	D	34.0	4	28.8	V	25.0	S3	11.6	N1
10	S3	S3	Class 3	Class 3	69.6	B	57.6	3	51.3	III	50.8	S2	29.3	S3
11	N1	S3	Class 3	Class 5	54.7	C	57.8	3	36.8	IV	32.6	S3	24.3	N1
12	N1	S2	Class 2	Class 5	54.7	C	54.7	3	51.8	III	50.0	S2	24.2	N1
13	S3	S2	Class 2	Class 3	58.0	C	56.5	3	61.4	II	57.2	S2	38.7	S3
14	S3	S3	Class 2	Class 3	44.6	D	54.0	3	34.4	IV	28.3	S3	19.1	N1
Windblown sand soils														
15	Sc	N1	Class 4	Class 4	41.7	D	60.0	2	25.7	V	25.7	S3	27.0	S3
16	Sc	N1	Class 4	Class 4	50.6	D	57.0	3	27.6	V	26.1	S3	25.9	S3
Coastal plain soils														
17	N1	N1	Class 5	Class 5	33.6	D	28.5	4	8.0	V	8.0	N2	8.5	N1
18	S2	S2	Class 2	Class 2	67.0	C	68.9	2	83.6	I	85.8	S1	58.1	S2
19	S2	S2	Class 2	Class 2	67.0	C	60.8	2	58.1	III	53.6	S2	42.9	S3
20	S3	S2	Class 2	Class 3	58.1	C	62.0	2	57.5	III	55.4	S2	34.3	S3
Miscellaneous Land types														
21	Sc	S3	Class 4	Class 4	29.7	E	27.4	4	30.0	IV	32.2	S3	31.6	S3
22	N1	S3	Class 4	Class 5	30.6	D	27.0	4	18.0	V	16.0	N1	8.9	N1

Where :

FAO (1979)

S1	Highly suitable
S2	Moderately suitable
S3	Marginally Suitable
Sc	Conditionally Suitable
N1	Currently not Suitable
N2	Potentially not suitable

USBR related to FAO (1979)

Class 1	Highly suitable
Class 2	Moderately suitable
Class 3	Marginally suitable
Class 4	Special use land
Class 5	Non- arable (requires further studies)

USBR (Griffiths, 1975)

Class 1	Highly suitable
Class 2	Suitable
Class 3	Moderately suitable
Class 4	Marginally suitable
Class 5	Unsuitable

Storie (Nelson, 1963)

Class	Capability index (Ci)
A	85 – 100
B	70 – 84
C	55 – 69
D	30 – 54
E	< 30

Storie (1978)

Class	(Ci)
1 (Excellent)	80 - 100
2 (Good)	60 – 79
3 (Fair)	40 – 59
4 (Poor)	20 – 39
5 (Very Poor)	10 – 19
6 (Non agricultural)	<10

Sys and Verheye (1974)

Class	(Ci)
I (Excellent)	>80
II (Suitable)	60 – 80
III (Slightly suit.)	45 – 60
IV (Almost unsuitable)	30 - 45
V (Unsuitable)	< 30

Sys and Verheye (1978) & Sys et al. (1991)

Class	(Ci)
S1 (Highly suitable)	>75
S2 (Moderately suitable)	50 - 75
S3 (Marginally suitable)	25 - 50
N1 (Currently not suitable)	< 25
N2 (Potentially not suitable)	

b- Parametric methods:

- The potential suitability of the two Storie methods indicate different grade in 50 % of the sites. The differences are mainly due to the relatively high rating of the character of soil profile in the Stroie method (Storie, 1978) and also for the range of the capability index grades.
- The current suitability of the Sys methods indicate similar classes in only 6 out of the 22 examined sites most of them in the Nile Delta soils. The proposed rating of Sys *et. al.* (1991) records the lowest suitability indices while Sys and Verheye (1974) indicates the highest one.

c- Descriptive and parametric methods:

- 14 sites indicate almost similar classes between Griffiths (1975) and Storie (1978). The differences were observed in 8 sites represent windblown sand and most of the old alluvial soils. The different are more clear with Storie (1963) method.
- 11 sites of Sys and Verheye (1974), 14 sites of both Sys and Verheye (1978) and Sys *et. al.* (1991) methods indicate almost similar classes of the descriptive FAO (1979), but with no clear trend observed for soil nature or profile numbers.
- The descriptive method regarding to land qualities and that of parametric individual soil characteristics (Sys *et. al*, 1991) indicate different classes in 10 sites and the more suitability classes were observed in the descriptive one.

According to the differences of the above-mentioned results, it could be concluded that the rating values in some soil factors need more modification to reduce the gap between them.

3. Proposed modifications of soil rating:

- The proposed rating of the parametric land suitability evaluation for irrigated agriculture is listed in Table (5). It depends mainly on the principles of land classification in arid and semi-arid regions that discussed by the working group acting at the International Training Center for Post-graduate Soil Scientists (Sys and Verheye, 1972). Also, the concepts of FAO Framework (1976) and Storie methods (1954 and 1978) as well as Sys *et. al.* (1991 and 1993) were taken into consideration. The proposed modifications of some soil factors imply the respect of the following:
- The rating values are assigned to the characteristics of the soil itself; including the more stable characteristics (factor a), the relatively less stable characteristics (factor b), surface characteristics (factor c) and the miscellaneous (factor x). The later factor which includes erosion hazard and soil fertility could be used only if necessary. The fertility criteria are not directly considered indeed, as weathering stage of arid lands is always in a recent stage, the apparent cation exchange capacity is high to medium. Base saturation is always high and a disturbed cation balance is going to be considered by other characteristics (Sys, 1980).

Table 5. The proposed land suitability rating chart for irrigated agriculture.

Factor (a) : More stable soil profile characteristics				
Soil characteristics	**Rating scale %**			
	Surface irrigation	**Sprinkler Or drip irrigation**	**Specific crops**	
-<u>Soil texture including gravel:</u> <u>Fine-loamy</u> CL,SiCL (18-35% clay)-SCL-L, SiL, SL (>18% clay). With <15% coarse fragm. 15-35%	100-90 90-80	100-90	100-90	Groundnuts,sesame,carrot,onion, green pepper, cabbage, watermelon, potato, olives, citrus, mango.
35-60 %	80-70	90-80		
60-90 %	70-50	80-60	90-70	
<u>Fine - clayey</u> CL,SiCL (>35% clay)-C (<60%)-SiC, SC With <15% coarse fragm. 15-35%	90-80 80-75		100-90	Rice, sugar beet, sugar cane, clover, alfalafa, cotton, soya, barley, wheat, maize, sorghum, cowpea, beans, pea, sunflower, guava, banana.
35-60 % 60-90 %	75-70 70-50		90-80 80-60	
<u>Coarse –loamy</u> L, SiL,SL(<18% clay) With <15% coarse fragm. 15-35% 35-60 % 60-90 %	85-70 70-60 60-50 50-30	90-80 80-70 70-60 60-40	95-85 85-75 75-65 65-50	Groundnuts, sesame, carrot, onion, green pepper, cabbage, watermelon, potato, olives, mango, citrus.
<u>Very fine-clayey</u> C (>60%) With <15% coarse fragm. 15-35% 35-60 % 60-90 %	80-70 70-65 65-60 60-50		100-95 95-90 90-85 85-70	For rice
<u>Sandy</u> LfS, LS, LcS, fS, S, cS. With <15% coarse fragm. 15-35% 35-60 % 60-90 %	60-35 50-30 40-25 25-20	85-60 75-55 65-50 50-45	90-65 80-60 70-55 55-50	Groundnuts, sesame, watermelon, potato, olives, citrus, mango.

Table 5. Cont.

Factor (a) : More stable soil profile characteristics				
Soil characteristics	**Rating scale %**			
	Surface irrigation	**Sprinkler or drip irrigation**	**Specific crops**	
- Soil depth: >150 cm (1) >100cm (2) >75 cm (3)	100-95			
150- 100cm (1) 100-75 cm (2) 75-50 cm (3)	95-85		100-90	Cabbage, potato, cowpea, pea, beans, onion, sorghum, barley, wheat, maize, groundnuts, sesame, guava, grape, banana.
100-50 cm (1) 75- 50 cm (2) 50-25 cm (3)	85-60		90-80	Cabbage, cowpea, sorghum, barley, wheat, potato, onion, guava.
< 50 cm (1) <50 cm (2) <25 cm (3)	60-25		80-60	Sorghum, cabbage, barley, wheat, onion, guava.
(1) Rock or hardpan. (2) >50% lime or >40% gypsum. (3) > 90% gravel				
Lime content: 1-15 %	100-95		100-90	Olives, grape, barley, wheat, sorghum, groundnuts.
<1 % 15-35 %	95-85			
35-50 %	85-75			
Gypsum content: <1 %	95	95	100	Beans, banana, carrot, citrus, green pepper, mango, onion, soya, tomato.
1-10 %	100	100	100-80	
10-15 %	95		80-60	
15-40%	95-50	100-80	60-40	

Factor (b): Relatively less stable characteristics.				
Soil characteristics	**Surface irrigation**	**Sprinkler or drip irrigation**	**Perfect drainage system**	**Specific crops**
-Wetness: Well drained. Water table >150 cm; Permeability > 6 cm/h	100-90	100-90	100-85	100-90 For rice
Moderately Well drained. Water table 150-100 cm; Permeability 6-2 cm/h	90-70			
Imperfectly drained. Water table 100-50 cm; Permeability 2-0.6 cm/h	70-40	90-75		
Poorly drained. Water table <50 cm; Permeability <0.6 cm/h	40-15	75-55	85-65	90-75

Table 5. Cont.

Factor (b): Relatively less stable characteristics.

-salinity and sodicity	Currently rating	Rating after soil reclamation	
		Well and moderately well drained soils	Imperfectly and poorly drained soils
< 4 dS/m with <15 % ESP >15 % ESP	100-95 95-75	100	100-95
4-8 dS/m with <15 % ESP >15 % ESP	95-85 85-65	100	95-90
8-16 dS/m with <15 % ESP >15 % ESP	85-75 75-55	100	90-85
16-32 dS/m with <15 % ESP >15 % ESP	75-65 65-45	100	85-80
>32 dS/m with <15 % ESP >15 % ESP	65-55 55-35	100	80-75

Factor (c): Surface characteristics.

Topography and slope	Surface irrigation	Sprinkler or drip irrigation	-Stony surface	Currently rating	After land cleaning
< 2 % 2 -5 % 5 - 10 %	100-95 95-85 85-60	100-95	< 5 % (distance > 20 cm) 5-15 % (distance 20-5 cm) 15-40 % (distance 5-2 cm) > 40 % (distance < 2 cm)	100 95 95-75 < 75	100
10-15 % > 15 %	60-45 < 45	95-80 < 80			

Factor (X): Miscellaneous characteristics

- Soil fertility		- Erosion	
Apparent CEC > 24 cmol/kg clay Base saturation > 60 % Sum of basic cations > 5 cmol/kg soil	100-90	Non to slight Moderate Severe	100-95 95-90 90-85
Apparent CEC 24-16 cmol/kg clay Base saturation 60-30 % Sum of basic cations 5-3 cmol/kg soil	90-60		

- The guidelines for soil profile description and the criterias of soil taxonomic units in both American and FAO systems were used as limits of soil characteristics rating. For example, the 15 – 40 % as many stony surface; 5 – 10 % as undulating topography; texture classes were grouped under the soil family names; more than 35 % coarse fragments as very gravelly and skeletal particle-size class; 15 % or more gypsum as gypsic mineralogy class and gypsic horizon according to FAO (1998) system; 40 % or more gypsum and more than 90% coarse fragments as gypseous and fragmental substitutes particle-size classes, respectively; 15 % or more and 50 % or more lime as calcic and hypercalcic horizons, respectively.

- The weighted average of soil characteristics were evaluated to a depth of 1.5 meter for texture and to 1-m. for lime, gypsum and salinity contents. The soil profiles with stratified or heterogeneous layers were subdivided to the surface 0-25 cm, 25-50 and 50-100 cm as soil control section, and 100-150 cm as substratum layers. The weighted average of these 4 sections is recalculated according to soil profile depth as the following:

>100 cm	**0-25 × 1.75, (43.75)**	**25-50 × 1.25, (31.25)**	**50-100 × 1, (50)**	**100-150 × 0.5, (25)**
50-100 cm	**0-25 × 1.5, (37.5)**	**25-50 × 1, (25)**	**50-100 × 0.75, (37.5)**	
25-50 cm	**0-25 × 1.25, (31.25)**	**25-50 × 0.75, (18.75)**		
0-25 cm	**0-25 × 1, (25)**			

- The suitable rates were chosen within the rating range in the table that arranged descendingly for each soil characteristics. For example, the rating scale of the sandy family class with less than 15 % c.f. ranges from 60 – 35 % were arranged desendingly for LfS, LS, LcS, fS, S and cS texture classes. The highest rate refers to LfS while the lowest one is for cS and the other classes are between by its arrangement. Also, the 60 % rate of LfS decreases gradually by increasing gravel content and reaches to 50 % that refers to the highest rate of the some texture with 15 – 35 % c.f.

- The rating of soil characteristics within each factor were multiplied together and the Storie Land Index is used to obtain the overall index by multiplying **factor (a) x factor (b) / 100 x factor (c) / 100 x factor (x) / 100** .

Six suitability classes were proposed having suitability indices (Si) as follows:

S1 (Si ≥ 80) Highly Suitable S4 (20 – 39) Marginally Suitable

S2 (60 - 79) Suitable SC (10 – 19) Conditionally Suitable

S3 (40 - 59) Moderately SuitableN (Si < 10) Unsuitable

The conditionally Suitable class (SC) is considered as the special use class in the USBR scheme, or by definition in the FAO Framework (1976) as a phase of land suitability order Suitable, employed in circumstances where small areas of land within the survey are poorly suitable for a particular use under the management specified for that use.

- The proposed system is listed in one chart to serve-in some extend-the qualitative land suitability concerned with the objectives of the evaluation. The chose of rating depend upon the current or potential suitability as well as the level of intensity of the survey.

4. Application of the proposed rating:

By using the proposed rating, the obtained current land suitability of the investigated soil profiles are shown in Table (6). The suitability classes refer to its present condition as virgin soils (10 sites) and cultivated (12 sites) either with existing or improved management practices. The results indicate the following:

- Suitability classes of the cultivated surface irrigation soils (9 sites) are almost similar to that obtained by the USBR quantitative base (Griffiths, 1975) and potential Storie (1978) methods. The less suitability grade were observed only in the recently reclaimed soils (site 7) and also in the insufficient soil drainage system (site 19). For comparison, the Sys methods which assessment under the same soil factors indicate only 3 or 2 out of these 9 sites similar to USBR and Storie methods.

- Only one site indicates unsuitable class which in agreement with the USBR and Storie methods, while most of the investigated other methods indicate 4 to 7 unsuitable class. Also, the proposed rating correct in some extent the differences between the Sys methods in most the investigated sites (Table 7). It is more closer to the average of the three Sys methods with exception the Recent Nile alluvial and windblown sand soil sites which indicate more high indices. These results are more reliable under the conditions prevailing in the soils of Egypt.

- According to the structure of the FAO Framework (1976), the symbols of both suitability subclasses and units are shown in Table (6). It reflects kinds of limitations and minor aspect of their management requirements. The using of such symbol depends upon the level of survey study and the objectives of land evaluation.

In conclusion, such data can be used for a qualitative evaluation in the pre-project, reconnaissance and even detailed phase of the survey. It will further help to select the most suitable lands for certain irrigation,system for which the economic land evaluation has to be made during the feasibility study. Also, it should be mentioned that neither land use requirements nor specific crop requirement are absolute data, both may be modified by different systems of land management. Similarly, land conditions are often not completely fixed, but may be modified by systems of management, e.g. the application of water and/or fertilizers, or by methods of land improvements, e.g. leaching of salts, methods of drainage, deep plowing of soils and removal of hardpans.

Table 6. Suitability evaluation of the investigated soils by using the proposed rating

Profile No	**Factor (a)**				**Factor (b)**		**Factor (c)**		**Land suitability**			
	Soil Texture	**Soil depth**	**Lime content**	**Gypsum content**	**Wetness**	**Salinity and**	**Topog. and**	**Stony surface**	**Index (Si)**	**Class**	**Sub class**	**Unit**
Recent Nile alluvial soils (Nile Delta)												
1	83.0	100	100	100	90	100	100	100	74.7	S2	S2a	S2a-1
2	78.5	100	100	100	80	95	100	100	59.7	S2/S3	S2/S3ab	S2/S3ab-1
3	92.0	100	100	98	100	100	100	100	90.2	S1	-	-
4	80.4	100	100	100	100	100	100	100	80.4	S1	-	-
Fluvio-Marine soils												
5	82.3	100	100	100	63.0	80.0	100	100	41.5	S3	S3ab	S3ab-2
6	85.0	100	100	100	65.0	85.0	100	100	47.0	S3	S3ab	S3ab-2
7	78.2	100	100	95	50.0	70.0	100	100	27.4	S4	S4ab	S4ab-1
Old alluvial soils												
8	52.5	100	97	95	100	97	97	100	45.5	S3	S3a	S3a-1
9	40.3	100	90	95	100	80	82	100	22.6	S4	S4abc	-
10	79.3	100	100	95	100	100	100	100	75.1	S2	S2a	S2a-2
11	51.1	100	97	95	100	65	97	100	29.7	S4	S4ab	S4ab-2
12	64.7	100	95	100	92	70	90	100	35.6	S4	S4ab	S4ab-3
13	76.8	100	100	95	90	83	95	100	51.8	S3	S3ab	S3ab-3
14	55.0	93	90	100	90	80	90	100	29.8	S4	S4ab	S4ab-3
Windblown sand soils												
15	39.0	100	100	95	100	100	100	100	37.1	S4	S4a	-
16	67.0	100	96	95	100	97	100	100	59.3	S2/S3	S2/S3a	S2/S3a-2
Coastal plain soils												
17	41.0	100	95	95	48	50	100	100	8.9	N	Nab	-
18	90.6	100	93	100	100	100	100	100	84.3	S1	-	-
19	72.7	100	90	100	70	97	100	100	44.4	S3	S3ab	S3ab-4
20	80.7	100	85	100	95	85	90	100	49.9	S3	S3ab	S3ab-4
Miscellaneous land types												
21	75.4	65	100	100	60	77	95	100	21.2	S4	S4ab	S4ab-4
22	57.8	60	100	100	70	55	90	100	12.0	SC	SCab	-

S1 Highly suitable (Si ≥ 80)
S2 Suitable (Si 60-79)
S3 Moderately suitable (Si 40-59)
S4 Marginally suitable (Si 20-39)
SC Conditionally suitable (Si 10-19)
N Unsuitable (Si < 10)

Table 7. The relation between the proposed suitability index and the indices of Sys methods

Profile No.*	Average of Sys methods	1974	1978	1991	Proposed index
Recent Nile alluvial soils					
1	69.9	+6.1	+0.8	-7.0	+4.8
2	52.3	+7.6	+0.3	-7.8	+7.4
3	88.5	+6.5	-2.2	-4.3	+1.7
4	68.8	+2.5	+6.2	-8.8	+11.6
Average	**69.9**	**+5.7**	**+1.3**	**-7.0**	**+6.35**
Fluvio-Marine soils					
5	41.9	-2.5	+6.6	-4.0	-0.4
6	42.5	+2.7	+3.5	-6.2	+4.5
7	27.4	-0.1	+4.7	-4.5	0.0
Average	**37.3**	**0.0**	**+4.9**	**-4.9**	**+1.3**
Old alluvial plain soils					
8	41.5	+5.7	+0.9	-6.7	+4.0
9	21.8	+7.0	+3.2	-10.2	+0.8
11	31.2	+5.6	+1.4	-6.9	-1.5
12	42.0	+9.8	+8.0	-17.8	-6.4
13	52.4	+9.0	+4.8	-13.7	-0.6
14	27.3	+6.7	+1.0	-8.2	+2.5
Average	**36.0**	**+7.4**	**+3.3**	**-10.6**	**-0.17**
Windblown sand soils					
15	26.1	-0.4	-0.4	+0.9	+11
Coastal plain soils					
17	8.2	-0.2	-0.2	+0.3	+0.7
19	51.5	+6.6	+2.1	-8.6	-7.1
20	49.1	+8.4	+6.3	-14.8	+0.8
Average	**36.2**	**+5.0**	**+2.8**	**-7.6**	**-1.8**
Miscellaneous land types					
21	31.3	-1.3	+0.9	+0.3	-10.1
22	14.3	+3.7	+1.7	-5.4	-2.3
Average	**22.3**	**+1.2**	**+1.3**	**-2.6**	**-6.2**

*Without the sprinkler and drip irrigation sites.

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نموذج معدل لتقييم صلاحية الأراضى للزراعة المروية

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التعديلات المقترحة لتقديرات صفات التربة تم إجراءها بدراسة مقارنة بين الطرق المستخدمة فى تقييم صلاحية الأراضى للزراعة المروية بالمناطق الجافة وشبة الجافة. وتم إختيار ٢٢ قطاع تربة تمثل بعض الأراضى بالوحدات الجيومورفولوجية الرئيسية بدلتا النيل والحواف الصحراوية المتأخمة لها فى مصر. وقدرت صلاحية تلك القطاعات باستخدام المعدلات الحسابية لأنظمة Sys , Storie وكذلك النظم المعتمدة على الصفات الوصفية للــ USBR , FAO .

وقد أظهرت النتائج عن وجود إختلافات فى درجات الصلاحية سواءا بالطرق الوصفية أو الحسابية. والتعديلات التى إجريت على تقديرات صفات التربة تم الأخذ فى الاعتبار بها القواعد والأسس الخاصة بتقسيم أراضى المناطق الجافة وشبه الجافة، والتصورات الخاصة بإطار تقييم الأراضى للــ FAO ، وطرق Sys, Storie ، وكذلك على حدود أدلة وصف قطاعات التربة ومعايير وحدات تصنيف التربة. وقد إشتملت قائمة تقديرات التربة على الصفات الأكثر ثباتا (factor a) ، والصفات الأقل ثباتا نسبيا (factor b) ، وصفات سطح التربة (factor c) ، وصفات أخرى مختلفة (factor x) . وتم حساب دليل الصلاحية (Si) المعبرة على درجاتها كما يلى:

Si = factor (a) x factor (b) / 100 x factor (c) / 100 x factor (x) / 100

حيث:

S1 (80 ≤ Si) عالية الصلاحية — S4 (20 – 39) هامشية الصلاحية

S2 (60 - 79) صالحة — SC (10 – 19) صالحة تحت شروط

S3 (40 - 59) متوسطة الصلاحية — N (10 > Si) غير صالحة

وبإستخدام التعديلات المقترحة، كانت النتائج اكثر وثوقا فى التطبيق والتقييم الوصفى لكل من درجات الصلاحية الحالية والمتوقعة لتناسب الدراسات الاولية والاستكشافية وكذلك الأكثر تفصيلا لمستويات حصر الأراضى.