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Potentiality of Land and Water Resources in African Sahara: A Case Study of South Egypt

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Abstract: The investigated area is located South Egypt, between latitudes 22° 00- and 24° 15- N and longitudes 28° 00- and 30°00- E. It covered a total area of about 95000.17 Km². The area was remotely sensed to identify landscape and its land and water resources. A reconnaissance survey followed by detailed one was done to verify the information resulted from satellite images. The prevailing deposits of the area could be expressed as 1-The Nubian sandstone. 2- The Quaternary sediments. 3- The sand-dunes belt. Fourteen main and sub-main landforms were recognized i.e. sand sheets (high, moderately high, moderate and low), depressions (high, moderately high, moderate and low), dry valleys, peniplains, footslopes, barchans, tablelands and scattered hills. Associated soils were distinguished and classified as Typic Torripsamments, Typic Haplocalcids, Typic Torrifluvents and Typic Haplodurids,. Spatial variability of soil and water characteristics was identified through using ordinary kriging interpolation method. Land surface temperatures in both summer and winter seasons were derived from thermal band and soil temperature regime were defined digitally as Hyperthermic. Water potentiality was identified and classified according to salinity and sodicity hazards to C2-S1 and C3-S1. Using GIS techniques Soil and water Potentiality Spatial Model (SWPSM) was designed to get potentiality classes for agricultural planning i.e. 1st, 2nd, 3rd, 4th and 5th grades.

Key words: Sahara · Remote sensing · GIS · Geology · Geomorphology · Land · Water resources · Spatial model

INTRODUCTION

African Sahara is a vast desert of northern Africa extending east from the Atlantic coast to the Nile Valley and south from the Atlas Mountains to the region of the Sudan (The free dictionary, 2010).The Sahara regions of northern Africa have complex environmental histories punctuated by sudden and dramatic regime shifts in climate and ecological conditions. Sahara regime was resulted from the sudden transition from vegetated to desert conditions about 5500 years ago. Explanations for climatic changes in northern Africa during the Holocene have suggested that millennial-scale changes in the Earth's orbit could have caused the wet conditions that prevailed in the early Holocene and the dry conditions prevalent today [1]. Since early 1970s, climate variability in Africa, particularly Saharan regions has shown a marked decline in rainfall and hydrometric series leading to an observed average decline in discharge of some watercourses in the range of 40-60 % [2]. Climate change will likely to reduce crop yields and exacerbate the risk of food insecurity in Africa [3]. Rainfall in the Western Desert of Egypt (Sahara) is very rare and occurs mainly from cyclonic winter storms, which could occur once every 10-20 years [4, 5]. Estimates predict economic losses as a result of climate change as up to 14 % of the African GDP if adaptation measures fail to be implemented [6, 7]. Integrative indicators of the current status of the agricultural production capacity of land and their change over time are needed [8]. Soil and water data are spatial in nature and they can be easily handled and analyzed using Remote Sensing (RS) and Geographic Information System (GIS) [9]. Advantages in use of RS&GIS in handling soil and water data are demonstrated in the current work specifying East Oweinat and West Tushka basin in the heart of Sahara south Egypt as a case study representing African Sahara. The current investigation, as an inventory of soil and water resources, aims at 1-identifying soil and water resources for the purpose of agricultural development. 2-designing Soil and Water Potentiality

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Spatial Model to be used as a prototype for evaluating the resources in Saharan country i.e., Egypt, Sudan, Libya and Chad that share in the Nubian sandstone aquifer in addition to the great similarity in, climate, landforms and associated soils.

MATERIALS AND METHODS

Description of the Investigated Area: The investigated area is located south Egypt, between latitudes 22° 00′ and 24° 15′ N and longitudes 28° 00′ and 30°00′ E. It covers a total area of about 95000.17 Km^2 representing part of the African Sahara. The adjacent areas are represented by Tushka basin on the East, Gebal El-Oweinat on the West, El-Dakhla Oasis on the North and the Egyptian-Sudanese borders on the South. Fig. (1) shows location of the study area. The study area is characterized by extreme aridity, virgin soils and huge storage of water resources. Topographically, the elevation of the area varies from 200 to 300 m. a.s.l and the general slope of land decreases from south to north and from both western and eastern borders toward the centre. Its micro-relief varies considerably from almost flat to undulating with scattered escarpments and isolated mounds.

Field Survey and Laboratory Analyses: Field survey was conducted through the project land and water resources of Egypt [10], using gridding system. Soil profiles were dug to depth of 150 cm, unless obstructed or hindered by bedrock. The total number of observation points was 688 (60 soil profiles, 600 augers and 28 mini pits). The soil profiles were thoroughly examined and morphologically described in the field according to the system outlined by FAO [11].

Samples that representing the subsequent variations within the soil horizons were collected. Electric conductivity (EC dS/m), soluble cations and anions, $CaCO_3$ %, O.M %, pH, Exchangeable. Na^+ and CEC (cmol+/Kg), were determined according to Bandyopadhyay, [12]. Soil color (wet and dry) was identified with the aid of Munssel color charts, Soil Survey Staff [13]. Eighty four water samples were collected from around the area for chemical analyses according to Nollet, [14]. Chemical analyses of water were determined including soluble cations and anions, total dissolved salts (TDS) and pH . Sodium Adsorption Ratio (SAR) was calculated using the formula $SAR = Na^+/(Ca^{++} + Mg^{++} / 2)^{0.5}$.

Digital Image Processing: Digital image processing of Landsat 7.0 ETM+ satellite images (Table 1) that acquired year 2005 was executed using ENVI 4.6 software [30]. Analyses included 1-pre-processing of: data that represented by calibration to radiance according to Lillesand and Kiefer [15], data manipulation (image stretching, filtering and histogram matching) and atmospheric correction using FLAASH module. 2-post processing was represented by rectification of satellite images, data fusion according to Ranchin and Wald [16], producing image mosaics from Landsat 7.0 ETM+ satellite images. ASTER DEM from ASTER images was generated to improve the accuracy of 25 meter topographic maps scale 1:50000.Additional spot heights collected from the field by using total station STONEX STS02 (accuracy 2 mm) were spatially added for deriving Digital Elevation Model (DEM) with high accuracy and finally land surface temperature (LST) were extracted from thermal bands (6.1) through three steps. The first step was to convert the

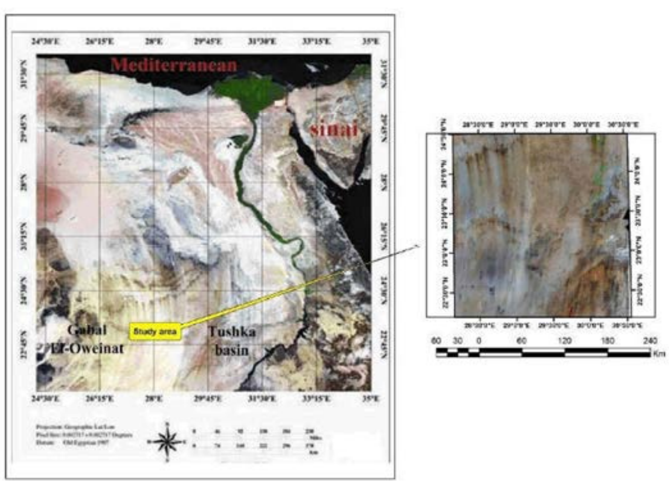

Fig. 1: Location of the study area

Table 1: ETM+ satellite images parameters

Satellite type	Path	Row	Acquisition date	Path	Row	Acquisition date
ETM+	176	43	2005-07-14	177	43	2005-08-12
ETM+	176	44	2005-07-14	177	44	2005-08-12
ETM+	176	43	2005-12-27	177	43	2005-12-18
ETM+	176	44	2005-12-27	177	44	2005-12-18

DNs to radiance values in mW/ (m^2.sr.cm) using the bias and gain values as follows: **$CVR= G * (CV_{DN}) + B$**, where: CVR is the cell value as radiance, CV_{DN} is the cell value digital number, G is the gain, B is the bias. The second step was to convert the radiance data to degrees in Kelvin as follows: **$T = K2 / \ln (K1 / CVR + 1)$**, where: T is degrees Kelvin, CVR is the cell value as radiance, K1 is 666.09 and K2 is 1282.71. The third step was to convert T from degrees Kelvin to degrees Celsius as follows: **T Celsius = T degrees Kelvin - 273.15**.

Geostatistical Analysis: Spatial variability of soil and water characteristics was obtained by ordinary kriging interpolation method, ESRI [17].

Potentiality Spatial Model (SWPSM): SWPSM was designed to get potentiality classes for agricultural planning using spatial analysis tools in ARCGIS environment, ESRI [17].

RESULTS AND DISCUSSIONS

Geology and Pedogeomorphology: Majority of the surface area was occupied by an overwhelming Mesozoic sandstone body attributed to the Nubian sandstone. However, this section was masked, at considerable parts of the area by the overlying Quaternary deposits. It was also hidden in the eastern part of the area under a tongue of younger sediments. The basement rocks were outcropping at some localities. Smaller basement occurrences were scattered in the areas, Klitzsch and List [18], Klitzsch *et al*. [19]. The prevailing deposits could be expressed as follows:

The Nubian sandstone section overlaid uncomfortably the basement complex throughout the studied area. It was uncomfortably overlain at considerable parts of the area by Quaternary deposits and was uncomfortably overlain by shale in a limited stretch in the East. The Nubian sandstone was composed lithologically of a succession of sandstone beds. The succession contained interbeds of sandy clay, siltstone and clay.However, the Nubian succession in the southern parts of the area was almost devoid of significant clay intercalations, yet clay beds develop and increase in number and thickness toward the north.

The Quaternary sediments were found, to a considerable extent, in the area, topping the Nubian sandstone. They were represented by aeolian sand and sand accumulations, sand-dunes, salt crusts and lake deposits. Aeolian sands were composed of loose, mostly fine, wind-blown sand, founded either in the form of thin sheets covering the flat tracts as accumulations filling the topographic lows. The sand-dunes were either forming continuous belts or isolated crescentic sand-dunes. Soil geomorphology is basically an assessment of the genetic relationship of soils and landforms [20]. These landforms and their associated soils that were classified according to Keys of Soil Taxonomy, USDA, [21] could be presented as follows:

Sand sheets as a geomorphologic unit are flat or gently undulating broad floors with little rock exposure. Sand sheets were mainly derived from Nubian sandstone scattered over the whole area, [22]. This landform could be subdivided into four subunits i.e. high (6581.75 km^2), moderately high (6412.78 km^2), moderate (7797.71 km^2) and low (5902.87 km^2). Associated soils could be presented as follows:

- High sand sheets have deep loamy sand profiles (>150 cm), salinity (EC) was low (2.15 to 4.00 dS/m). Soil reaction (pH) was mild in many locations, (7.06 to 8.10). Organic matter (OM) content was moderate (relative to draught conditions in Sahara) (1.10 to 1.60. %). $CaCO_3$ content was low (1.06 to 3.33 %). Cation Exchange Capacity (CEC) was moderate to high in such texture and organic content (8.00 and 14.00 cmol+/Kg. Exchangeable sodium percentage (ESP) was almost moderate (4.2 to 10.1). Soils of this unit could be classified as *Typic Torripsamments.*
- Moderately high sand sheets are moderately high deep soils almost sandy with some layers of loamy sand textured (110-120 cm depth), EC was low (3.1 to 4.2 dS/m). pH was neutral with few exception (7.06 to 8.10). OM content was moderate (1.10 to 1.36. %). $CaCO_3$ content was very low (1.01 to 2.33 %). CEC was low to moderate in such texture and O.M content (5.00 to 12.30 cmol+/Kg). ESP was moderate (5.6 to 10.2). Soils of this unit could be classified as *Typic Torripsamments*.

- Moderate sand sheets (75 cm thick) Soils have moderately deep profile almost sandy with some loamy sand layers; EC was slightly moderate (4.00 to 5.10 dS/m). pH was neutral (7.34 to 7.88). OM content was moderate (0.70 to 1.0 %). $CaCO_3$ content was low (1.0 to 4.33 %). CEC ranged between 6.00 and 12.70 cmol+/Kg. ESP was high (7.10 to 14.7). Soils of this unit could be classified as *Typic Torripsamments*.
- Low sand sheet was composed of gently inclined or nearly horizontal layers, (65 cm). It was limited by parent material. Soils have low elevated sandy profiles (around 65 cm depth) a lithic contact within 50 cm of the topsoil was found. EC was low to moderate (3.2 to 6.6 dS/m). pH ranged between 7.41 and 8.10. OM content was low (0.10 to 0.58. %). CEC ranged between 5.00 and 8.00 cmol+/Kg. ESP was high to very high (10.60 to 24.29). Soils of this unit could be classified as *Lithic Torripsamments*.

Depressions are low lying deflated area, called also blowouts. They are similar to hollows formed by the removal of particles by wind. Blowouts are generally small, but may be up to several kilometers in diameter. Some depression in the studied area were formed by tectonic movements in the past and recently reshaped by deflation processes which act as the removal of loose, fine-grained particles by the turbulent eddy action of the wind and by abrasion and wearing down of surfaces by the grinding action and sand blasting of windborne particles. Depressions could be subdivided into four subunits i.e. high (5689.61 km^2), moderately high (4608.76 km^2), moderate (3837.04 km^2) and low (3532.56 km^2).

- High depressions were characterized by relatively deep soils where soil depth ranged between 100 and 110 cm. sandy to loamy sand textured profiles, EC was low to slightly moderate (4.34 to 5.57 dS/m). pH was mild (7.06 to 7.90).OM content was slightly moderate (1.10 to 1.40.%). $CaCO_3$ content was low (2.06 to 4.33 %). CEC was suitable in such texture and O.M content (9.50 to 11.50 meq/100g), ESP ranged between 7.6 and 10.2. Soils of this unit could be classified as *Typic torripsamments*.
- Moderately high depressions. The main feature is parallel orientation of gravels and sand grains. Gravels cover is relatively lying on higher elevation, whereas active sand accumulation covered the low-lying areas. Soil depth is low (40 to 55 cm), sandy textured profiles. EC was moderate (6.18 to 8.12 dS/m). pH was mild (7.82 and 7.97.OM content was slightly moderate (0.90 to 1.20. %). $CaCO_3$ content was very high (23.16 to 40.27 %). Calcic horizon was observed through the abundance of white rounded nodules of secondary $CaCO_3$ in these soils. CEC was low (5.50 and 9.50 cmol+/Kg). ESP was moderate (4.52 and 10.30). Soils of this unit could be classified as *Typic Haplocalcids.*

Moderately Depression: Soil surface is leveled covered almost with desert pavement of dark gravels with different sizes. Soil depth was around 40 cm. sandy textured profiles. EC was moderate to slightly high (7.15 to 10.12 dS/m). pH ranged between 7.33 and 7.90.OM content was relatively low (0.30 to 0.90. %). $CaCO_3$ content was very high (27.36 to 41.37 %). Calcic horizon was observed in these soils where abundance of soft white segregation of $CaCO_3$ was identified. CEC was low (6.00 to 7.60 cmol+/Kg). ESP was moderate to high (5.8 to 14.1). Soils of this unit could be classified as *Typic Haplocalcids.*

- Low depression with shallow soils where soil depth ranged between 10 and 20 cm. sandy textured profiles. EC was high (10.1 and 15.23 dS/m). Soil reaction pH ranged between 7.72 and 7.97.OM content was low (0.10 to 0.60. %). $CaCO_3$ content was very high (24.56 to 46.67 %). Calcic horizon was observed through abundance of hard concretions in these soils. CEC was low (6.00 to 8.40 cmol+/Kg). ESP was high (10.1 to 12.74).Soils of this unit could be classified as *Typic Haplocalcids*.

Dry valleys encompass an area of 1427.621 km^2. They are linear depressions that lack a permanent stream but shows signs of past water erosion. It is a common landform in areas underlain by permeable rock (e.g. the chalk spread over the study area). The dry valley was eroded during an episode of surface drainage, to greater precipitation, or to a higher table. These were considered as the least abundant landform in the area. These valleys dissect the highest elevated areas, filled up with fluvial material and having undulating surface. Some dry desert shrubs and bushes are apparent.

Soils depth ranged between 100 and 110 cm. Loamy sand to sandy loam textured profiles depending upon the position from the valley bottom and slope. Salinity was low (3.13 to 4.34 dS/m). pH ranged between 7.41 and 8.01.OM content was very low to moderate (0.10 to 1.2 %). $CaCO_3$ content was low (4.26 to 6.15 %).CEC depends upon clay and organic matter contents (5.50 and 12.50 cmol+/Kg). ESP was low to moderate (4.00 to 10.35) in the successive layers of the studied soil profiles Soils of this unit could be classified as *Typic Torrifluvents*.

Peniplains occupy an area of 25917.51 km^2. They are low, nearly featureless, gently undulating land surface of considerable area, which presumably has been produced by the processes of long-continued sub aerial erosion, primarily mass-wasting of and sheet wash on inter-stream areas of a mature landscape, assisted by stream erosion, almost to base level in the penultimate stage of a humid, fluvial geomorphic cycle.

Soils depth was low (30 to 50 cm). Gravely sand textured profiles. A duripan layer was diagnosed within 30 to 50 cm of the soil surface. Salinity was high to very high (8.00 to 28.64 dS/m). pH ranged between 7.41 and 8.01.OM content was low (0.10 to 0.36. %). $CaCO_3$ content was low (4.09 to 5.25 %). CEC ranged between 5.50 and 12.50 cmol+/Kg. ESP was high to very high (12.8 to 23.35) in the successive layers of the studied soil profiles. Soils of this land form could be classified as *Typic Haplodurids.*

Footslopes are eroded surfaces with colluvial materials. This landform was mainly found at the marginal portion of slopes, where it was covered by fragmented weathered flakes of rocks dominated by Nubian sandstone and even granites. This landform constituted about 5500.09 km^2 of the whole area. Soil depth was shallow (17 to 25 cm), sandy textured profiles. Calcic horizon was observed with the evidence of abundance of hard concretions of $CaCO_3$ in these soils. EC was high (12.1 to 18.28 dS/m).pH was mild (7.68 to 7.90).OM content was relatively low (0.45 to 0.78. %). $CaCO_3$ content was very high (27.26 to 29.05 %). CEC ranged between 4.00 and 12.45 cmol+/Kg. ESP was high to very high (11.27 to 28.15). Soils of this unit could be classified as *Typic Haplocalcids.*

Barchan possesses two "horns" that face downwind, with the slip face (the downwind slope) at the angle of repose, or approximately 32 degrees. The upwind side was packed by the wind and stands at about 15 degrees. Simple barchan dunes may stretch from meters to a hundred meters or so between the tips of the horns. [23, 24, 25] Sand dunes that occupied an area of 301.56 km^2 are arc-shaped sand ridge, comprising well-sorted sand.

Tablelands are Flat topped lands occupying an area of 17490.37 km^2 called also Plateau consisting of relatively flat terrain with steep edges. Scattered Hills were identified with different forms i.e. conical, inselberg, turtle backs and or hog backs. Hills of the investigated area were scattered and have different lithological structure i.e. granite, limestone and basalt. Geomorphologic units and associated soils were shown in Fig. (2).

Spatial Variability of Soil Characteristics: Ordinary kriging interpolation method was used to visually identify patterns of the soil characteristics and to estimate the value of a continuous soil characteristic *z* at an unsampled location u using only data on this characteristic [*z* (ua), α = 1, . . ., *n*] as a linear combination of neighboring observations:

$$z^*_{OK}(\mathrm{u}) = \sum_{\alpha=1}^{n(u)} \lambda_\alpha(u) z(u_\alpha)$$

As for other linear regression procedures, ordinary kriging weights were chosen so as to minimize the estimation or error variance $\sigma_E^2(\mathrm{u}) = \mathrm{Var}\,[Z^*(\mathrm{u}) - Z(\mathrm{u})]$ under the constraint of unbiasedness of the estimator. These weights were obtained by solving linear equations:

$$\begin{cases} \sum_{\beta=1}^{n(u)} \lambda_\beta(u)\gamma(u_\alpha - u_\beta) - \mu(u) = \gamma(u_\alpha - u) \\ \qquad\qquad\qquad\qquad \alpha = 1,\dots,n(u) \\ \sum_{\beta=1}^{n(u)} \lambda_\beta(u) = 1 \end{cases}$$

Unbiasedness of the estimator was ensured by constraining the weights to sum to one, which requires the definition of the Lag range parameter m (u).

Semivariogram values for different lags were derived from the semivariogram model fitted to experimental values. The error variance computed as:

$$\sigma^2_{OK}(u) = \sum_{\alpha=1}^{n(u)} \lambda_\alpha(u)\gamma(u_\alpha - u) - \mu(u)$$

Under stringent hypotheses of normality and homoscedasticity, the kriging variance combined with the estimated value to derive a confidence interval of 95% as:

$$\text{Prob } \{Z(u) \in [z^*_{OK}(u) - 2\sigma_{OK}(u), z^*_{OK}(u) + 2\sigma_{OK}(u)]\} = 0.95$$

Six continuous surfaces of some variable were resulted from the geostatistical analysis as shown in Fig. (3). These six variables were used as inputs in the spatial model:

Land Surface Temperature and Soil Temperature Regime: Land Surface Temperature (LST) is a key indicator of land surface states and can provide information on surface atmosphere heat and mass fluxes, vegetation water stress and soil moisture., [26]. LST for the sand sheets, depressions, dry valleys, peniplains and

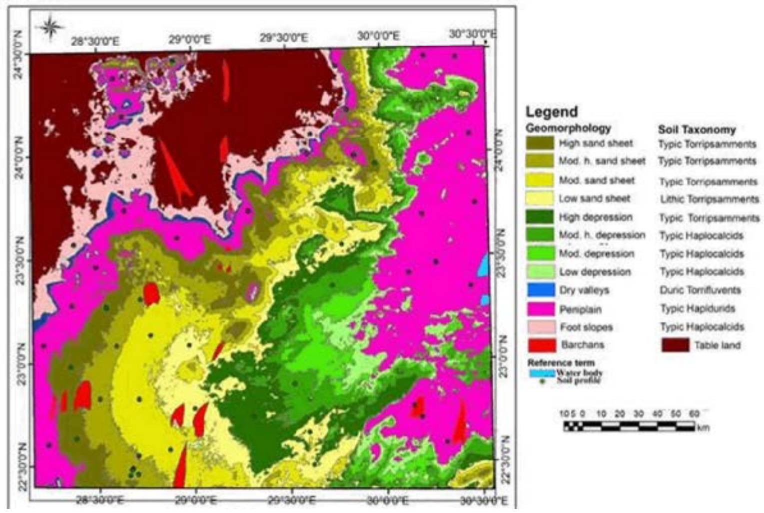

Fig. 2: Geomorphology and soils

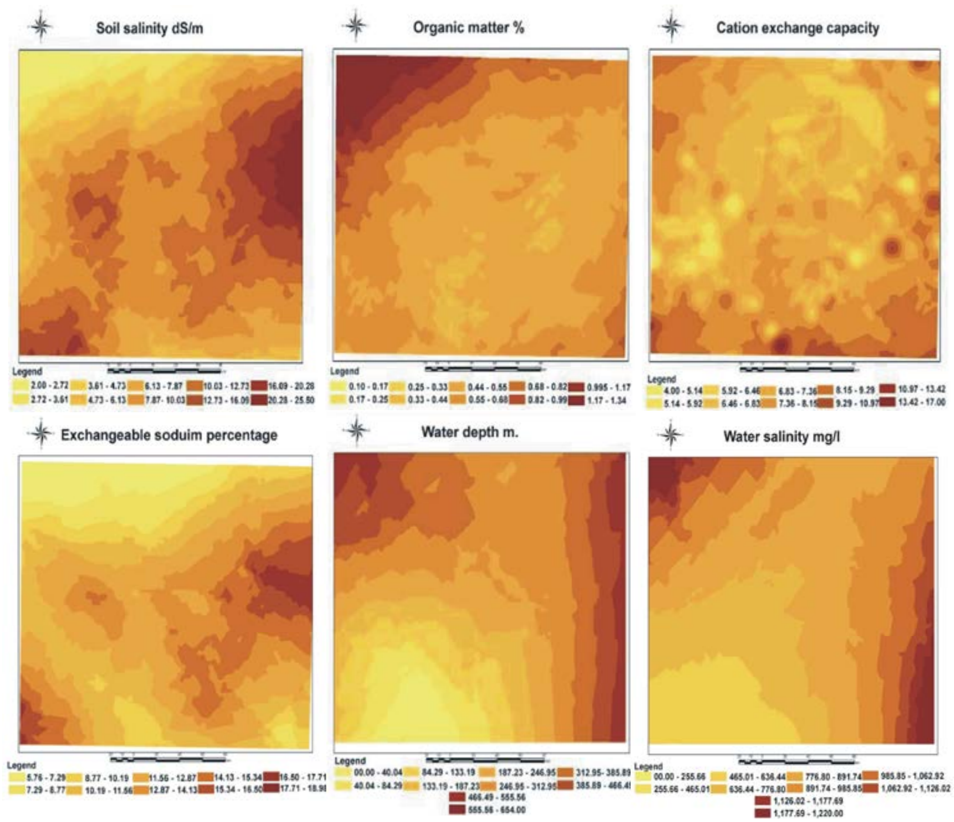

Fig. 3: Spatial variability of some soil and water characteristics

other landscapes sites were brought into agreement with field measurements, where LSD (in summer 2005) of dry valleys ranged between 33.75 and 35.2°C., hills recorded LST of 35.00 to 36.25°C due to its lithological formation of granite and basalt, high and moderately high sand sheets recorded LST in the range of 36.25 to 37.00°C, moderate sand sheets recorded a narrow range of 34.15 to 35.00°C. On the contrary low sand sheets have a wide range of LST where the values ranged between 34.15 to 37.05°C owing to the common colluvial fragments and boulders transported from the surrounding landscapes i.e. scattered hills of different lithology (granites and basalts).

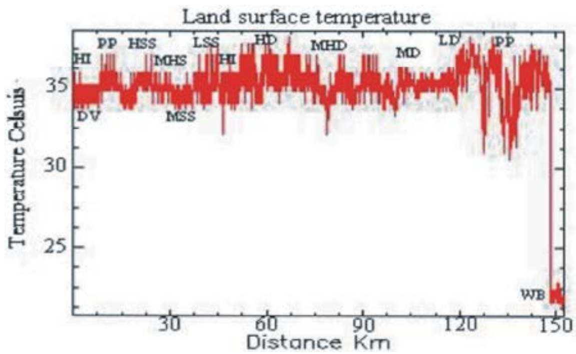

Fig. 4: Land surface temperature in summer

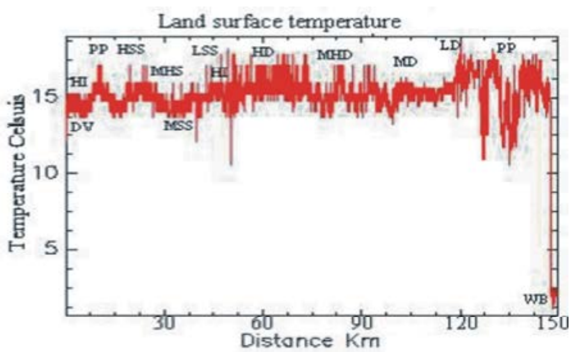

Fig. 5: Land surface temperature in winter

Abbreviations:
DV; Dry valley, HI; Hill, PP; Peniplain, HSS; High sand sheet, MHS; Moderate high sand sheet, MSS; Moderate sand sheet, LSS; Low sand sheet, HD; High depression, MHD; Moderate high depression, MD; Moderate depression, LD; Low depression and WB; Water body.

High and moderately high depressions have nearly the same LST ranging from 34.05 to 37.50°C. Moderate depression behaves like moderate high sand sheets. LST wide values of low depression are similar to those of the eastern peniplain (35.20 and 38.10°C. due to abundance of alluvial and colluvial sediments and rock fragments gained from the surrounding hills and other landscapes (boulders of different parent materials and some shrubs as well). The mean summer of soil temperature at a soil depth 50 cm was measured using soil thermometer as 34.38°C. Other records of soil temperature at 5, 10, 20 and 50 cm depth reveal that soil temperature decreases with depth by 1 to 2 Celsius. In general, the soil temperature increases in summer and reaches its maximum in August 38.10°C while it decreases in winter to reach its minimum in December, 12°C. The mean winter of soil temperature at a soil depth 50 cm was 14.49°C. Results revealed that the mean annual soil temperature was higher than 22°C and the difference between mean summer and mean winter soil temperatures was more than 6°C at a depth of 50 cm from the soil surface, so the soil temperature regime is Hyperthermic. Figs. (4&5) show Land surface temperature derived from ETM+ satellite images thermal bands in both summer and winter seasons.

Potentiality of Ground Water / Classification: Groundwater regimes and quality were determined both by natural factors and by the level of abstraction; it doesn't depend on administrative boundaries [27]. Comparing water salinity with some earlier publications, it was noticed that, water salinity increased as a result of over pumping to irrigate crop fields with furrows method. In his study on paleodrainage system Youssef, [28] delineated the paleodrainage system and their mega basin extent in the East Sahara area. One mega-drainage basin has been detected, covering an area of 256 000 km^2. It was classified into two sub mega basins. The Uweinate sub mega basin, which was composed of four main tributaries, collected water from a vast catchment region and drained eastward from the north, west and southwest, starting at highland areas. The first sub watershed basin is in the northern plateau, south of the Abu-Balas area, with a total catchment area of 25 045 km^2. The second sub watershed is in the Gilf Kebir plateau and has a total catchment area of 38 257 km^2. The third sub watershed drains from the Uweinate highlands and has a catchment area of 46 154 km^2. The fourth sub watershed, which is known as Wadi Mokhtafi in its upper reach and Wadi Arid in its lower reach, drains. In the northwestern highlands of Sudan and has a total catchment area of 28 653 km^2. The Tushka sub mega basin includes one watershed that drains from the northeast highlands of Sudan and has a total catchment area of 63 019 km^2. The Uweinate and Tushka sub mega basins were joined together to the North of the Tushka depression, which drains northward toward the Kharga oasis. It is worth to conclude that, the main source of water in the study area is the Nubian sand stone aquifer. The Nubian Sandstone Aquifer System is the world's largest fossil water aquifer system. It is located underground in the Eastern end of the Sahara Desert and spans the political boundaries of four countries in north-eastern Africa (Egypt, Libya, Sudan and Chad). This aquifer covers a land area spanning just over two million km^2, including north-western Sudan, north-eastern Chad, south-eastern Libya and most of Egypt. Containing an estimated 150,000 km^3 of groundwater [31]. Water of the studied wells was classified based on salinity (EC) and sodicity hazards

Table 2: Water classification of some selected wells

W. No	EC Mg/l	Q m^3/h	Well depth m	SAR	Water class	W. No	EC Mg/l	Q m^3/h	Well Depth m	SAR	Water class
1	370	24	32	2.85	C2-S1	23	1129	26	389	2.70	C3-S1
2	350	25	38	3.07	C2-S1	24	980	24	578	2.73	C3-S1
3	330	26	33	2.17	C2-S1	25	995	27	345	2.85	C3-S1
4	434	24	49	2.03	C2-S1	26	780	27	77	3.07	C3-S1
5	450	25	41	2.02	C2-S1	27	740	25	89	2.17	C2-S1
6	470	26	44	2.43	C2-S1	28	660	24	39	2.03	C2-S1
7	550	24	56	2.15	C2-S1	29	656	27	36	2.02	C2-S1
8	560	26	54	2.57	C2-S1	30	670	26	160	2.43	C2-S1
9	660	24	56	2.50	C2-S1	31	676	27	180	2.15	C2-S1
10	1210	27	379	2.26	C3-S1	32	980	26	234	2.57	C3-S1
11	1180	24	388	3.11	C3-S1	33	789	27	234	2.50	C3-S1
12	1120	27	35	2.38	C3-S1	34	1210	26	399	2.26	C3-S1
13	1130	25	470	2.40	C3-S1	35	670	25	324	3.11	C2-S1
14	1098	26	401	2.32	C3-S1	36	990	26	398	2.38	C3-S1
15	1000	25	380	2.31	C3-S1	37	1110	27	454	2.40	C3-S1
16	1220	26	358	2.70	C3-S1	38	1178	26	424	2.32	C3-S1
17	1170	24	481	2.64	C3-S1	39	980	27	388	2.31	C3-S1
18	450	25	39	2.25	C3-S1	40	1145	25	654	2.70	C3-S1
19	990	26	306	2.15	C3-S1	41	1019	27	567	2.64	C3-S1
20	880	27	308	1.61	C3-S1	42	1120	26	315	2.25	C3-S1
21	330	26	39	3.50	C3-S1	43	1145	25	345	2.15	C3-S1
22	1100	25	356	2.35	C3-S1	44	560	26	112	1.61	C2-S1

(SAR) as shown in Table (2). Waters of the study area were classified into two classes C2-S1 and C3-S1. The first class occurs in sixteen well, meanwhile the second one occurs in twenty eight well. According to US Salinity Laboratory Staff [32] C2-S1 was classified as medium salinity and low sodicity water, it can be used if a moderate amount of leaching occurs. Plant with moderate salt tolerance can be grown in most cases without special practices for salinity control. C3-S1 was classified as high salinity and low sodicity water. It can not be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control is required and plants with good salt tolerance should be selected.

Soil and Water Potentiality Spatial Model (SWPSM): The study developed land potentiality spatial model to identify the most appropriate area for agricultural planning based on the interaction among physical landscape elements. The model input included nine variables i.e., soil texture, land surface temperature, soil depth, EC, CEC, ESP, O.M, water salinity and wells depth. The model resulted in five potentiality classes 1st, 2nd, 3rd, 4th and 5th. Fig. (6) shows the model structure meanwhile Fig. (7) shows the potentiality map resulted from the aforementioned SWPSM. 1st grade potentiality unit includes high and moderately high sand sheets. It occupies an area of 12933.50 km^2. Deep soils, sand to loamy sand textured. Salinity was low. Organic matter content was relatively high. ESP was moderate in great part of this unit with very few exceptions. Water salinity was low and wells depth adjacent to the surface (32 to 49 m). No limiting factors was observed during the field survey or through laboratory analyses. 2nd grade potentiality unit includes high depressions and dry valleys. It occupies an area of 6939.43 km^2. Moderately high soils Sandy to sandy loam textured. Soil salinity was relatively low. Organic matter content has a wide range as it ranged from low to relatively high reflecting clay and O.M contents. ESP was moderate in great part of this unit with very few exceptions. Water salinity was moderately low and wells depth was laying around 112 m. No effective limiting factors were observed during the field survey or laboratory analyses. 3rd grade potentiality unit includes moderately sand sheets It occupies an area of 7888.63 km^2. Moderately deep sandy soils (75 cm) Soil salinity was moderate. Organic matter content was relatively moderate (0.70 and 1.0%. ESP was relatively high (7.10 to 14.7). Water salinity ranged between 550 and 660 mg/l and wells depth was (54 to 56 m). Limiting factors were expressed by texturee, soil depth and sodicity. 4th grade potentiality unit includes low sand sheets and mod. depressions It occupies an area of 9614.44 km^2 Low elevated sand sheet. Soil depth (40to 65cm), Salinity was high. Organic matter content was relatively low. ESP was moderate to high. Water salinity was moderate lying around 660 mg/l and wells depth was (36 to 39 m. limiting

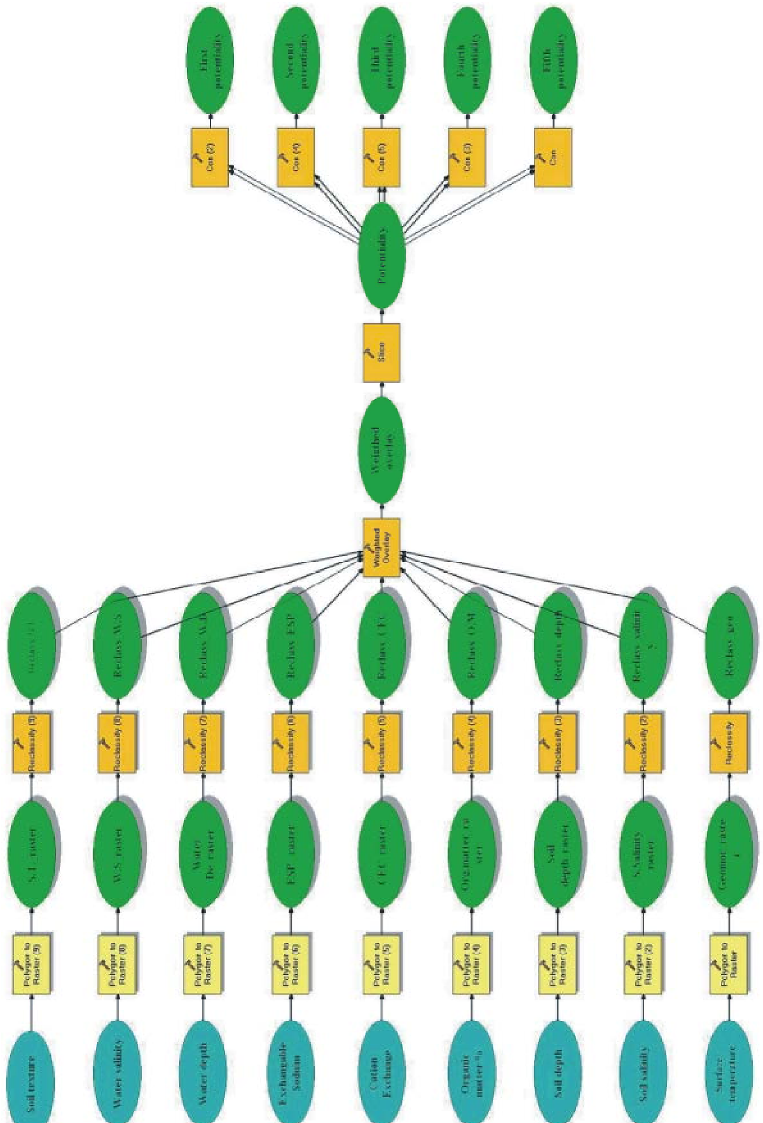

Fig. 6: Framework of soil and water potentiality spatial model (SWPSM)

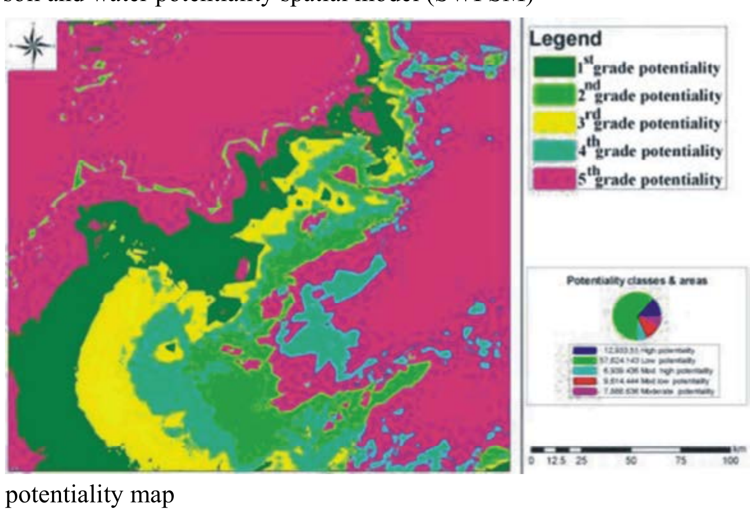

Fig. 7: Soil and water potentiality map

factors were expressed as texture, soil depth, hardpan and sodicity. 5th grade potentiality unit includes moderately high depressions. Low depressions, footslopes, sand dunes and peniplains It occupies an area of 57624.14 km^2. Shallow sandy textured soils. Salinity was high, O.M content was with few exceptions. ESP was high in great part of this unit. Water salinity was very high with few exceptions and wells are deep (315 to 654 m.) Limiting factors were observed as gravels and boulders covering the surface, texture, soil depth, soil and water salinity, O.M and sodicity.

CONCLUSION AND RECOMMENDATIONS

The investigated area is hot, barren, arid, where the topsoil has been whisked away by the wind. The area has low rainfall, hot desiccating high speed winds, very high evaporation rates and high temperatures. Typically most plants were absent; due to the inhospitable conditions that prevail there. Geomorphologic units are widely different in conditions affecting plant growth, such as soils, water quality and quantity, winds, average temperature and severity of the winters. At the present it is worthy to say that for this area we must have plants that will produce the maximum quantity of valuable crops with the minimum quantity and quality of water; and that their periods of growth must be the shortest as possible. Care should be taken to get large harvests and to secure varieties of crops that through generations of breeding have become adapted to the conditions prevailing. The breeding of new varieties by scientific methods is very important. The construction of shelterbelts, windbreaks and woodlots is urgent to provide protection against the wind for other plants and infrastructure. In the investigating area the key is to apply just enough water for optimal plant growth and health, without over watering using new methods of irrigation such as subsurface irrigation. Finally land and water conservation scheme should be taken into consideration by both the government and investors to get the benefit from these virgin soils.

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