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Landforms, Vegetation, and Soil Quality in South Sinai, Egypt

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ABSTRACT

The present study focused on the assessment of soil quality in South Sinai, an arid to extremely arid region, particularly the effect of landform type and vegetation on some of the studied soil properties. Vegetation and soil surveys were carried out in 200 plots selected in 8 different landforms. Soil productivity was evaluated using corn *Zea mays* seed plantation in greenhouse pot experiment. Some soil properties in addition to nutrients uptake in shoots and roots of corn were analyzed. The obtained results showed a variation in soil texture, water holding capacity, and nutrient elements among different landforms and vegetative cover categories. Soil pH, EC, silt and clay content, water holding capacity, and soil organic matter are the most important soil parameters or driving variables that influence the availability of soil nutrients and control coverage and structure of vegetation. Soil quality index was constructed based on rating of these driving variables. The provided model of soil quality index is specific for surface soil and it could be useful in evaluation and management of soil resources in arid ecosystems. Water availability is shown to be the key variable in controlling soil productivity. Total plant cover and vegetation structure are considered the easy visual indicators for preliminary inspection of soil properties, soil productivity, and soil quality.

Key words: Arid lands, landforms, soil productivity, soil quality index, South Sinai, vegetation, water availability.

INTRODUCTION

Environmental deterioration in arid ecosystems due to unmanaged human activities including harvesting of vegetation for fuel and medicine, overgrazing, urbanization and quarrying is evident in a decrease of plant cover, and deterioration of soil productivity, and aggravating of soil erosion (Batanouny, 1983). Damage to soil surface and vegetation in arid lands is not easily repaired (Milton *et al*., 1994). Exacerbated problems of sustaining production of food, fiber, and fuel from these lands are expected. Understanding of soil quality limitations to production of these goods and maintenance of services, such as clean water and air, can contribute to dealing with these needs. Soil Science Society of America (1997) defined soil quality as "the capacity of soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health". Soil quality is a useful model to evaluate and improve soil resources as it provides an integrated method for assessing multiple aspects of soil and their connections. By linking biological, physical, and chemical properties of soil, all of the components and interactions of a soil system are viewed together. This integrated approach leads to more comprehensive assessment as compared to assessing each soil property independently (USDA, 2001).

South Sinai, an arid to extremely arid region, is characterized by an ecological uniqueness due to its diversity in landforms, geologic structures, and climate that resulted in a diversity in vegetation types, which is characterized mainly by the sparseness and dominance of shrubs and sub-shrubs and the paucity of trees (Moustafa and Klopatek, 1995; Helmy *et al*., 1996), and a variation in soil properties (Ramadan, 1988; Kamh *et al*., 1989; Abd El-Wahab, 1995). Human impacts of settled societies and nomadic Bedouin groups have been recorded in South Sinai (Moustafa *et al*., 1999). These diversity aspects made South Sinai a good case study to build a soil quality index for arid ecosystems. The increased concern about the development of South Sinai reflects the importance of its natural resources assessment to improve the ability to manage the sustainability of these resources.

The study of soil and the interactions between soil and other components of the ecosystem provides us with the prerequisite knowledge to minimize the degradation and destruction of one of the most important natural resources, the soil. The objectives of this study were to assess the status of soil quality of South Sinai through constructing of soil quality index, and to evaluate the influences of geomorphic characters and vegetation on soil quality. The soil quality index for soil surface of the study area was constructed based on evaluation of: (a) soil and vegetation resources in nine main areas and 8 different landforms in South Sinai, (b) relationships between soil properties and environmental variables including physiographic features and vegetation parameters, and (c) soil productivity using two main indicators, namely plant cover percent and corn yield dry weight.

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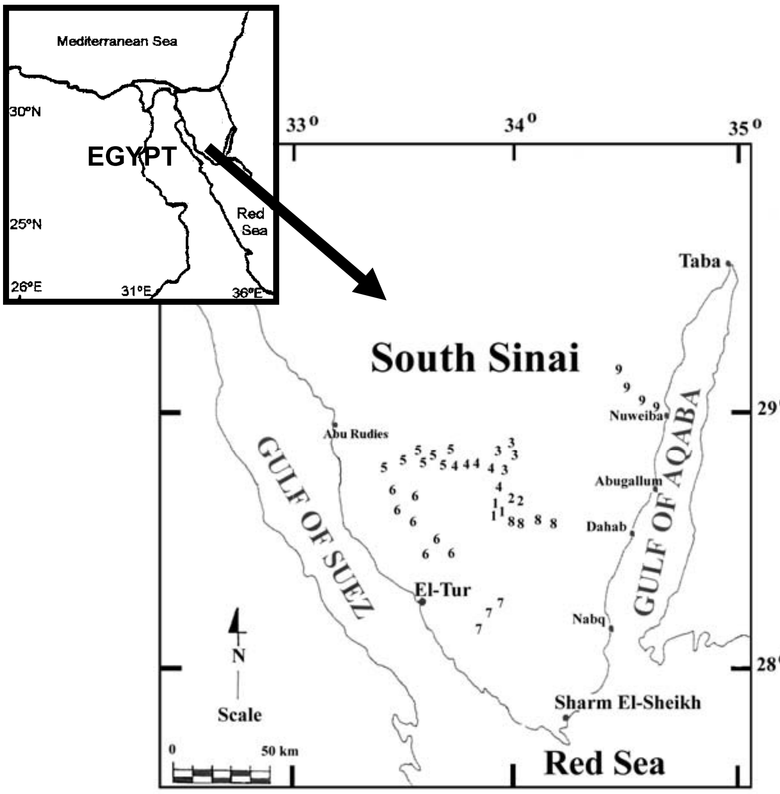

Figure (1): Location map of southern Sinai showing nine studied areas marked as numbers from 1 to 9 as follow: 1-St. Katherine area, (2) W. Sanad, (3) El-Agramia Plain, (4) W. El-Sheikh, (5) W. Feiran, (6) El-Qaa Plain, (7) W. Isla, (8) Rahaba – Nasb, (9) W. Watir.

MATERIALS AND METHODS

Site Description

South Sinai area (about 28,400 km^2) is mainly occupied by a triangular mass of mountains containing much granite and other magmatic and metamorphic rocks (Said, 1990). The study area is located between latitude 28°10' to 29°10'N and longitude 33°15' to 34°39'E (Fig. 1). It covers 9 main areas representing different vegetation types, altitude variations, landform types, and climatic variations. These areas are: (1) St. Catherine area, (2) Wadi Sanad area, (3) El-Agramia Plain area, (4) Wadi El-Sheikh area, (5) Wadi Feiran area, (6) El-Qaa Plain area, (7) Wadi Isla area, (8) Rahaba-Nasb area, and (9) Wadi Watir (Fig. 1). Six main landform types are recognized in the study area; they include slopes, terraces, gorges, wadis, fans, and plains. Slopes originate by a combination of tectonic and erosion activity. Terraces comprise platforms of bedrock mantled whether mantled with a sheet of gravel and sand or rocky surface. Gorges originate from joints or faults. The term wadi designates a dried riverbed in a desert area that may be transformed into a temporary watercourse after a period of heavy rain. Alluvial fans are the opening of large gorges or small wadis into the main valley (Moustafa and Zayed, 1996). Plains are flat expanses of desert where deep alluvial deposits are found. The desert plains represent a very late stage in the arid erosion cycle (Kassas, 1952; Moustafa and Klopatek, 1995).

South Sinai is characterized by an arid to extremely arid climate and irregularity in rainfall. The climate is influenced by the orographic impact of the high mountains (Migahid *et al*., 1959; Issar and Gilad, 1982; Danin, 1986). The mean temperature of the coldest month is 10 to 20°C and 20 to 30°C for the warmest month. Precipitation occurs mostly in winter and may occur as snow on the high peaks. Only rare and heavy showers cause floods, which contribute effective moisture for the vegetation in the wadis (Moustafa *et al*., 1999). St. Catherine is the coolest area in Sinai and Egypt as a whole due to its high elevation (1500-2641 m a.s.l.). The coastal strip along the Gulf of Aqaba is much warmer than that along the Gulf of Suez. Climatic diagrams of some stations in South Sinai clarify the aridity situation of the study area (Fig. 2).

Vegetation Survey and Soil Sampling

Two hundred plots (10x10 m) were selected in a restricted random fashion in 8 different landforms: fans (21 plots), gorges (18 plots), slopes (13 plots), terraces (14 plots), high elevated plains (HEP) with altitude range of 1200 to 1650 m (32 plots), low elevated plains (LEP) with altitude range of 30 to 210 m (26 plots), high elevated wadis (HEW) with altitude range of 1250 to 2150 m (24 plots), and low elevated wadis (LEW)

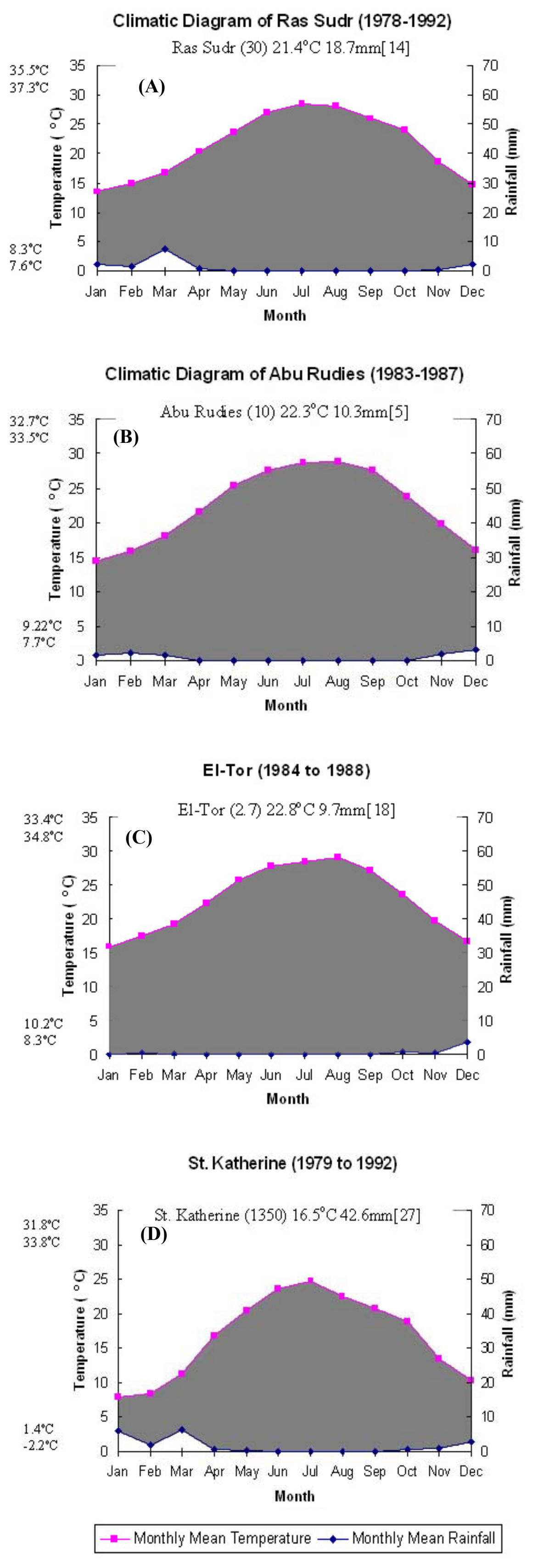

Figure (2): Climatic diagrams of some stations in southern Sinai. A- Ras Sudr, B- Abu Rudies, C- El-Tor, and D- St. Katherine.

with altitude range of 30 to 1200 m altitude (52 plots). In each plot, geographic location was recorded using GPS receiver "Trimble model". Plant cover as a canopy cover was measured (Barbour *et al.*, 1987). Identification of plant species was according to Täckholm (1974) and Boulos (1995, 1999, 2000, 2002). Nature of soil surface (Hausenbuiller, 1985) and soil color (Munsell, 1995) were described. Two hundred soil samples, 0 to 30 cm depth, were collected from the study area, mainly from under canopy of the dominant plant species. Soil samples were air-dried and sieved through 2 mm sieve to obtain representative sub-samples for chemical and physical analyses and to exclude larger particles that are relatively less reactive (Robertson *et al.*, 1999).

Vegetation Analysis

Species richness and species diversity (Shannon-Weiner diversity index) were calculated (Barbour *et al.*, 1987) using EcoSim software (Gotelli and Entsminger, 2002). Determination of plant communities was conducted by classification of 190 plots based on the basal cover percentage of 91 species using Two-Way INdicator SPecies ANalysis (TWINSPAN) (Hill, 1979; Gauch, 1982). TWINSPAN was carried out using PC-ORD software (McCune and Mefford, 1999).

Soil Analysis

Soil water holding capacity (WHC) and particle-size were measured as indicators of soil physical quality (Klute, 1986). Indicators of the soil chemical quality measured in the present study were pH, EC, soil organic matter (SOM), total carbonates, total nitrogen (TN), available phosphorus (P), Cation Exchange Capacity (CEC), water soluble cations "K, Ca, and Mg", and available trace elements "Fe, Mn, Cu, and Zn". Soil chemical analyses were done according to Sparks *et al.* (1996).

Greenhouse Pot Experiment and Plant Analysis

Greenhouse pot experiment was set up in St. Catherine Research Center for bioassay measurements. About 1500 ml of each soil sample was placed in a plastic pot and replicated three times. Corn (*Zea mays*), Single Hybrid Igacid 13 seeds were sown in the pots and grown for 50 days. Plants were oven dried at 70°C for three days. The dry weights of shoots and roots were measured. Total nitrogen was analyzed in fine ground samples of shoots and roots by dry (Dumas) combustion. P, K, Ca, Mg, Fe, Mn, Cu, and Zn were measured in plant-acid mixture extract (Kalra, 1998). Data were statistically analyzed (Zar, 1984) using SPSS software (Statistical Package for Social Sciences, version 10.1).

Soil Quality Index

Soil quality index was constructed using two soil productivity indicators namely, total plant cover and total corn dry weight. Plots were classified according to the total plant cover into three categories, low (0-5%), medium (5-15%), and high (>15%). Corn dry weight was also classified into three main categories; low (1.5-3 g pot^{-1}), medium (3-5 g pot^{-1}), and high (5-9 g pot^{-1}). Mean, standard deviation, standard error, minimum, and maximum of soil physical and chemical variables of each group of plots were measured at different categories of the soil productivity indicators. Soil quality at each plot was ranked using physical and chemical characteristics of soil. Soils support the low total plant cover or low *Zea mays* production were considered as low quality, while soils support high total plant cover or high *Zea mays* production were considered as high soil quality.

RESULTS

Generally, soils of the study area are light or yellowish brown in color, gravelly in wadis and plains, having rocky surface at mountains, and sandy to loamy sand in texture. They are characterized by low content of silt and clay, SOM, CEC, and most of the essential nutrients. They are alkaline and range from non-saline to slightly saline.

Altitude Variations and Vegetation Parameters

The study area shows a wide range of altitude (Table 1). LEP has the lowest mean value of altitude (72 m), whereas terraces, HEW, gorges, slopes have the highest values that range between 1564 and 1782 m. Altitude means of LEW and fans are homogenous (629 and 668 m altitude, respectively). Plant cover in South Sinai ranges between 2% at Wadi Sanad and 30% at St. Catherine. Slopes, gorges, terraces, and HEW are richer in vegetative cover than LEW, plains, and fans. Terraces and gorges have the highest plant cover (29.1% and 23.9%, respectively), while HEP and fans show the lowest plant cover (3.07% and 5.99%, respectively) (Table 1). Gorges, terraces, and slopes have higher values of species richness (8.44, 8, and 6.38 species/100m^2, respectively) and species diversity (1.63, 1.38, and 1.29, respectively) than wadis, plains, and fans (species richness range is 2.28-4.08, species diversity

Table (1): Variation in vegetation parameters, physiographic factors, and soil properties among different landforms. *F* ratio and its significance are included. Mean values of each variable with similar letters indicate no significant variation according to Duncan's multiple range test.

Landform	Gorges	Slopes	Terraces	HEW	LEW	HEP	LEP	Fans	*F ratio*
Altitude m	1669^{d}	1781^{d}	1564^{cd}	1599^{cd}	629^{b}	1399^{c}	72^{a}	668^{b}	81.05**
Slope	24.89^{b}	28.75^{b}	4.6^{a}	4.15^{a}	3.33^{a}	4.24^{a}	3^{a}	3.32^{a}	49.56**
Plant Cover%	23.88^{d}	14.85^{bc}	29.05^{d}	15.42^{c}	11.15^{abc}	3.07^{a}	10.91^{abc}	5.99^{ab}	7.94**
Species Richness	8.44^{b}	6.38^{b}	8.00^{b}	4.08^{a}	2.98^{a}	2.28^{a}	3.27^{a}	2.33^{a}	9.57**
Species Diversity	1.63^{b}	1.29^{b}	1.38^{b}	0.61^{a}	0.66^{a}	0.54^{a}	0.77^{a}	0.42^{a}	10.24**
Soil Physical Analysis (Particle Size Distribution)									
Gravel%	52.9^{d}	50.75^{d}	52.11^{d}	45.31^{cd}	39.13^{bc}	45^{cd}	26.51^{a}	34.18^{ab}	7.56**
Coarse Sand%	43.08^{bc}	40.98^{bc}	46.13^{bc}	50.19^{c}	40.17^{bc}	49.35^{c}	23.99^{a}	38.73^{b}	8.02**
Fine Sand%	44.17^{a}	42.01^{a}	43.49^{a}	40.49^{a}	55.05^{b}	42.94^{a}	72.5^{c}	57.45^{b}	15.63**
Silt%	8.73^{e}	11.56^{f}	7.46^{de}	5.88^{cd}	2.73^{ab}	4.55^{bc}	2.03^{a}	1.88^{a}	25.03**
Clay%	4.03^{c}	5.44^{d}	2.92^{b}	3.44^{bc}	2^{a}	3.16^{b}	1.51^{a}	1.94^{a}	19.56**
Silt&clay%	12.76^{d}	17^{e}	10.38^{cd}	9.32^{bc}	4.73^{a}	7.71^{b}	3.54^{a}	3.83^{a}	26.60**
WHC%	15.63^{bc}	17.22^{c}	14.86^{b}	13.97^{b}	10.70^{a}	10.89^{a}	10.19^{a}	10.57^{a}	13.82**
Soil Chemical Analysis									
pH(1:2.5)	8.23^{a}	8.19^{a}	8.17^{a}	8.28^{ab}	8.36^{ab}	8.79^{c}	8.26^{a}	8.47^{b}	10.80**
EC(1:1) (dS m^{-1})	0.81^{a}	0.48^{a}	0.7^{a}	0.94^{ab}	0.65^{a}	0.89^{ab}	1.57^{b}	0.54^{a}	2.25*
$CaCO_3$ (g kg^{-1})	38.2^{ab}	36.9^{ab}	28.7^{a}	37.3^{ab}	74.7^{b}	42.5^{ab}	217^{c}	47.7^{ab}	25.74**
SOM (g kg^{-1})	51.4^{c}	62^{d}	48.5^{c}	36.1^{b}	19.8^{a}	22.4^{a}	27.5^{b}	20.1^{a}	9.56**
TN (g kg^{-1})	0.78^{b}	1.04^{b}	0.92^{b}	0.77^{b}	0.23^{a}	0.26^{a}	0.17^{a}	0.13^{a}	14.92**
Available P (mg kg^{-1})	0.37^{d}	0.3^{bcd}	0.32^{cd}	0.3^{bcd}	0.21^{abc}	0.25^{bcd}	0.1^{a}	0.16^{ab}	3.82**
Water Soluble Ions (soil water extract 1:1)									
Na^{+} (meq l^{-1})	3.45^{a}	1.96^{a}	2.69^{a}	4.21^{ab}	3.21^{a}	6.01^{ab}	10.24^{b}	2.71^{a}	2.32*
K^{+} (meq l^{-1})	0.43	0.36	0.86	0.57	0.52	0.83	0.62	0.4	0.99
Ca^{2+} (meq l^{-1})	3.21^{ab}	1.9^{a}	2.14^{a}	3.45^{ab}	2.91^{a}	1.64^{a}	4.14^{b}	1.75^{a}	2.75*
Mg^{2+} (meq l^{-1})	1.03	0.63	1.42	1.66	0.94	0.69	1.65	0.63	1.4
Cl^{-} (meq l^{-1})	0.87^{a}	0.98^{a}	2.01^{a}	1.44^{a}	1.98^{a}	1.65^{a}	4.24^{b}	1.07^{a}	2.70*
SO_4^{2-} (meq l^{-1})	0.38^{a}	0.44^{a}	0.96^{a}	4.21^{b}	1.25^{a}	1.32^{a}	4.55^{b}	0.86^{a}	4.49**
HCO_3^{-} (meq l^{-1})	6.89	3.34	4.06	2.86	3.83	5.95	5.81	3.45	1.13
Available trace elements (DTPA extract)									
Fe (mg kg^{-1})	12.24^{abcd}	14.53^{bcd}	15.57^{d}	15.26^{cd}	11.45^{abc}	11.08^{ab}	9.32^{a}	14.08^{bcd}	3.31**
Mn (mg kg^{-1})	28.33^{c}	15.57^{b}	25.42^{c}	19.12^{c}	8^{a}	8.78^{a}	4.27^{a}	5.77^{a}	15.82**
Cu (mg kg^{-1})	2.33^{c}	3.01^{d}	2.31^{c}	1.79^{bc}	1.12^{a}	1.27^{ab}	0.71^{a}	0.94^{a}	16.40**
Zn (mg kg^{-1})	1.58^{c}	1.26^{c}	1.45^{c}	1.34^{c}	0.73^{ab}	0.9^{b}	0.57^{a}	0.71^{ab}	12.87**
CEC (cmol kg^{-1})	11.82^{c}	14.61^{d}	12.08^{c}	9.27^{b}	4.51^{a}	5.34^{a}	3.67^{a}	4.11^{a}	30.15**

* F ratio is significant at the 0.05 level, ** F ratio is significant at the 0.01 level.

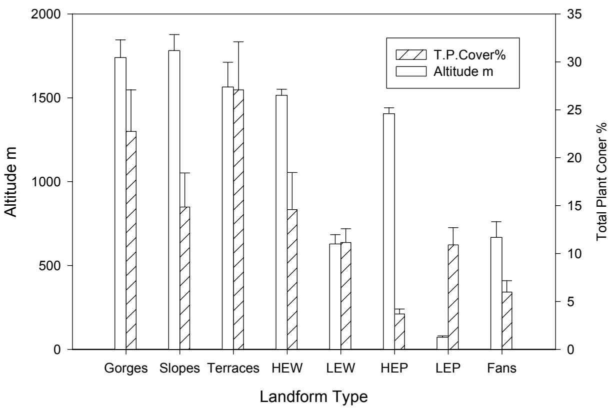

Figure (3): The relationship between altitude and total plant cover in different landforms in southern Sinai.

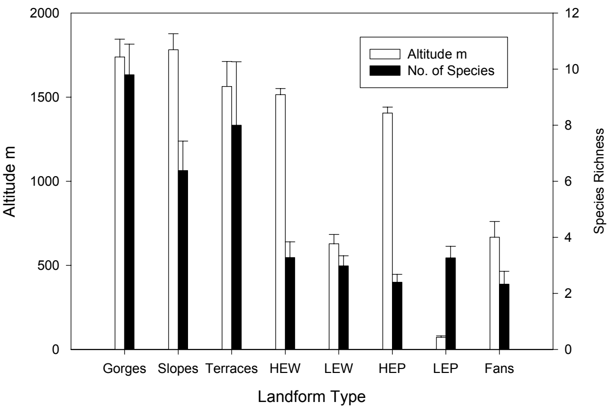

Figure (4): Association of species richness and altitude at different landform types.

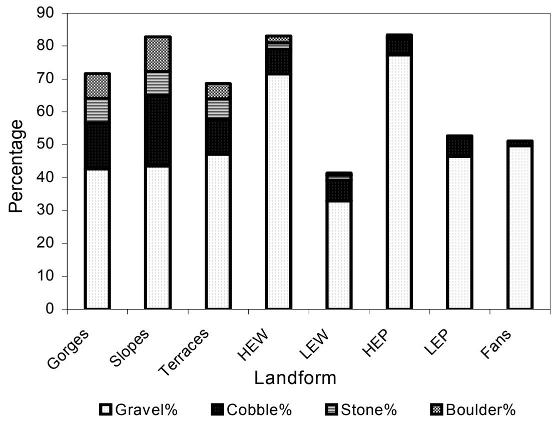

Figure (5): Nature of soil surface at different landform types in southern Sinai.

range is 0.42-0.77, Table 1). With the exception of plain habitats, positive association between altitude and vegetation parameters (plant cover and species richness) was recognized at different landforms (Figure 3 and 4).

Soil Physical Properties

Slopes show the highest value of rocky fragments (39.3%) followed by gorges (28.9%) and terraces (21.5%). Wadis show a medium percent of rocks (15.5% in HEW, 8.6% in LEW), whereas plains and fans have the lowest rock percent in their soil surface (6.2% in HEP, 6.3% in LEP, 1.5% in fans). Soil surface is more gravely in HEW (65.2%) and HEP (77.3%) (Fig. 5).

Most of soil colors in South Sinai are light or yellowish brown (Hue10YR). Mountainous landforms have dark soil that range between light yellowish brown to yellowish brown in gorges, dark brown in slopes, and brown in terraces and HEW. On the other hand, LEW, plains, and fans have whitish soil color that range between very pale brown to light yellowish brown. Carbonates, such as calcite, may impart the whitish color.

Based on the soil fraction analysis data, soils of the study area have three different textural classes, namely sand, loamy sand, and sandy loam. Gorges and slopes are generally loamy sand. The sandy soils dominate plains, wadis, and fans, whereas HEW, and HEP have few loamy sand sites.

WHC is mainly influenced by soil texture and highly correlated with silt and clay content at different landforms. Soils of slopes, gorges, and terraces are rich in silt and clay content (17.0%, 12.76%, and 10.38%, respectively), followed by soils of HEW, and HEP (9.32% and 7.71%, respectively). LEP, fans, and LEW have the lowest silt and clay content that ranges between 3.54% and 4.73%. Soils of slopes and gorges have the highest means of WHC (17.22% and 15.63%, respectively), followed by terraces and HEW (14.86% and 13.97%, respectively). Soils of LEP, fans, LEW, and HEP have a narrow range of WHC (10.19-10.89%, Table 1). Soils of LEP have the highest fine sand content (72.50%), followed by soils of fans (57.45%) and LEW (55.05%), whereas soils of HEW, slopes, HEP, terraces, and gorges have the lowest means of fine sand content (40.49-44.17%). Soils of the study area are generally gravely (gravel% > 26%). Soils of HEP, HEW, slopes, terraces, gorges have the highest means of gravel content (45.00-52.90%, Table 1).

Soil Chemical Properties

Soils of terraces, slopes, gorges, LEP, and wadis have a narrow pH range (8.17-8.36). The highest values of pH are recorded in soils of fans (8.47) and HEP (8.79). Soils of LEP have the highest EC (1.57 dS m^{-1}), water soluble Cl^{-} (4.24 meq l^{-1}), SO_4^{2-} (5.55 meq l^{-1}), Na^{+} (10.24 meq l^{-1}), and Ca^{2+} (4.14 meq l^{-1}). Soils of the other landforms have EC, ranges between 0.48 dS m^{-1} (slopes), and 0.94 dS m^{-1} (HEW). Soils of LEP have the highest mean of calcium carbonate content (217 g kg^{-1}) followed by LEW (74.7 g kg^{-1}). The other landforms have calcium carbonate content ranges between 28.7 g kg^{-1} (Terraces) and 47.7 g kg^{-1} (Fans) (Table 1).

Soils of slopes, gorges, terraces, and HEW are rich in SOM (62.0, 51.4, 48.5, and 36.1 g kg^{-1}, respectively), TN (1.04, 0.78, 0.92, and 0.77 g kg^{-1}, respectively), available P (0.30, 0.37, 0.32, and 0.30 mg kg^{-1}, respectively), and CEC (14.61, 11.82, 12.08, and 9.27 cmol kg^{-1}, respectively). On the other hand, low means of TN, available P, and CEC were recorded in soils of LEW (TN = 0.23 g kg^{-1}, P = 0.21 mg kg^{-1}, and CEC = 4.51 cmol kg^{-1}), LEP (TN=0.17 g kg^{-1}, P=0.10 mg kg^{-1}, and CEC = 3.67 cmol kg^{-1}), HEP (TN = 0.26 g kg^{-1}, P = 0.25 mg kg^{-1}, and CEC = 5.34 cmol kg^{-1}), and fans (TN = 0.13 g kg^{-1}, P = 0.16 mg kg^{-1}, and CEC = 4.11 cmol kg^{-1}, Table 1).

LEP soils have the lowest means of available trace elements (Fe = 9.32; Mn = 4.27, Cu = 0.71, and Zn= 0.57 mg kg^{-1}). Mountainous landforms have higher content of available trace elements than wadis, plains or fans (Table 1).

Soil Properties Interactions

Obvious positive correlation between soil silt and clay content, SOM, TN, and CEC was recognized. SOM has a highly significant direct influence on a number of soil variables including WHC, TN, available Mn, available Zn, and CEC (r = 0.856, 0.827, 0.632, 0.535, and 0.801, respectively). Highly significant positive correlations are also recognized between soluble Ca and Mg (r = 0.856), available Fe and Zn (r = 0.662), and available Cu and Zn (r = 0.633). Silt and clay content is another important variable that influences many soil properties including WHC (r = 0.742), available P, Fe, Mn, Cu, and Zn (r = 0.321, 0.306, 0.429, 0.442, and 0.529, respectively) and CEC (r = 0.802). Results of simple linear regression analysis between silt and clay content, WHC, SOM, and EC as independent variables and other soil properties and nutrients indicates the importance of these variables as indicators for other soil properties and nutirents. The following are examples of the regression equations that describe these relationships.

$$\text{TN g kg}^{-1} = -0.9711 + 0.1146 * \text{WHC\%}$$
"$r^2 = 0.778$, $F = 503.65$, Sig. $F \leq 0.0001$"

$$\text{TN g kg}^{-1} = -0.2086 + 0.2084 * \text{SOM\%}$$
"$r^2 = 0.678$, $F = 396.21$, Sig. $F \leq 0.0001$"

$$\text{CEC cmol kg}^{-1} = 1.611 + 0.720 * \text{Silt and Clay\%}$$
"$r^2 = 0.650$, $F = 348.71$, Sig. $F \leq 0.0001$"

$$\text{CEC cmol kg}^{-1} = -5.145 + 0.997 * \text{WHC\%}$$
"$r^2 = 0.651$, $F = 351.06$, Sig. $F \leq 0.0001$"

Soil Properties and Plant Cover

Plant cover is positively correlated with WHC, gravel fraction, and silt and clay content, soil surface large fragments (cobbles, stones, and boulders), SOM, TN, available trace elements (Fe, Mn, Cu, Zn), and CEC, whereas plant cover shows negative correlation with soil pH. Low significant correlation was recognized between plant cover and soluble Ca or Mg. No significant correlations were recognized between plant cover and number of soil properties such as coarse and fine sand in soil texture, EC, calcium carbonate, available P, and water soluble K.

Bioassay of Soil Productivity

Variations of corn dry weight were highly significant within different landforms. Corn yield dry weight is higher in soils of HEW (5.03 g pot^{-1}), slope (4.93 g pot^{-1}), and fans (4.87 g pot^{-1}) than in soils of terraces (4.76 g pot^{-1}), gorges (4.47 g pot^{-1}), LEW (4.18 g pot^{-1}), and plains (4.03 g pot^{-1} in LEP, and 3.80 g pot^{-1} in HEP) (Table 2). Uptake of TN, K, and P was higher in shoots than in roots, whereas uptake of trace elements was mostly higher in roots than in shoots.

Correlations between corn yield parameters and soil properties and nutrients uptake indicated the importance of bioassay analysis in evaluating soil productivity and how far the soil nutrient analysis could express accurately the amount of nutrients that plants will take up. Soil properties that have a positive influence on shoots, roots, and total yield of corn are WHC, silt and clay content, SOM, TN, available Fe and Zn, and CEC, whereas pH, EC, and soluble Na^+, Cl^-, SO_4^{2-}, and HCO_3^- have a negative influence. Calcium carbonate, soluble K^+ and Ca^{2+}, and available Mg^{2+}, Mn, and Cu showed low or insignificant correlations with corn biomass.

Some soil properties such as SOM and TN have higher correlations with shoot dry weight than with root dry weight. Dry weight of shoots, roots, or total yield has higher correlation with nutrient uptake than with soil nutrients. Shoot dry weight has high correlations with TN (r = 0.710), soluble K^+ (r = 0.827), soluble Mg^{2+} (r = 0.856), available P (r = 0.802), and available Zn (r = 0.683), whereas root dry weight has high correlations with soluble Ca^{2+} (r = 0.768), available Mn, Fe, and Cu (r = 0.637, 0.726, 0.465, respectively). Total Yield has highest correlations with Mg^{2+} (r = 857), soluble K^+ (r = 0.800), soluble Ca^{2+} (r = 8.00), available P (r = 0.795), available Mn (r = 0.649), TN (r = 0.643), and available Zn (r = 0.694).

In general, correlation test between soil nutrients and their uptake reveal that total nitrogen, available P, soluble Ca^{2+}, and available Fe, Cu, and Zn have highly significant positive correlations especially with root nutrient uptake. Soluble K^+, Mg^{2+}, and available Mn in soils and their uptake by plant showed insignificant correlations. Correlation between soil total nitrogen and nitrogen uptake in shoots or roots was highly significant (r = 0.628 and 0.619, respectively). Available Fe and Zn were also significantly correlated with their uptake by shoots and root. Soil soluble Ca^{2+} and available Cu are correlated with their uptake in roots. Soil available P is correlated with its uptake by roots and total yield.

Soil Quality Index

The preceding statistical evaluation of soil properties and their relationships with soil productivity indicators (plant cover and corn yield) clarify that the most important soil properties driving the soil system to produce plants are silt and clay content, WHC, pH, EC,

Table (2): Variation in dry weight and some shoot and root nutrients of corn at different landforms. F ratio and its significance are included. Mean values of each variable with similar letters indicate no significant variation according to Duncan's multiple range test

Landform	Gorges	Slopes	Terraces	HEW	LEW	HEP	LEP	Fans	*F*
Dry weight (g pot^{-1})									
Shoot	2.12^{ab}	2.40^{b}	2.24^{ab}	2.35^{b}	1.95^{ab}	1.83^{a}	1.82^{a}	2.26^{ab}	2.74**
Root	2.35^{ab}	2.53^{ab}	2.52^{ab}	2.67^{b}	2.23^{ab}	2.02^{a}	2.21^{ab}	2.61^{b}	2.49*
Yield	4.47^{ab}	4.93^{b}	4.76^{ab}	5.03^{b}	4.18^{ab}	3.84^{a}	4.03^{ab}	4.87^{b}	2.78**
Shoot Nutrients									
TN (g kg^{-1})	17.97^{bc}	19.88^{c}	15.82^{ab}	13.8^{a}	15.55^{ab}	15.86^{ab}	16.79^{b}	13.82^{a}	4.60**
K (g kg^{-1})	37.84^{c}	39.23^{c}	33.13^{b}	30.09^{ab}	30.28^{ab}	33.29^{b}	27.65^{a}	28.59^{a}	8.10**
Ca (g kg^{-1})	8.13^{b}	10.31^{c}	8.85^{bc}	9.31^{bc}	8.8^{bc}	9^{bc}	5.93^{a}	8.76^{bc}	7.96**
Mg (g kg^{-1})	4.75^{bc}	5.56^{c}	4.93^{bc}	4.46^{b}	4.38^{b}	4.54^{b}	3.43^{a}	4.4^{b}	3.77**
P (g kg^{-1})	2.08^{b}	2.61^{cd}	1.75^{a}	2.53^{cd}	2.77^{cde}	3.07^{e}	2.82^{de}	2.48^{c}	13.54**
Mn (mg kg^{-1})	108^{bc}	80.93^{a}	92.12^{ab}	97.9^{ab}	87.72^{ab}	123^{c}	101^{ab}	93.22^{ab}	5.67**
Fe (mg kg^{-1})	479^{a}	505^{a}	560^{ab}	475^{a}	434^{a}	714^{b}	502^{a}	554^{ab}	2.97**
Cu (mg kg^{-1})	37.74	33.35	36.52	35.96	48.07	43.84	52.38	32.31	1.28
Zn (mg kg^{-1})	78.09	82.14	56.11	68.35	61.17	65.51	71.09	55.33	0.99
Root Nutrients									
TN (g kg^{-1})	10.71^{a}	12.72^{b}	10.21^{a}	9^{a}	10.08^{a}	10.59^{a}	10.78^{a}	8.83^{a}	2.94**
K (g kg^{-1})	18.89^{bc}	19.43^{c}	16.56^{ab}	18.82^{bc}	15.74^{a}	18.96^{bc}	14.31^{a}	14.44^{a}	7.55**
Ca (g kg^{-1})	8.46^{ab}	8.44^{ab}	8.91^{ab}	8.07^{a}	12.55^{c}	7.48^{a}	14.87^{d}	10.33^{b}	20.07**
Mg (g kg^{-1})	4.25^{ab}	4.23^{ab}	4.08^{a}	4.06^{a}	5.6^{c}	5.25^{c}	4.97^{bc}	5.24^{c}	7.41**
P (g kg^{-1})	1.05^{b}	1.17^{bc}	1.33^{c}	1.04^{b}	0.95^{ab}	0.7^{a}	0.94^{ab}	0.76^{a}	4.77**
Mn (mg kg^{-1})	151^{ab}	130^{a}	146^{ab}	164^{bc}	155^{ab}	205^{d}	133^{a}	183^{cd}	10.41**
Fe (mg kg^{-1})	4515^{a}	4832^{a}	5378^{abc}	5303^{abc}	5930^{bcd}	6243^{cd}	4989^{ab}	6769^{d}	5.89**
Cu (mg kg^{-1})	50.85^{c}	33.29^{a}	43.12^{abc}	44.69^{bc}	41.49^{abc}	37^{ab}	33.85^{ab}	40.08^{abc}	2.58*
Zn (mg kg^{-1})	92.97^{bc}	80.15^{ab}	82.82^{ab}	101^{c}	79.62^{ab}	75.48^{a}	82.5^{ab}	74.08^{a}	5.04**

* *F* ratio is significant at the 0.05 level, ** *F* ratio is significant at the 0.01 level

SOM, TN, available P, and CEC. These eight soil quality indicators were rated to build soil quality index (Table 3), which led to ranking or classifying the 200 plots for soil quality. The index has three categories; low, medium, and high. The 200 Plots were ranked for each of the variables listed using 1 as lowest quality value and 3 as highest quality. Rank values are summed and the totals used to rank plots for overall soil quality. This model of soil quality is specific to the surface soils of the study area in South Sinai and the overall ratings of soil quality indicators reflect the suitability of the soil for growing corn and for supporting plant cover.

Means of soil quality index have high significant variations between different areas and landforms. St. Catherine surface soil represents the highest soil quality followed by soils of Rahaba-Nasb, El-Qaa Plain, and W. Feiran. Soils of Agrameia Plain and W. El-Sheikh have medium quality. The lowest quality is assigned for soils of W. Isla, W. Watir, and W. Sanad (Fig. 6). Surface soils of slopes represent the highest soil quality followed by soils of gorges and terraces. Soils of HEW show medium soil quality, whereas soils of LEP, LEW, HEP, and fans have low to medium soil quality (Fig. 7).

Table (3): Soil quality ranking based on soil physical and chemical indicators measured in each plot. Indicators are classified into three categories; low (1), medium (2), and high (3). Rank values of the eight indicators are summed and the total is used to rank plots for soil quality. Rating of soil quality indicators reflects the suitability of soil for growing corn and for supporting plant cover

Index	Low (1)	Medium (2)	High (3)
Soil Physical Indicators			
WHC%	<15	15-25	>25
Silt & Clay%	<10	10-20	>20
Soil Chemical Indicators			
pH (1:2.5)	9.1-10.5	8.5-9	7.3-8.4
EC (1:1) (dS m^{-1})	>5	2-5	<2
SOM (g kg^{-1})	<20	20-50	>50
TN (g kg^{-1})	<0.5	0.5-2	>2
Available P (mg kg^{-1})	<0.2	0.2-0.8	>0.8
CEC (cmol kg^{-1})	<5	5-15	>15

Plant Communities as Bio-indicators of Soil Quality

Eleven main plant communities were recognized in the study area. These plant communities are named according to the dominant species that have the highest presence percentages. Associated species of each plant community, their habitat landforms and locations, in addition to describing color and texture of different soils supporting these different communities are described in Table (4).

Low lands (LEW and LEP) are dominated with communities of *Zygophyllum coccineum* (group I), *Haloxylon salicornicum* (group II), and *Acacia tortilis* - *Zygophyllum coccineum* (group III). These communities are characterized by very pale brown and gravelly sand

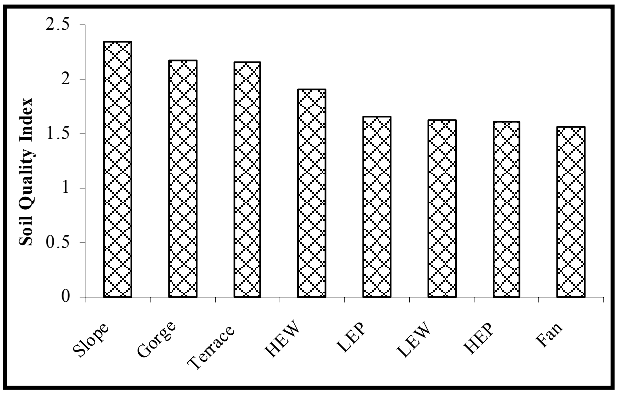

Figure (6): Soil quality at different areas in South Sinai. Mean values with similar letters indicate no significant variation according to Duncan's multiple range test (*F* = 46.437, *P* <0.0001).

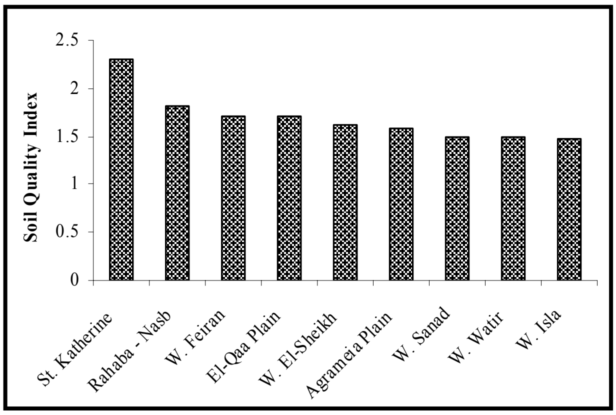

Figure (7): Soil quality at different landform types in South Sinai. Mean values with similar letters indicate no significant variation according to Duncan's multiple range test (*F* = 28.199, *P* <0.0001).

soil to sand in texture. *Retama raetam* community (group IV), one of the widey ecologically distributed communities, dominates LEW, HEW, and fans. Soils support this community are very pale brown to brownish yellow in color and gravelly sand to sand in texture. HEP is characterized by two main plant communities; *Anabasis articulate - Fagonia mollis* (group V) and *Artemisia judaica* (group VI). Soils of these communities are light yellowish brown to brownish yellow in color and gravelly sand in texture

Mountainous landforms (slopes, gorges, and terraces) and HEW are dominated by the following communities: *Artemisia herba-alba* (group VII), *Tanacetum santolinoides-Artemisia herba-alba* (group VIII), *Stachys aegyptiaca - Teucrium polium* (group IX), *Phlomis aurea - Tanacetum santolinoides - Echinops spinosissimus* (group X), and *Mentha longifolia - Nepeta septemcrenata* (group XI). Soils of these communities are darker in color, and have more silt and clay content than soils of low lands (Table 4). Soils at plant communities number VIII and X have the highest silt and clay content (17.17% and 16.58%, respectively), whereas soils at plant communities I and II have the lowest values of silt and clay content (4.04%, and 3.07%, respectively) (Table 5). Altitude and most of soil properties, especially WHC, silt and clay, SOM, TN, and CEC have highly significant variations between different vegetation groups, whereas soil EC has low significant variation. Generally, vegetation groups dominated the mountainous landforms showed higher values of silt and clay, SOM, TN, CEC, and WHC than vegetation groups dominated the wadis, plains or fans.

Discussion

Soils of South Sinai, as desert soils (Aridisols), are characterized by spatial heterogeneity, where soil properties vary over quite small distances. The causes of this heterogeneity include variation in plant cover, vegetation composition, slope, and topography (Schlesinger *et al.*, 1996; Durnkerley and Brown, 1997). In agreement with El-Nennah *et al.* (1981), Ramadan (1988), Kamh *et al.* (1989), Balba (1995), and Moustafa and Zayed (1996), soils of the study area are gravelly in wadis and plains, rocky at mountains in surface, sand to loamy sand in texture, alkaline, nonsaline to slightly saline. They are characterized by low content of essential nutrients and CEC.

The present study indicated that water availability and landform types are the predominant determiners controlling many aspects of soil conditions (soil nutrients, organic matter, and soil texture) and vegetation parameters. In agreement with some previous studies (El-Ghareeb and Shabana, 1990; Moustafa and Zaghloul, 1993; Moustafa and Zayed, 1996) soil moisture availability, which is a function of altitude variation, slope degree, nature of soil surface and soil texture, is the most limiting factor in the distribution of plant communities in South Sinai. The wide altitudinal variation in South Sinai represents a complex gradient related to its effect on temperature and moisture availability (Whittaker, 1975; Peet, 1988). The low elevation sites are climatically characterized by very dry summers with 5-30 mm precipitation per year. On the other hand, the high elevation district of South Sinai receives 35-50mm of precipitation per year (Moustafa and Zayed, 1996). Zohary (1973) concluded that moisture, in the form of rainfall, is the most decisive factor controlling productivity, plant distribution, and life form in arid lands. Due to variation in physiographic features that control moisture availability (Kassas, 1960; El-Ghareeb and Shabana, 1990) and orographic precipitation (Kassas and Girgis, 1970), slopes, gorges, terraces, and HEW have abundant water supply, which may interpret the relatively rich vegetation cover, species richness, and species diversity (Ayyad *et al.,* 2001). Altitude and slope have a direct relation with roughness of soil surface, which plays an important role in effectiveness of rainfall. Large outcrops of smooth-faced rocks maximize the availability of every shower to plants growing in rocks and concentrate run-off water

Table (4): Description of the 11 vegetation groups and their habitats

Plant Community (Dominant Species)	Associated Species	Landform and Location	Color and Soil Texture
I. Zygophyllum coccineum L.	*Fagonia mollis* Delile *Zilla spinosa* (L.) Prantl *Haloxylon salicornicum* (Moq.) Bunge *Fagonia arabica* L. *Iphiona scabra* DC.	LEP at El-Qaa Plain, W. Watir, and W. Isla	Very pale brown, G. sand to sand
II. Haloxylon salicornicum (Moq.) Bunge	*Zygophyllum cocenieum* L. *Fagonia mollis* Delile	LEP, LEW, and Fans at El-Qaa Plain, W. Feiran, and W. El-Sheikh	V.p.br. to Light yellowish brown G. sand to sand
III. Acacia tortilis (Forssk.) Hayne - *Zygophyllum coccineum* L.	*Aerva javanica* (Burm.f.) Juss. Ex Schult. *Pulicaria crispa* (Forssk.) Oliv. *Ochradenus baccatus* Delile *Zilla spinosa* (L.) Prantl *Haloxylon salicornicum* (Moq.) Bunge	Mainly at LEW, sometimes at gorges, terraces, and fans, at El-Qaa Plain, Rahaba Nasb, and W. Watir	V.p.br. to Light yellowish brown G. sand to sand
IV. Retama raetam (Forssk.) Webb & Berthel.	*Artemisia judaica* L.	LEW, HEW, and fans, W. El-Sheikh, Rahaba Nasb, W. Isla, W. Feiran	V.p.br., L.y.br. to brownish yellow G. sand to sand
V. Anabasis articulata (Forssk.) Moq.- *Fagonia mollis* Delile	*Zilla spinosa* (L.) Prantl *Artemisia judaica* L.	HEP at W. Sanad and Agramia Plain	L. y. br. to Br.y. G. sand
VI. Artemisia judaica L.	*Fagonia mollis* Delile *Zilla spinosa* (L.) Prantl *Achilea fragrantissima* (Forssk.) Sch.	HEW, HEP, LEW, and Fans, at W. El-Sheikh, Agramia Plain, W. Sanad, Rahaba - Nasb, and W. Feiran	V.p.br., L.y.br. to brownish yellow - G. sand
VII. Artemisia herba-alba Asso	*Peganum harmala* L. *Zilla spinosa* (L.) Prantl	HEW, HEP, Slopes, LEW at St. Katherine, Rahaba-Nasb, and W. Feiran	L.y.br. To Y. brown G. sand to sand loam
VIII. Tanacetum santolinoides (DC.) Feinbrun & Fertig - *Artemisia herba-alba* Asso	*Teucrium polium* L. *Varthemia Montana* (Vahl) Boiss.	Terraces and slopes at St. Katherine	L.y.br. to dark brown G. sand to G. loamy sand
IX. Stachys aegyptiaca Pers. - *Teucrium polium* L.	*Alkanna orientalis* (L.) Boiss. *Artemisia herba-alba* Asso *Tanacetum santolinoides* (DC.) Feinbrun & Fertig *Ballota undulate* (Fresen.) Benth. *Galium sinaica* (Delile ex Decne.) Boiss. *Varthemia montana* (Vahl) Boiss. *Schismus barbatus* (L.) Thell.	Terraces, Slopes, HEW, and gorges at St. Katherine, W. El-Sheikh, and W. Feiran	L.y.br. to brown - G. sand to G. loamy sand
X. Phlomis aurea Decne.*- *Tanacetum santolinoides* (DC.) Feinbrun & Fertig - *Echinops spinosissimus* Turra	*Alkanna orientalis* (L.) Boiss. *Nepeta septemcrenata* Benth.* *Teucrium polium* L. *Artemisia herba-alba* Asso *Origanum syriacum* L.*, *Ballota undulata* (Fresen.) Benth.	Gorges and HEW at St. Katherine	L.y.br., Y. br. to brown G. sand, G. L. sand, and loamy sand
XI. Mentha longifolia (L.) Huds. - *Nepeta septemcrenata* Benth.*	*Arenaria deflexa* Decne. *Crateagus* x *sinaica* Boiss. *Ficus palmata* Forssk.	HEW, and gorges at St. Katherine	Y. br. to dark grayish brown G. sand to loamy sand

* Endemic species, Br.: Brown, G: Gravelly, L: Light, P: pale, V: very, Y: Yellowish.

in crevices and soil pockets (Zohary, 1973). On the other hand, LEW, plains, and fans are characterized by sparse vegetation, low species richness, and species diversity because their openness, in addition to the scarcity of rainfall, causes high evaporation which exacerbates water scarcity. Only rare and heavy showers cause floods, which contribute effective moisture to the plants in the LEW (Danin, 1972).

Soils of mountainous landforms are shallow in depth but rich in silt and clay, WHC, SOM, and different soil nutrients, whereas plains, fans, and LEW have deep alluvial deposits (Kassas, 1952) of rough sand texture, which characterized by low content of WHC, organic matter, and poorness of many essential soil nutrients such as N, P, and K (Balba, 1995). Soil pH, EC, silt and clay content, WHC, and SOM are the most important indicators of soil quality, and represent driving variables in the soil system, influencing the availability of soil nutrients and controlling the coverage and structure of vegetation.

Table (5): Mean and Standard deviation (SD) of some soil properties and their variations at different vegetation groups

Gr. No.		WHC (%)	Silt + Clay (%)	pH (1:2.5)	EC (1:1) (dS m^{-1})	SOM (g kg^{-1})	TN (g kg^{-1})	P (mg kg^{-1})	CEC (cmol kg^{-1})
I	Mean	10.14	4.04	8.32	0.87	24.6	0.18	0.11	3.88
	SD	1.64	3.08	0.29	0.89	10.3	0.11	0.09	1.26
II	Mean	10.71	3.07	8.39	1.06	20.8	0.14	0.10	3.76
	SD	2.04	1.42	0.33	0.81	9.3	0.12	0.08	1.43
III	Mean	11.31	5.27	8.20	0.86	22.7	0.27	0.21	4.85
	SD	1.57	3.09	0.34	0.71	10.4	0.17	0.11	2.36
IV	Mean	10.74	4.62	8.28	0.82	20.3	0.24	0.34	4.65
	SD	1.59	2.20	0.28	0.69	8.7	0.15	0.36	1.60
V	Mean	10.88	9.11	8.98	1.56	26.1	0.31	0.26	5.62
	SD	1.34	2.28	0.57	2.35	9.3	0.15	0.27	1.28
VI	Mean	10.10	5.11	8.54	0.37	17.6	0.17	0.19	4.63
	SD	1.09	2.11	0.24	0.16	5.5	0.12	0.14	1.06
VII	Mean	13.23	11.92	8.44	0.54	38.6	0.53	0.40	9.05
	SD	3.54	5.75	0.23	0.27	16.1	0.28	0.25	4.21
VIII	Mean	18.59	17.17	8.13	0.42	59	1.09	0.21	18.89
	SD	7.69	10.54	0.21	0.21	29.6	0.76	0.18	7.40
IX	Mean	15.72	12.93	8.16	0.65	55.6	1.01	0.37	13.11
	SD	4.58	4.69	0.23	0.95	26.4	0.59	0.26	5.54
X	Mean	18.66	16.58	8.13	0.93	69.5	1.25	0.38	15.70
	SD	4.57	5.83	0.30	1.92	23.7	0.59	0.28	2.94
XI	Mean	25.21	15.58	7.77	1.74	73.1	2.41	0.47	18.24
	SD	8.13	6.55	0.38	0.59	6.0	1.71	0.49	0.63
	F	21.84**	25.81**	10.43**	2.24*	26.58**	29.39**	4.91**	46.09**

* *F* ratio is significant at the 0.05 level, ** F ratio is significant at the 0.01 level

Artemisia herba-alba, Tanacetum santolinoides, Stachys aegyptiaca, Teucrium polium, Phlomis aurea, Echinops spinosissimus, Mentha longifolia, and *Nepeta septemcrenata* are the dominant plant species characterizing the mountainous habitats. These plant species may be considered as indicators of high soil quality. On the other hand, plant species such as *Zygophyllum coccineum*, *Haloxylon salicornicum*, and *Retama raetam characterizing the* LEW and LEP may be considered as indicators of low to medium soil quality. Using of vegetation cover and structure as indicators of soil quality is in agreement with Wilson *et al*. (2001).

Soil quality management is a useful and effective approach for resource conservation and best management strategies. Soil quality is an important tool for measuring soil degradation. Evaluation of soil quality periodically will help in monitoring and improving soil resources. The provided model of soil quality index is specific for surface soil and it could be useful in evaluating soil quality in arid ecosystems characterized by sand and loamy sand soils.

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أشكال الأرض والكساء النباتى و جودة التربة فى جنوب سيناء، مصر

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الملخص العربـــى

تهدف هذه الدراسة إلى تقييم جودة التربة كواحد من أهم الموارد الطبيعية فى منطقة جنوب سيناء، ودراسة تأثير العوامل الطبوغرافية وأشكال الأرض والكساء النباتى على خصائص التربة وجودتها. تم اختيار عدد مائتى موقع (10 x 10m) فى تسع مناطق مختلفة بجنوب سيناء تعبر عن ثمانية أنواع مختلفة من أشكال الأرض. اشتمل العمل الحقلى على دراسة تركيب الكساء النباتى، و أخذ عينات التربة السطحية. تم زراعة نبات الذرة فى مختلف أنواع التربة لقياس التغيرات فى إنتاجية التربة. تم القيام بالعديد من التحليلات الطبيعية و الكيميائية لعينات التربة المختلفة كذلك تم تحليل العديد من العناصر الكبرى والصغرى فى المجموع الخضرى والمجموع الجزرى لنبات الذرة. خضعت النتائج للعديد من التحليلات الإحصائية و متعددة المتغيرات للوقوف على خصائص التربة وجودتها فى المناطق وأشكال الأرض المختلفة وعلاقاتهم بالكساء النباتى و المجتمعات النباتية.

أوضحت النتائج تميز المناطق الجبلية بسانت كاترين والتى تشتمل على الأخوار و المصاطب و المنحدرات و الوديان العالية، بوفرة الغطاء النباتى والذى يصل إلى (25%) و التنوع البيولوجي والعديد من خصائص التربة مثل زيادة محتوى السلت والطين (15%) والقدرة على الاحتفاظ بالماء (15%) و المحتوى العضوى (6%) وزيادة نسبة العناصر الغذائية وذلك مقارنة بالمناطق الأخرى والتى تشمل السهول والوديان المنخفضة و المراوح حيث يصل الغطاء النباتى إلى (2-13%)، و يقل محتوى السلت و الطين إلى (3.03-8.15%) والقدرة على الاحتفاظ بالماء إلى (9.08-11.52%) و المحتوى العضوى إلى (1.24-2.86%) وزيادة نسبة العناصر الغذائية. وقد أوضحت الدراسات الإحصائية لهذه العوامل بين المناطق المختلفة وأشكال الأرض المختلفة وجود اختلافات معنوية فى معظم هذه العوامل. اظهرت دراسة إنتاجية التربة وجود ارتباط بين بعض خصائص التربة بالغطاء النباتى و إنتاجية الذرة. كذلك وجود علاقة طردية بين معظم العناصر الغذائية التى تم قياسها فى التربة و التى تم قياسها فى المجموع الخضرى والجذرى لنبات الذرة الأمر الذى يؤكد دقة التحاليل الخاصة بالعناصر الغذائية المتاحة فى التربة والتى يمكن الاعتماد عليها فى تقييم جودة التربة.

خلصت الدراسة إلى إنشاء مقياس لجودة التربة خاص بالتربة السطحية لمنطقة الدراسة والذى اعتمد على ثمانى خصائص للتربة أوضحت الدراسة أهميتها كدلائل على جودة التربة وهى نسبة السلت والطين فى قوام التربة، وقدرة التربة على الاحتفاظ بالماء، الرقم الهيدروجينى، والقدرة على التوصيل الكهربائى، و محتوى المادة العضوية، و المحتوى الكلى للنيتروجين، و كمية الفوسفور المتاح، والسعة التبادلية للكاتيونات. أظهرت التحليلات الإحصائية لتطبيق هذا المقياس بمناطق الدراسة وأشكال الأرض المختلفة إلى تميز التربة بمنطقة سانت كاترين بأعلى درجات الجودة (2.303) يليها التربة بمنطقة الرحبة والنصب (1.822)، منطقة سهل القاع (1.709)، ومنطقة وادى فيران (1.707)، ويأتى بعد ذلك التربة السطحية بمناطق علوة العجرمية (1.589)، ووادى الشيخ (1.605) فى حين أوضحت النتائج أن اقل درجات الجودة للتربة السطحية تواجدت بمناطق وادى إسلا (1.470)، ووادى وتير(1.490)، ووادى سند (1.502). كذلك اوضحت النتائج تميز التربة السطحية بالمنحدرات باعلى درجات الجودة (2.335) يليها الأخوار (2.166) و المصاطب (2.161) ثم الوديان العالية (1.907). فى حين تقاربت درجات جودة التربة فى بقية اشكال الأرض إلى أقل معدلاتها حيث تراوحت من (1.645) إلى (1.570). وقد بينت الدراسة مدى إمكانية إستخدام النباتات السائدة وخصائص الكساء الخضرى بصفة عامة كدلائل لجودة التربة.