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USING MODELING APPROACH FOR PLANNING SOIL CONSERVATION MEASURES UNDER NORTH SINAI CONDITIONS

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ABSTRACT: Three hundred and two soils samples from 75 representative profiles taken from North Sinai, which will irrigate from El-Salam Canal. In this study present a framework to facilitate the selection of soil conservation for sustainable agriculture on North Sinai soils, being based on the evaluation of two basic land qualities: soil productivity index (PI) and soil erosion risk index (ERI). The differences and distribution patterns of soil productivity index and soil erosion risk index among various soils were discussed. The range, and mean of soil productivity index (PI) and soil erosion risk index (ERI) in the studied profiles were: PI, 0.0238 to 0.5933, 0.1312 and ERI, 0.0319 to 0.5179, 0.2281. According to the relative values of soil productivity show that 52.00% (39 soils) are low soil productivity index, 45.40% (34 soils) are within moderate productivity index, 1.33% (1 soil) are high productivity index and 1.33% (1 soil) are very high productivity index. Also, according to the relative values of soil erosion risk index show that 36% (27 soils) are low erosion risk index, 29.34% (22 soils) are within moderate erosion risk index, and 34.66% (26 soil) are high erosion risk. The value of these two indexes (PI and ERI) is entered in a matrix; a matrix is generated, showing different land classes as well as soil conservation priorities, conservation requirements and proposed land uses. According to the agricultural classification of lands by matrix show that 62.68% (47 soils) are reserve lands (R) (4th priority conservation treatment). These lands at present have soil a moderate to low productivity and with slight risk of erosion. While, 34.66% (26 soils) of the soil are within critical lands (C) (2nd priority conservation treatment). These lands at present have a moderate to low soil productivity, but are in a condition of strong risk of erosion. Moreover, 2.66% (2 soils) of the soil are sub-critical lands (S) (3rd priority conservation treatment). These are lands that at present have soil with a high to very high

productivity, and with only slight risk of erosion. This is a systematic way to selection of soil conservation practices for North Sinai soil, included the following soil conservation categories: (I) Practices to improve soil productivity and soil erosion resistance, as well as to reduce rainfall erosivity impacts; and (II) Practices to reduce runoff impacts.

INTRODUCTION

The Governmental plans aims at the reclamation and cultivation of about 400.000 feddans concentrated mainly in El-Tina Plain (50.00 feddans), South East El- Qantara (75.000 feddans), Rabaa (70.000 feddans), Bir El-Abd (70.000 feddans) and El-Ser and El-Qawarir (135.000 feddans) areas. Within the from of El-Salam canal project.

Most of the soils of the area in north of Sinai are widely varied in their particle size distribution whether among the profiles or along the entire depths of each profile, as the texture class is ranged between clay to sand (Nasr, 1988). The climatic conditions in the area located north of Sinai indicated that the chemical weathering and the development are weak and there is mostly physical weathering due to variation in temperature, wind and scarcity of rainfall (Mansour, 1997).

Research and development of models to estimate soil mass loss due to erosion have been disproportionate compared with development of tools to estimate and predict soil erosion impact on soil productivity (Pierce, 1991; Pierce and Lal, 1994; and Garcia Prechac and Duran, 2001). This inequality is even more accentuated by the increasing need of environmental impact evaluation in physical but also economic terms.

The sophistication of the existing soil erosion- productivity models is quite variable. They vary from deterministic mathematical models like the erosion productivity impact calculator (EPIC) (Laflen et al., 1985; Williams et al., 1983), simulating storm-based soil erosion, solute movement over and through soil and soil fertility-crop growth, to models that only simulate reduction of soil water storage capacity by continued soil erosion (Stocking and Pain, 1983; Timlin et al., 1986). Sophisticated models such as EPIC require data base that are not readily available in many developing countries (Kiome, 1992). Simple models like those simulating the effect of soil erosion on soil water storage capacity cannot always give accurate predictions of the effect of soil erosion on soil-crop productivity because they do not take into account the physical and chemical properties of soils important for crop growth and affected by soil erosion.

Soil erosion affects many soil characteristics which are related to crop growth and yield (Stocking, 1984, 1994; Pierce and Lal, 1994). Continued soil erosion results in reduced rooting depth and soil water storage capacity, crusting, soil compaction, change in root zone, cation exchange capacity (CEC), aluminium and manganese toxicity, soil acidity, soil alkalinity and deterioration of soil biological properties (Pierce and Lal, 1994; Payton and Shishira, 1994; Stocking and Pain, 1983). Unless a model takes into account most of the important factors affecting crop growth that are affected by soil erosion its accuracy will remain unreliable. The modified productivity index (MPI) model presented in the paper by Mulengera and Payton (1999) takes into account most of the important parameters affecting crop growth and that are affected by soil erosion. The parameters considered in the model are also readily available in developing countries.

Also, Mulengera and Payton (1999) reported that a soil erosion-productivity model which considers the effect of soil water storage capacity, crop evapotranspiration, soil chemical and physical properties important for crop growth has been modified. The model is shown to give good predications and promises to be an improvement over the former productivity index (PI) because it accounts for weather and cropping conditions. It also promises to give more reliable results than the currently used insufficient model which consider only soil water storage capacity and crop evapotranspiration.

There are various methodologies for land classification, evaluation and planning in arid environments. The majority of these methods are oriented towards evaluating the most decided potentials and limitations for agricultural production of lands considered "marginal": the productive capacity of soil (potential) and erosion risk (limitation) (Fernando, 2002).

The methodology first quantifies the two land qualities upon which the classification is sustained: soil productivity and erosion risk. Both are quantified according to their characteristics, by applying multi-factorial methods. In this manner two indexes are obtained: Soil Productivity Index (PI) and Erosion Risk Index (ERI). Each evaluates its respective quality with the following functions:

PI = *f*(biophysical characteristics of the land that encourage root growth)

ERI = *f*(physical characteristics of the land that encourage water erosion)

Main objective of this study are:

a) to determine a relative contributions to variation in soil productivity index and erosion risk index to evaluate the respective soil quality,
b) selection requirements of soil conservation practices according to the matrix of soil productivity and erosion risk.

MATERIALS AND METHODS

In order to study the soil erosion-productivity index in north Sinai soils, 75 soil profiles were selected to represent the area under reclamation (Map 1). The studied area vary in its geological, geomorphological and soil genetic characteristics. In this area the soil productivity index (PI) of these soil profiles was determined. The calculated parameter (Kiniry et al., 1983; Pierce et al., 1983) is based on the determinations of pH, EC, BD, moisture availability and root zone depth.

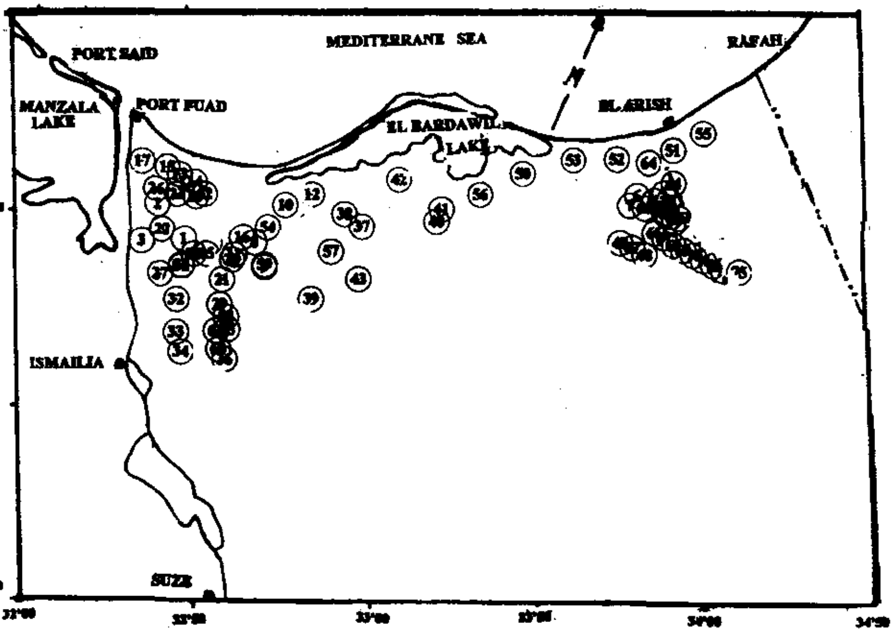
Field work:

302 disturbed and undisturbed soil samples were collected from the studied profiles. The soil samples representing the morphological variations throughout the entire depths of each profile were collected (according to morphological feature and cultivated profile depth of water table or parent material). Soil samples collected from the different layers and analysised from the different determination.

Laboratory analysis:

Soil samples were air-dried and sieved through a 2 mm sieve. Particle size distribution was carried out according to Piper (1950). The water extract components were determined in the soil paste extract, and the determinations of cations and anions were carried out using the standard methods of analysis presented by Jackson (1969). Soil reaction (pH) was determined in the soil paste, according to method proposed by Richards (1954). Collin's calcimeter were used for $CaCO_3$ determination according the method described by Wright (1939), Organic matter was determined following the modified

Walkley and Black method, Jackson (1969).



Map (1): Location of studied soil profiles

Bulk density was determined according to the core methods as described by Blacke (1986).

The soil erosion-productivity index model:

The modified soil productivity index (MPI) model is a hybrid of the productivity index (PI) models proposed by Kiniry et al., (1983) and Pierce et al., (1983). The models simulating soil moisture availability to plants and yield relationships (Stocking and Pain, 1983; Timlin et al., 1986). The PI model as originally developed by Kiniry et al., (1983) and subsequently modified by Pierce et al., (1983) is

$$PI = \sum_{i=1}^{n} (Ai * Ci * Di * Ei * RIi)$$

where A_i is sufficiency of soil water holding capacity in the ith layer(i = Number of soil layers), C_i is sufficiency of soil bulk density (and aeration) in the ith layer, D_i is sufficiency of soil pH of the ith layer, E_i is sufficiency of soil electrical conductivity (salinity) in the ith layer, RI$_i$ is root weighting factor of the ith soil layer, and n is the number of soil layers of the root zone depth.

Sufficiency of potential available water storage capacity - The assumption was that potential available water storage capacity (PAWC) of 0.20 or large was non-limiting. The following linear equation was used to describe sufficiency of PAWC (SUFFPAW)

$$\text{SUFFPAW} = \begin{cases} 1.00 & \text{if PAWC} > 0.20 \\ \text{PAWC}/0.20 & \text{if PAWC} < 0.20 \end{cases}$$

The bulk density sufficiency value determined from Fig. (1) is adjusted to take into account permeability rates (for water and air) by equation:

$$C_i = 1 - (1 - SUFF_g) * \beta,$$

Where $SUFF_g$ is sufficiency of bulk density obtained from Fig. (1), and β is adjustment factor determined by Pierce et. al., (1983) (Table 1).

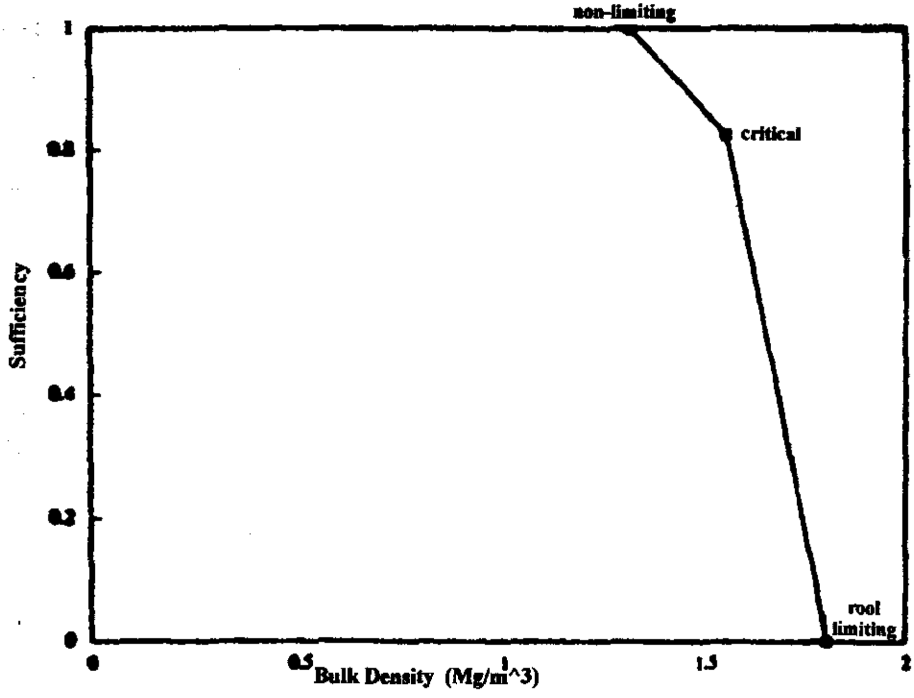


Fig. (1): Sufficieny of bulk density used in the soil erosion-productivity, PI, model (Pierce et. al., 1983)

Table (1): Adjustment factors (*β*) for sufficiency of bulk density used in equation of sufficiency C_I (Pierce et.al., 1983)

	Permeability (mm/h)				
	< 1.5	1.5-5.1	5.1-15.2	15.2-50.8	>50.8
Fine Loamy	1.0	1.0	0.9	0.7	0.5
Coarse Silt	1.0	1.0	1.0	0.9	0.7
Fine Silt	1.0	1.0	0.9	0.7	0.5
Clay					
35-60%	1.0	0.9	0.7	0.6	0.5
> 60%	1.0	0.8	0.6	0.5	0.4

The pH sufficiency, D_i, is determined using the following Equations (Pierce et. al., 1983):

$D_I =$ pH
0.75 for $pH > 8.0$
2.086-0.167pH for $6.5 < pH < 8.0$
1.0 for $5.0 < pH < 6.5$
0.12+0.16 pH for $pH = 5.0$ to 5.5
0.44 pH -1.31 for $pH = 2.9$ to 5.0
0.0 for $pH < 2.9$

The sufficiency of electrical conductivity, E_I, for soils affected by salinity is determined using equation (Kiniry et. Al., 1983):

$$\mathbf{E_i = 1.14 - 0.07\ EC},$$

where EC is the electrical conductivity (dS/m).

The weighting factor, RI_i , is based on the seasonal distribution of plant water uptake from different layers within the root zone. The equation predicting the profile of fractional water uptake from a moist soil is given by (Gantzer and McCarty, 1987):

$$\mathbf{RI_i = 0.152 \log\{R + (R^2 + 6.45)^{0.5}\} - 0.152 \log\{D + (D^2 + 6.45)^{0.5}\}},$$

Where RI_i is the fractional seasonal water uptake from a given soil depth, D was the depth in the profile and R is the maximum plant rooting depth.

Erosion Risk Index (ERI)

The erosion risk index (ERI) is caculated using the following multi-factorial model (Fernando, 2002) :

$$\mathbf{ERI} = \alpha * \beta * \eta$$

where α is factor evaluates the soil runoff potential beginning with granulometry and soil structure degree. Granulometry (using the nomograph) includes the determination of the texture class and the coarse fragments (> 2mm particles) of topsoil. The soil structure mainly includes the evaluation of its degree of development (weak, moderate or strong) (Fernando, 2002).

The β factor evaluates the relative rainfall aggressiveness with Fournier Index. It is determined according to Morgan (1986) (using the nomograph).

The η factor evaluates the impact of the topography on erosion risk. The value of the factor is determined by the terrain slope and is expressed as a percentage (Fernando, 2002) (using the nomograph).

RESULTS AND DISCUSSION

The area under investigation is located along El-Salam Canal territory in the North Sinai between El-Qantara Shark to the West Wadi El-Arish. Topography of the area under investigation represented by microcatchment Fig. (2) that combined the elevation, longitude and latitude of the area under investigation.

The studied soil samples varied widely in their texture classes, samples represented by (sandy (44%), loamy sand (6%), sandy loam (6%), sand clay loam (10%), loamy (2%), clay loam (8%), silty loam (6%), silty clay (2%), and clay (16%)) were predominant among north Sinai studied 302 soil layers (Fig. 3). The data in Table (2) showed that the texture of surface samples varied (sandy (36%), loamy sand (12%), sandy loam (12%), sand clay loam (5.33), loamy (1.33%), clay loam (8%), silty loam (14.67%), and clay(10.67%)).

Concerning the content of organic matter in the studied soil profiles ranged from 0.01 to 1.84%, with an average value 0.28%, while the value of organic matter content in the surface layers of soils (Table 2) ranged from 0.10 to 1.84%, with an average 0.58%. In general the organic matter content, was very low (less than 1.5%) for 297 soil samples of the 203 collected samples, while five samples showed a higher value of organic matter content (> 1.5%).

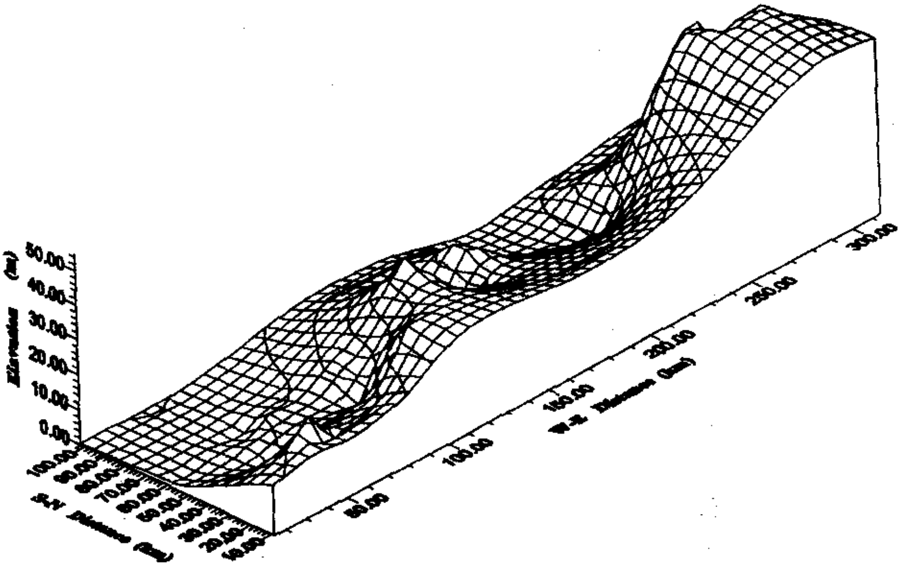


Fig.(2): Microcatchment of topography of the area under investigation

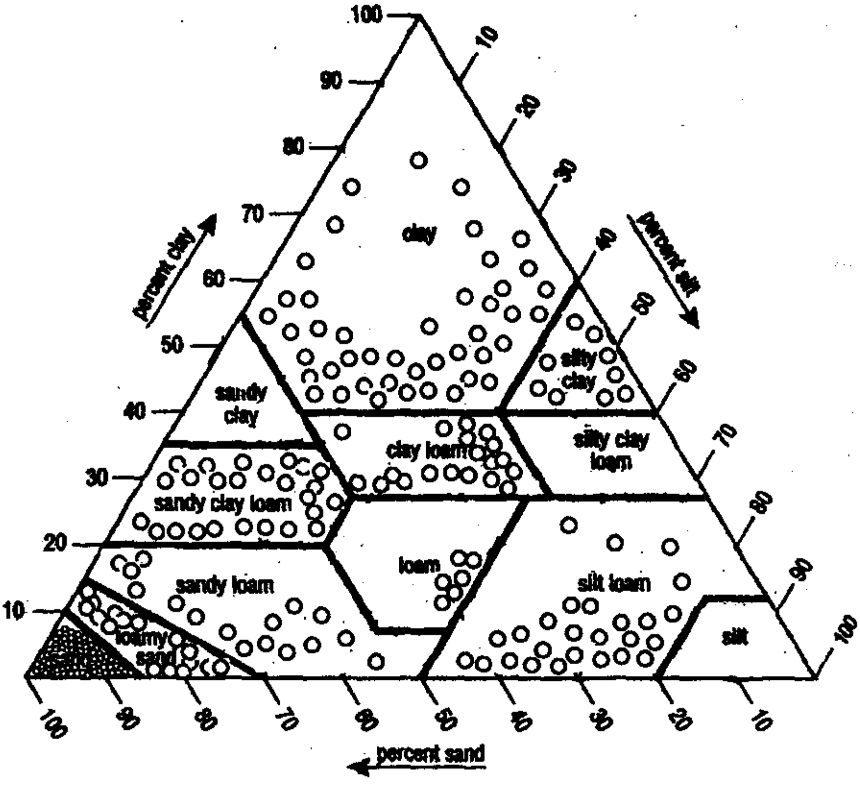


Fig. (3) : Texture composition of the soil data set.

Table (2): Some physical and chemical characteristics of the surface soil samples.

Profile No.	pH	EC_e dS/m	O.M %	$CaCO_3$ %	Texture Class	Bulk Density g/cm^3	Available Water %
1	7.70	6.60	0.70	4.60	LS	1.504	8.37
2	7.90	7.00	0.80	2.00	CL	1.493	15.87
3	7.90	3.00	1.20	2.00	CL	1.470	15.80
4	7.90	4.10	0.40	10.20	SL	1.558	6.80
5	7.90	3.50	1.20	11.10	CL	1.397	22.44
6	7.90	6.30	0.60	27.30	SL	1.547	9.63
7	7.80	6.10	0.60	26.90	SL	1.545	8.17
8	7.50	9.50	1.52	0.60	C	1.419	37.87
9	7.40	8.00	0.56	4.00	SiL	1.439	15.73
10	7.80	8.00	0.62	4.60	SiL	1.494	11.22
11	7.90	8.00	0.95	2.50	C	1.473	23.06
12	7.80	9.00	0.35	0.40	SiL	1.508	9.18
13	7.70	6.60	1.60	4.60	SCL	1.423	10.64
14	7.90	4.50	1.50	2.00	CL	1.451	15.90
15	7.90	4.10	1.46	2.00	CL	1.455	14.80
16	8.40	10.00	0.98	4.40	SCL	1.416	10.64
17	7.50	8.50	0.60	1.00	SL	1.490	8.97
18	7.50	14.50	0.20	9.30	S	1.637	5.57
19	7.30	3.10	0.40	7.90	LS	1.577	8.54
20	7.50	4.50	1.66	0.50	C	1.409	27.45
21	7.30	10.00	1.32	2.30	C	1.342	29.09
22	7.40	13.10	0.85	4.00	SiL	1.422	10.73
23	7.90	10.80	0.39	3.40	SCL	1.503	13.07
24	7.80	12.78	1.35	4.60	SiL	1.451	8.22
25	8.40	8.79	1.82	1.00	C	1.351	37.79
26	7.90	13.40	1.33	2.50	C	1.450	32.49
27	8.10	9.80	0.88	0.60	SiL	1.475	9.55
28	7.80	10.40	0.55	0.40	SiL	1.494	8.03
29	7.40	9.30	0.40	0.50	SiL	1.472	9.31
30	7.60	12.70	0.54	0.84	SiL	1.497	10.15
31	7.30	15.10	1.84	0.75	C	1.440	27.08
32	7.60	11.00	0.46	4.02	L	1.446	10.24
33	8.40	3.87	0.25	1.21	S	1.628	5.54
34	8.40	4.98	0.21	1.12	SL	1.529	7.25
35	7.80	2.75	0.23	1.83	S	1.625	5.75
36	7.90	11.45	0.74	1.85	S	1.586	6.88
37	8.30	1.75	0.54	0.95	S	1.620	5.24
38	8.20	4.20	0.26	0.97	S	1.626	4.33
39	8.30	1.25	0.30	1.10	S	1.624	5.49
40	8.20	1.31	0.19	0.83	S	1.633	5.16
41	8.30	2.35	0.32	1.07	S	1.630	5.91

Table (2): Cont.

Profile No.	pH	EC dS/m	O.M %	$CaCO_3$ %	Texture Class	Bulk Density g/cm^3	Available Water %
42	8.40	2.61	0.30	0.97	S	1.650	6.34
43	8.30	5.98	0.21	0.77	S	1.624	5.41
44	8.50	6.30	0.26	10.05	S	1.598	5.25
45	7.40	12.70	0.15	28.24	S	1.606	6.02
46	8.10	3.76	1.42	41.30	CL	1.347	14.24
47	7.80	14.90	0.19	24.67	S	1.620	5.42
48	8.40	4.12	0.32	34.04	LS	1.593	9.03
49	8.40	3.94	0.30	12.95	S	1.622	4.47
50	8.40	3.40	0.28	1.33	S	1.635	6.53
51	7.70	3.20	0.20	0.20	S	1.634	5.60
52	8.20	1.40	0.18	0.50	S	1.640	4.89
53	7.90	1.90	0.20	0.70	S	1.642	5.35
54	7.70	7.70	0.18	5.60	S	1.642	5.87
55	7.60	2.50	0.20	0.40	S	1.627	5.11
56	7.90	1.70	0.12	0.30	S	1.643	5.68
57	7.70	1.40	0.25	1.50	S	1.637	5.71
58	7.40	6.20	0.18	6.60	S	1.642	5.92
59	7.80	5.00	0.30	4.20	S	1.635	5.35
60	7.60	4.60	0.30	1.80	SCL	1.521	11.99
61	7.80	2.20	0.26	0.40	C	1.408	29.44
62	7.70	4.56	0.70	4.60	LS	1.519	9.37
63	7.80	1.27	0.35	4.60	SiL	1.358	8.22
64	8.45	8.56	0.50	0.30	S	1.603	5.38
65	8.90	1.62	0.60	17.09	LS	1.521	5.01
66	7.60	11.30	0.45	59.82	SL	1.483	7.46
67	7.91	4.10	0.25	70.50	SiL	1.417	13.55
68	8.40	2.50	0.50	59.84	LS	1.533	7.65
69	7.97	3.15	0.10	66.23	SL	1.486	10.25
70	8.33	3.60	0.35	76.91	S	1.610	5.16
71	8.27	3.50	0.15	61.32	LS	1.550	8.87
72	8.60	2.50	0.25	66.22	SL	1.512	12.20
73	7.75	16.15	0.12	53.40	SL	1.490	7.38
74	7.95	1.10	0.45	19.22	LS	1.565	6.98
75	8.30	2.62	0.55	3.22	LS	1.522	7.11

Calcium carbonate content in the studied soil profiles ranged from 0.20 to 81.18%, while, the values of calcium carbonate content in the surface layers of soils (Table 2) ranged from 0.30 to 76.91%.

The studied soil have EC_e values ranged from 0.40 to 16.15 dS/m, with an average 5.81 dS/m and have pH values ranging from 7.10 to 9.10. While, the survey data of (Table 2) show that the EC_e values in the surface layers of soils ranged from 1.10 to 16.15 dS/m , with an average 6.24 dS/m. Moreover, the pH values in the surface layers of soils anging from 7.30 to 8.90.

Concerning the bulk density values in the studied soil profiles values one ranged between 1.342 to 1.650 g/cm^3, with an average of 1.549 g/cm^3, while the value of bulk density in the surface layers of soils (Table 2) ranged from 1.342 to 1.643g/cm^3, with an average value of 1.525 g/cm^3. While, the survey data of (Table 2) show that the available water capacity values in the surface layers of soils ranged from 4.37 to 37.87% , with an average 10.82%.

The Soil Productivity Index (PI)

The results of applying the productivity index (PI) approach are presented in Table (3). Soil productivity index (PI) values varied depending on the initial soil properties within the root zone (Tables 2 and 3). Inspection of Table (3) reveal the fact that PI for studied soils (75 profiles) ranged between 0.038 and 0.5931 with an average of 0.1312. In addition, the differences between the productivity index for studied soils, depending upon the sufficiencies of five soil properties, pH, ECe, bulk density, potential available water storage capacity (PAWC) and rooting depths.

The profiles of estimated soil properties were converted to sufficiency values according to equations presented by Kiniry et. al. (1983), and Scrivner et. al. (2002). Sufficiency of PAWC is 1.00 if PAWC is equal to or greater than 0.20 cm/cm. Sufficiency of PAWC is equal 0.20 if PAWC is less than 0.20 cm/cm.

Sufficiencies of pH in the layer of profiles were set equal 0.75 to 0.90 regard of the value of pHs, is partially limiting between the layer of profiles. Moreover, the density sufficiency is less limiting, the values set equal 0.80 to 0.90. While, the sufficiency of EC show weighting factor, the value equal 0.111 to 0.910.

Soil productivity based on soil properties and application of a PI

Table (3): Productivity Indices (PI), fractional change(FPI), vulnerability (V) and erosion risk index (ERI) in soil profiles of representative soils.

Profile No.	PI	PFI	V	ERI
1	0.1348	-0.0872	-0.00147	0.28518
2	0.1127	-0.0182	-0.00090	0.28224
3	0.1576	-0.0088	-0.00047	0.26880
4	0.1050	-0.0148	-0.00068	0.46075
5	0.1899	-0.0042	-0.00043	0.29988
6	0.0846	-0.0001	-0.00004	0.46530
7	0.0785	-0.0098	-0.00030	0.40458
8	0.1964	-0.0008	-0.00035	0.27930
9	0.1207	-0.0297	-0.00273	0.35851
10	0.0596	-0.0087	-0.00029	0.34629
11	0.2216	-0.0042	-0.00019	0.32928
12	0.0509	-0.0119	-0.00035	0.30272
13	0.1738	-0.0012	-0.00005	0.28560
14	0.1717	-0.0098	-0.00063	0.31920
15	0.1884	-0.0033	-0.00017	0.27063
16	0.0929	-0.0052	-0.00017	0.29920
17	0.0797	0.0018	0.00003	0.40332
18	0.0238	-0.0255	-0.00017	0.36184
19	0.0879	-0.0156	-0.00079	0.51798
20	0.2596	-0.0006	-0.00003	0.39922
21	0.1535	-0.0057	-0.00024	0.08751
22	0.0568	-0.0225	-0.00081	0.35851
23	0.0517	-0.0251	-0.00038	0.36666
24	0.4772	-0.0008	-0.00014	0.34221
25	0.5933	-0.0098	-0.00148	0.39925
26	0.1099	-0.0137	-0.00021	0.09332
27	0.0805	-0.0116	-0.00023	0.35851
28	0.0315	-0.0282	-0.00068	0.08412
29	0.1035	-0.0153	-0.00036	0.38848
30	0.1286	-0.0106	-0.00033	0.11424
31	0.0741	-0.1217	-0.00021	0.14574
32	0.0832	-0.0095	-0.00024	0.27165
33	0.0955	-0.0047	0.00011	0.29750
34	0.0832	-0.0047	-0.00012	0.34000
35	0.0741	-0.0016	-0.00003	0.25500
36	0.1030	-0.0404	-0.00082	0.25585
37	0.0855	-0.0002	-0.00004	0.41800
38	0.0489	-0.0010	-0.00001	0.42750
39	0.0865	-0.0002	0.00001	0.37905

Table (3): Cont.

Profile No.	PI	PFI	V	ERI
40	0.0861	-0.0005	-0.00001	0.29040
41	0.0969	-0.0107	-0.00021	0.25520
42	0.1045	-0.0017	-0.00001	0.29040
43	0.0915	-0.0021	-0.00001	0.24200
44	0.0925	-0.0116	-0.00023	0.16168
45	0.0769	-0.0121	-0.00023	0.45120
46	0.0813	-0.0033	-0.00001	0.36652
47	0.0708	-0.0702	-0.00034	0.24650
48	0.0975	-0.0013	-0.00001	0.35700
49	0.0511	-0.0001	-0.00001	0.25500
50	0.0874	-0.0014	-0.00001	0.19720
51	0.1871	-0.0047	-0.00016	0.26675
52	0.1217	-0.0016	-0.00001	0.27111
53	0.1166	-0.0150	-0.00068	0.18769
54	0.1158	-0.0113	-0.00044	0.19186
55	0.1046	-0.0016	-0.00001	0.25026
56	0.1224	-0.0195	-0.00103	0.20020
57	0.0979	-0.0086	-0.00033	0.29197
58	0.0727	-0.0223	-0.00076	0.34920
59	0.1229	-0.0058	-0.00025	0.38412
60	0.0814	-0.0290	-0.00173	0.52066
61	0.1106	-0.0037	-0.00016	0.40875
62	0.0928	-0.0559	-0.00106	0.07295
63	0.0917	-0.0234	-0.00145	0.08369
64	0.2459	-0.0590	-0.00215	0.17110
65	0.2033	-0.0160	-0.00063	0.40740
66	0.2559	-0.0377	-0.00152	0.45000
67	0.1328	-0.0069	-0.00035	0.44880
68	0.2184	-0.0113	-0.00093	0.50440
69	0.2906	-0.0063	-0.00053	0.46800
70	0.1456	-0.0078	-0.00035	0.16750
71	0.1773	-0.0017	-0.00008	0.45760
72	0.2013	-0.0222	-0.00224	0.43460
73	0.1212	-0.1856	-0.00016	0.48400
74	0.1503	-0.0217	-0.00193	0.4505
75	0.2152	-0.0035	-0.00001	0.38740

model showed the lowest PI in the shoulder and highest PI in the footslope positions (Fig. 4). The changes in soil productivity reflect a reduction in topsoil depth and root zone depth in the shoulder and backslope positions, and a corresponding increase in topsoil and root zone depth in the footslope and toeslope positions (the values of stander deviation of the pH, EC_e , BD, PAWC, root zone and elevation in the studied profiles are 0.53, 3.78, 0.83, 0.71, 20.98 and 21.77, respectively). These findings are in agreement with those obtained by Schumacher, et. al. (1999).

Relative values of soil productivity, estimated with the productivity index (PI) may be qualified as indicated in Table (4).

Table (4): Evaluation of soil productivity in terms of the values of productivity index (PI) mentioning the most promising agricultural uses (after, Fernando 2002)

PI	Soil productivity
≤ 0.10	Low
0.11 – 0.30	Moderate
0.31 – 0.50	High
≥ 0.51	Very high

According to the relative values of soil productivity reported by Fernando (2002) the data in Table (3) of soil productivity index show that 52.00% (39 profiles) are low soil productivity index, 45.40% (34 profiles) are within moderate productivity index, 1.33% (1 profile) are high productivity index and 1.33% (1 profile) are very high productivity index.

Erosion and Soil Productivity Index

Erosion is a form of soil change. The PI model can be used to estimate the effects of erosion and conservation programs. The PI model has been modified and used successfully to assess the long-term effects of erosion in areas other than North Sinai (Larson et.al. 1983; Pierce et.al. 1983; Rijsberman and Wolman 1984 and Schumacher et.al. 1999).

The data in Table (3) can be analyzed in such a manner that a few numbers can lead to estimates of changes in productivity associated with erosion. A definition of each number in Table 3 follows:

FPI = Fractional change in PI per cm of erosion

= $(PI_{sub} - PI_s / PI_s / 30$ cm

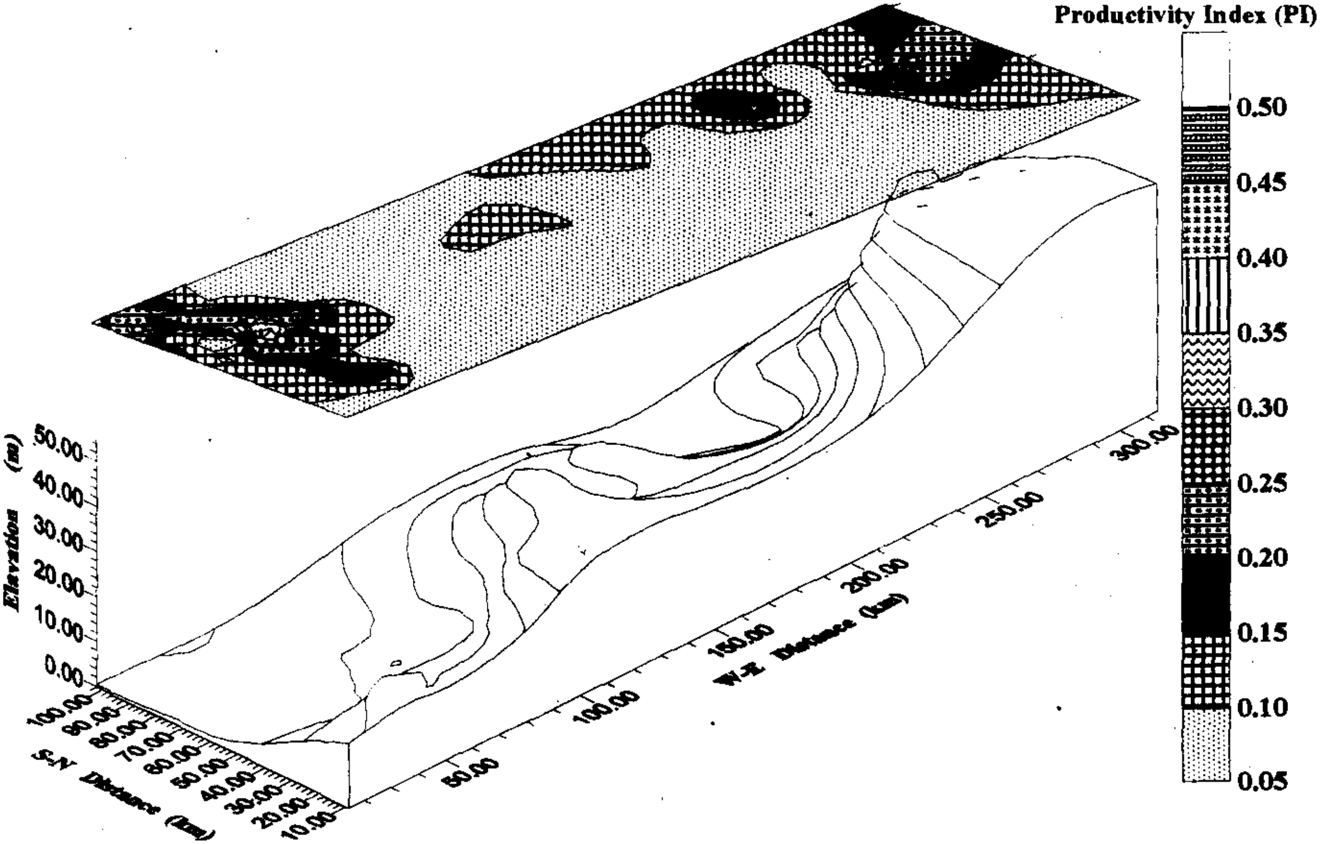


Fig. (4): Microcatchment of soil productivity index (PI) and topography of the area under investigation

V = Vulenerability

= $(PI_{sub} - PI_s)/30$ cm

This number can be used in comparing one soil with another on the basis of absolute change in yields associated with erosion (Scrivner et. al.,2002).

Where PI_s = PI of surface layer at the present time or at T=0

PI_{sub} = PI of subsurface layer.

The seventy five numerical values for each soil in Table (3) provide a quantitative basis for assessing the effects of erosion. Those seventy five values can be generated for any soil for which the PI input value are known. For studied soils, the values of PFI are varied from -0.0702 to -0.0001, with an average -0.01271.

This number is the fractional loss relative to the original PI(PI_0) for each cm (0.39 inches) of erosion. The number will useful where the yield potential of a tract has been established for a given combination of weather and management. On a farm field, for example, the loss in yield for 1 cm of erosion equals (FPI) x (established yield potential). One multiplies that value by 2.54 to convert to yield loss from 1 inch of erosion (Scrivner, et. al 2002).

The vulnerability (V) value in Table (4) represents the loss in potential productivity (PI) that would result from 1 cm or 0.39 inches of erosion. It differs from FPI as loss is not relative to the particular site. To convert V to estimated yield loss, one multiplies V by the estimated yield from Table 5. For studied soils, the values of V are varied from -0.00273 to -0.00001, with an average -0.00047.

Soil erosion is currently estimated in units of tons per acre. A common target in erosion control is to restrict erosion to less than 5 t/a/year soil loss. A conversion from tons per acre to inches or cm per acre is required (Scrivner et. al. 2002). That conversion is as follows:

a. 7 acre inches is equivalent to 2,000,000 Ibs. or 1,000 t.
b. At 5 t/a/year for 20 years, 100 T or 1/10 of 7 inches is lost.
c. The loss is 0.7 inches/acre or 1.778 cm/acre.

The constant of 1.778 can be used to convert data from Table (3) into the estimated losses. The fractional change in potential productivity = FPI x 1.788. The loss in yield potential = FPI x 1.788 x (established yield potential). If established yield are not available, the vulnerability can be used in conjunction with estimated yield. The change in PI over the 20-year period = V x 1.778. The estimated annual loss in yield potential after 20 years of erosion = V x 1.788 x (established yield potential) (Scrivner et. al. 2002).

Erosion Risk Index:

Erosion risk or potential erosion is understood to mean the maximum loss of soil possible in the absence of a cover crop and conservation practices, that is to say, only taking into consideration the interaction of the physical factors of the land: soil, climate and topography (Fernando, 2002).

The results of applying the erosion risk index (ERI) approach are presented in Table (3). Erosion risk index (ERI) values varied depending on the initial soil properties within the climate (Table 3). Inspection of Table (3) will reveal the fact that ERI for studied soils (75 profiles) ranged between 0.03192 and 0.51798 with an average of 0.51798. In addition, the differences between the erosion risk index for studied soils, depending upon the sufficiencies of soil properties, climate and topography. These realties are in agreement with those obtained by Fernando (2002).

Relative values for the erosion risk of a unit of land, estimated by means of the Erosion Risk Index (ERI), can be classified as indicated in Table (5) (Fernando, 2002)

Table (5): Classification of erosion risk in terms of the values of the Erosion Risk Index (ERI) (after, Fernando 2002)

ERI	Erosion Risk
≤ 0.10	Low
0.11 – 0.30	Moderate
0.31 – 0.60	High
≥ 0.61	Very high

According to the relative values of soil erosion risk index by Fernando (2002) the data in Table (3) show that 36% (27 soils) have low erosion risk index, 29.34% (22 soils) have within moderate erosion risk index, and 34.66% (26 soil) have high erosion risk.

Soil erosion risk index (ERI) values varied depending on the initial soil properties within climate. Soil erosion risk index showed the lowest ERI in the footslope and highest ERI in the summit position (Fig. 5). A large change in ERI was observes at shoulder position and backslope position due to the combined effects of soil structure, slop and climate.

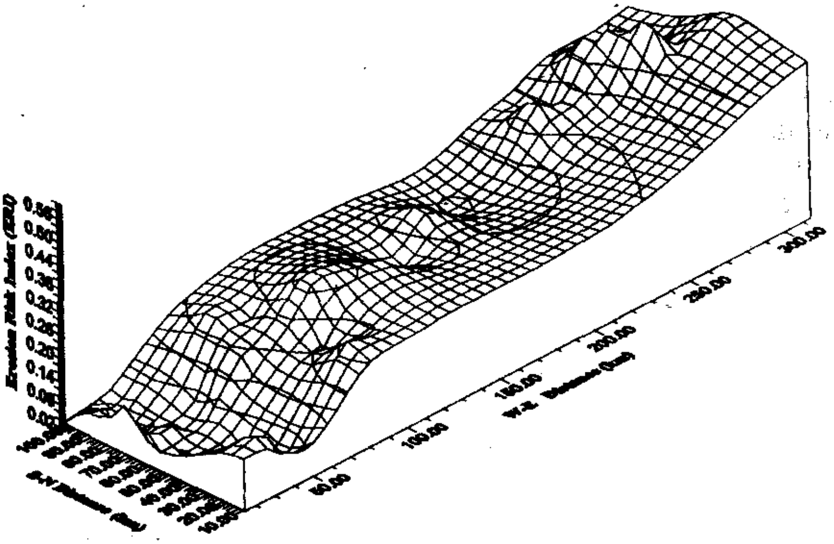


Fig.(5): Microcatchment of soil erosion risk index (ERI) and topography of the area under investigation.

Agricultural Classification of Lands

Soil productivity (PI) and erosion risk index (ERI) have finally permitted establishing a classification system of agricultural lands based on these two fundamental qualities. This system appears in Figure (6) (Fernando, 2002).

<table>
<tr><th rowspan="2">Soil Productivity Index (PI)</th><th colspan="4">Erosion Risk Index (ERI)</th><th rowspan="2">General Land Use</th></tr>
<tr><th>≤010
Low</th><th>0.11 –0.30
Moderate</th><th>0.31-0.60
High</th><th>>0.61
very high</th></tr>
<tr><td>≤010
Low</td><td colspan="2" rowspan="2">Reserve Lands (R)
(4th priority conservation treatment)</td><td colspan="2" rowspan="2">Critical Lands (C)
(2nd priority conservation treatment)</td><td>Permanent vegetation / Agroforestry</td></tr>
<tr><td>0.11 –0.30
Moderate</td><td>Special crops/ Agroforestry</td></tr>
<tr><td>0.31-0.50
High</td><td colspan="2" rowspan="2">Sub-critical Lands (S)
(3rd priority conservation treatment)</td><td colspan="2" rowspan="2">Super-critical Lands (P)
(1st priority conservation treatment)</td><td>Semi-intensive agriculture</td></tr>
<tr><td>>0.51
very high</td><td>Intensive agriculture</td></tr>
<tr><td></td><td>Low</td><td>Moderate</td><td>High</td><td>Very High</td><td></td></tr>
<tr><td></td><td colspan="4">Soil Conservation requirements</td><td></td></tr>
</table>

Fig.(6): Classification of land system and soil conservation priority (After, Fernando 2002)

According to the agricultural classification of lands by Fernando (2002) the data in Table (3) and Fig. (6) of soil productivity index (PI) and soil erosion risk index (ERI) show that 62.68% (47 soils) are reserve lands (R) (4th priority conservation treatment). These lands at present have soil with moderate to low productivity and with slight risk of erosion. They may be dedicated to limited agricultural uses and for only a small variety of crops or for non-agricultural purposes. Usually they are considered marginal land for soil conservation programs. Eventually they could be incorporated to more intensive agricultural uses once soil productivity has improved substantially. They are placed at a fourth priority level for conservation treatment (Fernando, 2002). These soils represented by soils No.1, 2, 3, 8, 9, 12, 13, 14, 15, 16, 17, 20, 21, 22, 23, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 39,40, 41, 42, 43, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, and 68 (Fig. 7).

While, 34.66% (26 soils) of the soil are within critical lands (C) (2nd priority conservation treatment). These lands at present have a moderate to low soil productivity, but are in a condition of strong risk of erosion. They could be incorporated in special agricultural programs with specific crops for low productivity soil, or use for non-agricultural purposes, but with a strong conservationist component. These lands could be incorporated eventually to more intensive agricultural uses when soil management directed to improve their productivity combined with intensive practices of soil conservation treatment. These soils represented by soils No. 4, 5, 6, 7, 18, 19, 37, 38, 41, 44, 45, 46, 47, 49, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, and 75 (Fig. 7).

Moreover, 2.66% (2 soils) of the soil are sub-critical lands (S) (3rd priority conservation treatment). These are lands that at present have soil with a high to very high productivity, and with only slight risk of erosion. They are ideal for continuous, intensive and diversified agricultural production of an ample variety of crops, but with permanent conservation management programs that will guarantee the maintenance of the productive capacity of the soil. They are situated at a third priority level for conservation treatment. These soils represented by soils No. 24 and 25.

Selection of Soil Conservation Practices

In terms of the main limitations detected in the analysis of factors

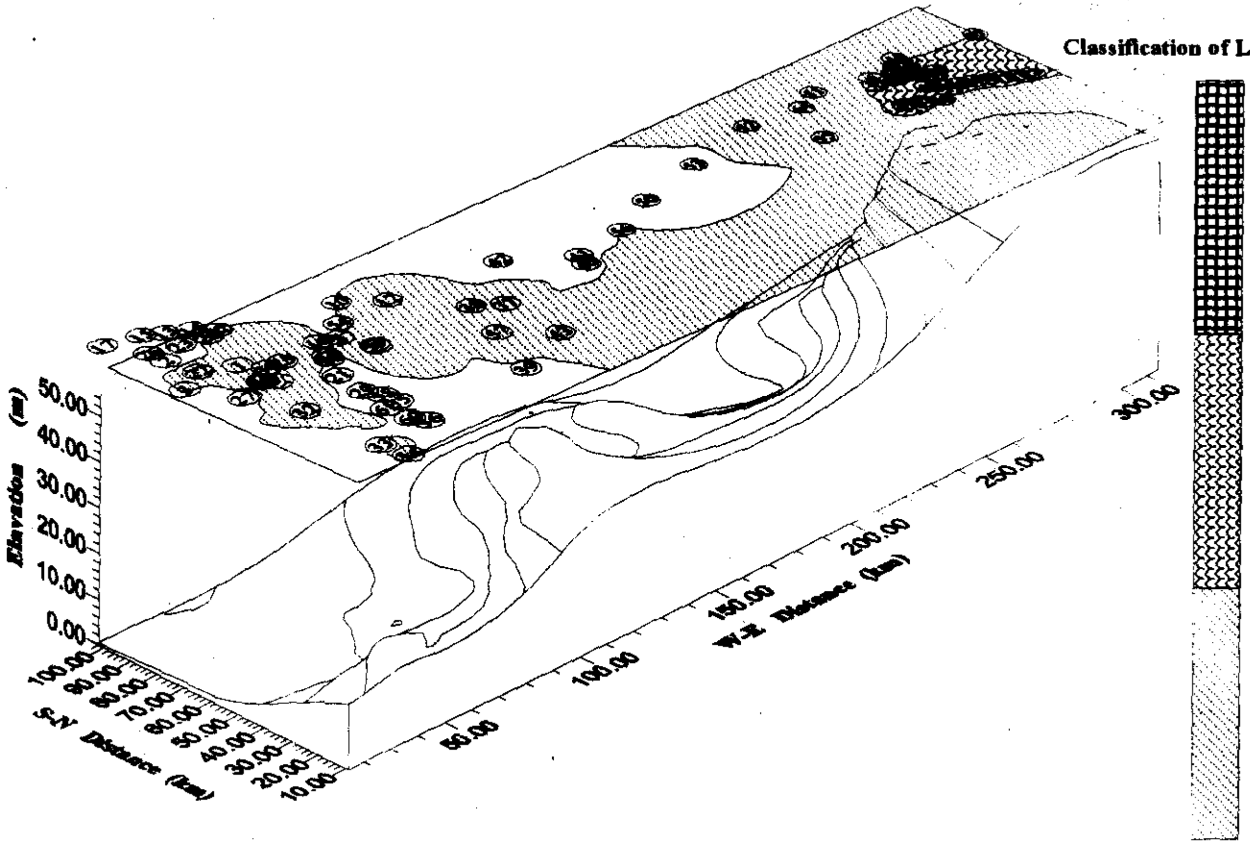


Fig.(7): Microcatchment of classification of land system and topography of the area under investigation.

corresponding to soil productivity index and erosion risk index, there are some management and conservation practices that could be used to improve it and could be used to reduce such erosion risks.

For improving the reserve lands (R), following a group of land qualities which should consider in order to evaluate the improvements in the studies soil:

1) Soil Improvement

This umbrella term can include deep ploughing (for heavy texture , represented by some profile in El-Tina Plain), mulch tillage (for sandy soil, represented by profiles in East El-Qantara, some profile in El-Tina Plain, Rabaa, and Bir El-Abd), residue incorporation, organic manures (for sandy soil), application of green manures, soil amendments (for heavy texture), and synthetic conditioners (for sandy soil, use of organic polymers to improve soil structure and aggregate stability). In reserve lands (R) with advanced soil conservation programs the concept of conservation tillage is the main theme of the recommendations for reserve lands (R). The application is mainly in mechanized high production farming with low productivity index, or for the control of erosion where there is large-scale mechanized cereal production.

2)Ground covers and plant management

The principles are equally effective in any conditions – to maximize soil productivity by returning crop residues and by using high crop density of vigorous crops. Conservation tillage also has the advantage of reducing the need for terraces or other permanent structures. There are several advantages of application of conservation tillage in arid conditions:

- Multiple cropping may be compatible with the well-tested strategy of using plant populations to suit moisture availability, the soils represented in East El-Qantara can be growth with field crops (alfalfa, barely, cotton, groundnut, onion, sesame soybean, sunflower, corn and sorghum) followed by vegetables (carrots, green pper, potato, tomato, watermelon and pea) and also fruit trees (citrus, guava, mango and olives).
- crop rotations.
- tolerant crops, the soils represented in El-Tina Plain, used for growing crops (alfalfa, barley, and sorghum) followed by vegetables (carrots and watermelon) and fruit trees

olives, This may be due to the relatively high salinity and high water table level(> 75 cm). .

- perennial crops.
- tree replanting and afforestation.

3) Irrigation system and drainage

One of the reasons for low yields in arid areas is the limited amount of moisture available to crop roots. The available moisture will be increased by application of conservation tillage in arid conditions:

- trickle irrigation
- sprinkler irrigation

Pressurized systems trickle – sprinkler for coarse texture

- drainage (especially for relatively high clay soils).

For high levels of production for critical land (C), conservation farming demands skilled labour, expensive equipment and the costly use of herbicides to reduced weed competition for moisture and nutrients. So, demonstrates the urgent need to adopt the conservation farm concepts in critical land (C).

There are several advantages which application of conservation tillage in critical land (C). General layout, conservation farming description for reserve lands (R) can be used and following:

- ♦ Slowing down runoff speed
  - Contour cropping
  - Strip cropping
- ♦ Runoff catchment and / or transporte
  - Retention ditches
  - Filtering ditches
  - Retention terraces
  - Contour furrows

There are two main goals for conservation sub-critical land (S):

- ♦ to improve the physical and chemical conditions of the soil; and
- ♦ to shield the soil surface from the destructive risk erosion using mulches or productive cover crops.

For improving the sub-critical lands (S), following a group of land qualities which should consider in order to evaluate the improvements in the studies soil:

- ♦ Reduced tillage
- ♦ Mulch tillage
- ♦ Organic manures
- ♦ Trick irrigation
- ♦ Sprinkler irrigation

This is a systematic way to selection soil conservation practices for North Sinai soils, included in the following soil conservation categories: (I) Practices to improve soil productivity and soil erosion resistance, as well as to reduce rainfall erosivity impacts; (II) Practices to reduce runoff impacts; (III) Complementary practices.

This paper underlines the importance of land use planning as fundamental to guarantee the success of soil conservation programs in North Sinai area. Moreover, the relevance of soil productivity and erosion risk are emphasized, as qualities that permit integrating several relevant characteristics of these lands, as well as to adequately formulate a coherent and simple system, adapted to the particular conditions of North Sinai soil, for the identification and selection of soil conservation alternatives and priorities.

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استخدام النماذج في تخطيط أساليب صيانة التربة تحت ظروف شمال سيناء

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لدراسة أساليب صيانة التربة بهدف الزراعة المستدامة في شمال سيناء و المزمع ريها بمياه ترعة السلام تم اخذ عدد ٣٠٢ عينه تربة من ٧٥ قطاع أرضي وتم تقدير دليل إنتاجية الأرض (PI) و دليل خطر انجراف التربة (ERI) . وكانت قيم دليل إنتاجية الأرض (PI) و دليل خطر انجراف التربة (ERI) وكذلك المتوسط الحسابي كالتالي : دليل إنتاجية الأرض (PI) من ٠,٠٢٣٨ آلي ٠,٥٩٣٣ بمتوسط ٠,١٣١٢ و دليل خطر انجراف التربة (ERI) من ٠,٠٣١٩ آلي ٠,٥١٧٩ بمتوسط ٠,٢٢٨١ .

وطبقا للقيم النسبية لدليل إنتاجية الأرض وجد آن ٥٢,٠٠ % من الأراضي المدروسة في مجال معدل إنتاجية منخفض و ٤٥,٤٠ % من الأراضي المدروسة في مجال معدل إنتاجية متوسط و ١,٣٣% من الأراضي المدروسة في مجال معدل إنتاجية عالي. وأيضا وطبقا للقيم النسبية لخطر انجراف التربة وجد آن ٣٦ % من الأراضي المدروسة في مجال منخفض لخطر انجراف التربة و ٢٩,٣٤ % من الأراضي المدروسة في مجال متوسط لخطر انجراف التربة ٣٤,٦٦% من الأراضي المدروسة في مجال عالي لخطر انجراف التربة .

وعند وضع قيم (PI) و (ERI) في مصفوفة لتقسيم الأراضي تبعا لعمليات الخدمة المقترحة. وطبقا لقيم المصفوفة وجد آن ٦٢,٦٨ % من الأراضي المدروسة في مجال الـ **reserve lands** وهذه الأراضي ذات إنتاجية من معتدلة الى منخفضة الإنتاجية ومع معدل منخفض للتعرض لخطر الانجراف. بينما ٣٤,٦٦ % من الأراضي المدروسة في مجال **critical lands** وهذه الأراضي ذات إنتاجية من معتدلة الي منخفضة الإنتاجية ومع معدل عالي للتعرض لخطر الانجراف. ووجد أيضا آن ٢,٦٦ % الأراضي المدروسة في مجال **sub-critical lands** وهذه الأراضي ذات إنتاجية من مرتفعة الي مرتفعة جدا في الإنتاجية ومع معدل منخفض للتعرض لخطر الانجراف. وهذا هو النظام المتبع لاختيار عمليات الخدمة المقترحة لأراضى شمال سيناء و تتضمن اتباع الأساليب الخدمة التي تؤدى الى :

١- تحسين إنتاجية الأرض ومقاومة عمليات الانجراف و أيضا تقليل خطر الانجراف نتيجة اصطدام قطرات المطر

٢- تقليل اثر الانجراف نتيجة الجريان السطحي للمياه.