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Evaluation of the Land Degradation Severity by Using the Ordinary Kriging in West Nubariya Region, Egypt.

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SUGAR beet area (80,000 fed.) represents one of the newly reclaimed areas in West Nubariya since 1989. The agriculture development in the area is facing human-induced degradation of water logging and salinity problems mainly due to unsustainable agricultural practices. The present study aims to apply ordinary kriging technique to estimate the spatial variability of land degradation severity at Ssugar beet area during years from 1997 to 2003. The study involves: (1) Creating Digital Terrain Model (DTM) to obtain physiographic mapping units, (2) Defining the differentiating land qualities and creating soil thematic value maps, (3) Determining the degradation status of each soil mapping units and defing the extent of land degradation severity between years 1997 and 2003.

The study revealed that water logging and salt affected on sugar beet zone1 of West Nubariya increased during years from 1997 to 2003. The land degradation rate might be due to drainage system and the use of drainage water (low quality) for flooding irrigation. Also, the irrigation schedule in the area was inadequate due to insufficient irrigation water and some problems in the irrigation canals design.

Keywords: Land degradation evaluation, Geostatistical analysis, Ordinary Kriging, West Nubariya, Egypt.

The national strategy of Egypt for horizontal expansion of agricultural lands until year 2017 aims at adding about 4.32 million feddans in different regions, depending on land suitability and water resources. The region of the West Delta lying west of the Nubariya Canal presents one of the most promising areas that include local reclaimed land of 558,500 feddans. These areas were previously uninhabited deserts, but about 70% have already been reclaimed and now are occupied by investors and joint venture company's, public companies and small holders. The majority of settlers has been settled in the area for over 20 years and has by now become well established. The productivity of these recent settlers is limited, their use of water is wasteful, and the institutional services to help them are either weak or under developed.

Sugar beet area (80,000 fed.) represents one of the newly reclaimed areas in the west of the Nile Delta. It is subdivided into 35 villages distributed in the area from 1989 – 1992 to 9293 settler as part of national project allocated graduates. The actual situation is that only 30.47% of the graduates are still permanently settling in the area, and traditional farmers now cultivate the majority of the land. The soils from surface and go down are calcareous sandy loam to silt clay loam and permeable clays. Their high content of carbonates (30-40%) causes fixation of phosphorus, low availability of certain micro-nutrient (Fe, Zn, Ni, Cu), weak top soil structure (capping) and relatively low available moisture content. Hardpans consisting of carbonate are observed in some locations at depths varying from 1.2 to 3 m. The localized presence of this layer obstructs proper natural drainage and represents production difficulty on this type of soil. The area depends on flooding irrigation with intervals: 14 days, without irrigation and seven days of irrigation in both winter and summer times. In most cases, the farmer is only allowed for one-day irrigation every 21 days. However, crust formation on the soil surface after irrigation hinders the full germination of most crops.

The agriculture development in the area is facing human-induced degradation mainly water-logging and salinity problems. Those are due to seepage from irrigation canals, inadequate drainage systems, and conversion of pressurized irrigation system to surface-flooding, direct use of low quality drainage water in irrigation, and mixing drainage and wastewater with irrigation water system. Also, lack of field experience and training in managing the reclaimed calcareous desert fringes increased the existing implementation of degradation problems.

The technologies such as geographic Information System (GIS), geostatistical analysis, and remote sensing (RS) enable researchers and land use planner, to better understand the spatio-temporal variability of land degradation in a specific area. The ANOVA and Geostatistical analyses could contribute to obtain the thematic value maps of the selected soil qualities. The status of the degradation process is characterized by the degree of soil degradation. GIS operation capability could estimate the extent of land degradation severity per soil mapping units. The overall severity level of soil degradation is aggregate the status degree and relative extent of the soil degradation process.

The purposes of this study are to: (1) Create Digital Terrain Model (DTM) to obtain physiographic mapping units, (2) Define the differentiating land qualities and create soil thematic value maps, (3) Determine the degradation status of each soil mapping unit and define the extent of land degradation severity between 1997 – 2003.

Study area

The total studied area covers about 40000 feddans encompassing 21 villages. It represents one of the newly reclaimed areas in the west of the Nile Delta. The location map of the study area is shown in Fig. 1. The area has a Mediterranean climate, characterized by rainy winter and prolonged hot and dry summer. The maximum monthly temperature is 30.3° in August and the minimum temperature is 6.3° in January. The annual rainfall is low (104 mm) and the relative humidity ranges between 59% and 81%, within an average of 69%. In summer, the north trade wind comes from the Mediterranean Sea bringing moisture with it and during the period of February to July the Khamaseen wind, coming from the southwest direction, from the vast area of Western Desert, prevails. Soil moisture regime is Torric or Aridic and the soil temperature regime is hyperthermic.

Methodology

The integrated land and watershed management system, ILWIS 3.11 (2001), has been used as a GIS package software. The topographic maps of the area sheets NH35-K5b "Alam Musaylikh", NH35L-5d "El Hammam", NH35-L6a "Alam Al Jataa", NH35L-6b "Jabal Khashm Al Qaud", NH35L-6c "Burj AlArab", and NH35L-6d "Iking Maryut", scale 1:50,000 produced by the Egyptian General Survey Authority (1994), were used as base maps. Map projection: Transeverse Mercator, Datum: Old Egyptian 1907, Central Meridian: 31E, Origin Latitude: 30N, False Easting: 615000 m, and False Northing: 810000 m. Satellite images of TM, 1999 and 1997 were georefernced using the topographic map, then the field observations, roads, irrigation and drainage systems, and villages were located. The geological map of Egypt, scale 1:2,000.000 was produced by the Ministry of Industry and Mineral Resources (1981).

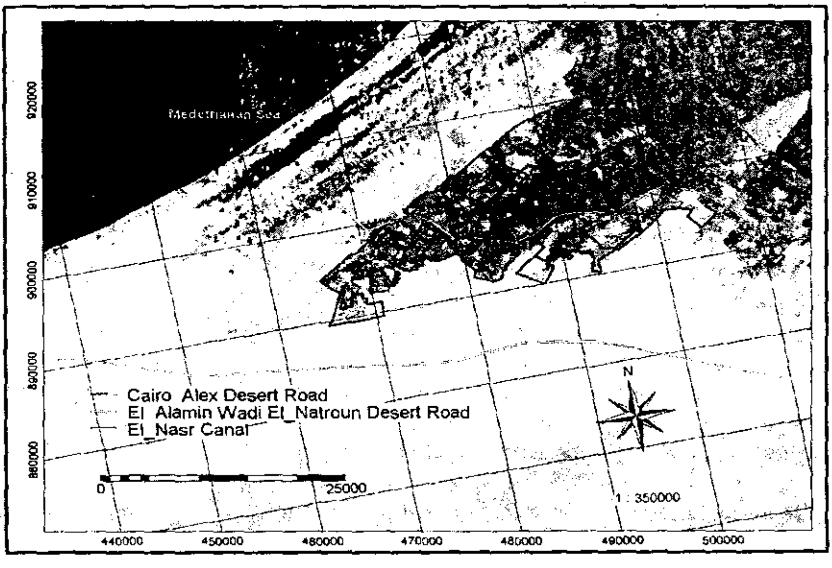

Fig. 1. The location of the studied area .

During the year of 1997, the effective soil depths, soil salinity and drought data of 100 soil profiles from soil surface up to 2 meters and 346 mini pits at 80 cm depth from soil surface, followed by auger holes were evaluated in the field in a grid system with spacing of approximately 1000 meters (Erian & Yacoub, 1999). Based on the same location of 1997 observation, mini-pits and auger observations were morphologically described and sampled for physical and chemical analysis. The physical and chemical analyses of the representative profile were showed in Table 1 & 2.

Geostatistical analysis was carried out at a two step procedure: (a) the calculation of the experimental semi-variogram and fitting a model; and (b) interpolation through ordinary Kriging, which uses the semi-variogram parameters (Stein, 1998). The semi-variogram is defined as a spatial dependence function of the distance h between locations in the observation space. Ordinary Kriging takes into account both the structured and random characteristics of spatially distributed variables, thus providing tools for their description and optimal estimation. Fitted Semi-variogram model for contour points was achieved and DTM was created using the histogram and slicing operations. Based on DTM, axially information, and geological map of Egypt (1:2,000.000), physiographic mapping units were assigned using the approach of Zinck (1998). Analysis of variance (ANOVA) was used to define the differentiating land qualities of the physiographic mapping units for 1997 and 2003 (Davis, 1986 & 1998).

Ordinary Kriging algorithm was applied to delineate the most accurate purified boundaries for the different soil qualities. The soil quality value difference maps were calculated using the MapCalc operation between years 1997 and 2003. Year 1997 was used as a reference initial state. The degradation status of different soil qualities per year were calculated by the following formula: The differences (value raster map) per one year = ((year1997 – year 2003)/5) .

The percentage of land degradation severity was calculated through the following formula :

The % of land degradation severity = ((year 1997-year 2003) / year1997)*100 .

The degradation status per year and the percentage of land degradation severity of 5 yeas were evaluated and classified according to FAO (1978) and Farchad 1989. The degradation status classes and extends degradation percent were crossed with the physiographic mapping units. The extent of land degradation severity for each soil mapping unit was evaluated by using the relative frequency of occurrence within the delineated mapping unit, which is given in GLASOD (Oldeman, 1994 and Oldeman & van Lynden, 1998) according to the following five classes: Infrequent: up to 5% of the mapping unit is affected, Common: 6 to 10% of the mapping unit is affected, Frequent: 11 to 25% of the mapping unit is affected, Very frequent: 26 to 50 % of the mapping unit is affected, Dominant: over 50% of the mapping unit is affected. The overall degradation severity were evaluated according to the method of GLASOD (Global Assessment of Desertification) using the status of severity level and the extent areas, in two-diminution Table.

TABLE 1. The Chemical analysis of the representative profiles of year 2003.

Profile No.	Depth (cm)	pH	EC (dS/m)	Cations (meq/L)				Anions (meq/L)			Mapping Unit
				Ca2+	Mg2+	Na+	K+	HCO3-	Cl-	SO42-	
P8	0-30	7.85	0.87	3.53	1.30	3.11	0.92	1.90	4.70	2.30	Hil11
	30-60	7.87	0.56	2.89	1.23	1.50	0.75	0.54	3.48	1.70	
	60-150	7.38	0.45	2.30	1.10	1.20	0.19	0.31	2.65	1.89	
P9	0-30	7.26	2.87	15.99	3.31	9.50	1.32	3.50	20.30	5.50	Hil12
	30-60	7.42	1.12	5.52	1.15	4.42	0.65	2.30	7.53	1.50	
	60-150	7.51	0.95	5.30	1.10	-4.15	0.62	2.00	7.32	1.30	
P38	0-30	7.90	4.88	22.09	6.20	19.20	1.96	3.50	37.59	9.11	
	30-60	7.52	4.15	21.30	4.78	14.76	1.68	3.38	34.38	4.20	
	60-150	8.00	2.34	11.59	2.70	8.30	1.35	2.30	17.68	3.50	
P1	0-30	7.70	0.87	3.93	1.00	2.75	1.24	1.85	4.93	2.10	Hil13
	30-60	7.50	0.73	3.20	0.85	2.98	0.85	1.26	4.26	2.30	
	60-150	7.51	0.44	2.32	1.14	1.20	0.17	1.01	2.50	1.30	
P19	0-30	7.41	3.16	14.30	3.64	17.14	4.51	26.94	7.07	29.10	
	30-60	7.65	4.61	20.86	5.31	25.00	6.57	39.30	10.31	20.10	
	60-150	7.48	5.21	23.58	6.01	28.26	7.43	44.42	11.65	27.90	
P25	0-30	7.25	2.74	14.20	3.16	9.32	1.91	2.35	20.30	5.60	Hil14
	30-60	7.35	2.75	13.94	3.17	10.35	1.85	2.50	21.30	4.68	
	60-150	7.69	2.16	10.49	4.49	6.50	1.20	2.35	16.42	3.60	
P45	0-30	8.50	3.14	15.42	5.63	9.35	1.92	3.20	21.66	7.10	
	30-60	8.42	2.78	13.68	3.20	10.20	1.65	3.10	18.96	6.50	
	60-150	7.94	2.41	11.36	2.78	9.58	1.44	2.34	16.92	5.36	
P15	0-30	7.70	6.70	34.56	10.10	22.58	2.10	4.10	49.57	15.30	Val11
	30-60	7.49	4.16	21.10	6.80	12.35	1.95	3.50	29.30	9.30	
	60-150	7.51	4.43	21.86	5.98	16.35	1.65	3.50	33.54	8.30	
P59	0-30	8.01	12.64	61.62	7.19	57.98	4.30	5.43	100.32	31.60	
	30-60	8.30	9.96	48.56	5.67	45.69	3.20	4.10	71.59	25.34	
	60-150	8.00	7.03	34.57	4.00	31.56	2.56	3.50	45.69	23.30	

Results and Discusions

The study was carried out at two spatial scale, the first involved the west Nubariya area comprises the four topographic map sheets, the second involved the sugar beet zone 1 as a case study (Fig. 1).

West Nubariya area

Semi-variogram

In total 6,629 contour point's covers four topographic maps. The values of the contour point's map ranged between 0 to 149 meters ASL (Above Sea Level) and the average was 53.2 meters ASL. The standard deviation was 31.1 m ASL. Using the ILWIS 3.11 facility, the dependent output table will be defined and calculated. From the results of the spatial correlation operation, the semi-variogram models were developed (Table 3).

TABLE 2. The physical analysis of the representative profiles of year 2003.

Sample No.	Depth cm	Sand %	Silt %	Clay %	Texture Class	$CaCO_3$ %	Mapping Unit
P8	0-30	71.20	7.80	20.90	S.C.L	22.29	
	30-60	58.40	15.60	26.00	S.C.L.	24.31	Hi111
	60-150	76.80	7.70	15.40	S.L.	18.64	
P9	0-30	82.00	7.70	10.30	L.S.	21.27	
	30-60	74.00	7.80	18.20	S.L.	22.29	
	60-150	63.60	13.00	23.40	S.C.L.	16.82	Hi112
P38	0-30	71.40	10.40	18.20	S.L.	24.31	
	30-60	76.60	10.40	13.00	S.L.	28.36	
	60-150	81.80	5.20	13.00	S.L.	20.26	
P1	0-30	65.80	21.00	13.20	S.L.	19.25	
	30-60	71.10	7.90	21.00	S.C.L	14.18	
	60-150	58.40	15.60	26.00	S.C.L.	14.18	Hi113
P19	0-30	74.00	10.40	15.60	S.L.	16.21	
	30-60	71.40	15.60	13.00	S.L.	22.29	
	60-150	71.40	15.60	13.00	S.L.	10.13	
P25	0-30	74.00	7.80	18.20	S.L.	19.25	
	30-60	71.40	10.40	18.20	S.L.	23.30	
	60-150	70.10	10.40	19.50	S.L.	29.38	Hi114
P45	0-30	76.80	7.70	15.40	S.L.	13.57	
	30-60	70.10	10.40	18.20	S.L.	23.30	
	60-150	66.20	10.40	23.40	S.C.L.	14.18	
P15	0-30	71.60	10.30	18.10	S.L	20.26	
	30-60	76.70	7.80	15.60	S.L	27.35	
	60-150	76.50	7.80	15.70	S.L	21.27	Va111
P59	0-30	74.00	10.40	19.50	S.L.	20.26	
	30-60	71.40	15.60	13.00	S.L.	23.30	
	60-150	76.60	5.20	18.20	S.L.	16.21	

TABLE 3. The DTM model parameters of the five models and their goodness of fitting.

Models	Parameters			Goodness of fitting semi-variogram (R^2)
	Nugget	Sill or slope	Range	
Spherical	0.0	2050	89,500	0.759
Exponential	0.0	2650	62,150	0.704
Gaussian	40	1500	29,000	0.636
Power	50	0.0013	1.3	0.871*
Wave	40	1395	12,750	0.765

* The most fitting module

Ordinary Kriging

The parameters of the best fitting model were used to calculate the interpolation of the contour point values map as the following definition:

Map Kriging Ordinary (contour, sub area, power (50.0, 0.0013, 1.30), 40000, 1, 8, 14, average, 0.0, 1000).

The result of applying Kriging shows that the values of the raster map ranged from -2 to 149.7 m ASL. The mean, the median, and the domain values were 48.82, 42.0 and 22.0 m ASL, respectively. The result shows that the values of the raster error map ranged from 7.37 to 31.49 m ASL. The mean, the median, and the dominant values were 11.15, 8.07 and 7.56 m ASL, respectively. Notes: the big difference between the estimated error of Kriging and the standard deviation of the contour points map (31.1 m ASL.).

Physiographic mapping units

The DTM value map was used to delineate the boundaries of the physiographic mapping units after using the histograms operation. Using the slicing operation with the interval values, we can transfer the DTM value map to a classified map. The slicing operation was used to determine the physiographic mapping units. The landscape was classified as Coastal plain, Elongated hills, Mean valley, plain of Maryout tableland, and Plain of Marmarica formation. The main relief types were Sea beach, Bar, Lagoon Maryout, Extensive ridge, Depression, Series of Terraces, and Knop. The geomorphic mapping unit's legend was shown in Table 4.

TABLE 4. The Physiographic mapping units legend.

Environmental deposits	Landscape	Relief	Lithology	Landform	Unit	Area in Hectares	%
Marine deposits	Coastal plain	Sea beach	Pliocene formation	Beach	CP111	435	0.16
		Bar		Bar	CP211	605	0.22
				Swale	CP212	3680	1.31
		Lagoon maryout		Shore	CP311	5130	1.82
				Water	CP312	2450	0.87
	Elongated hills	Extensive ridge		Summit	HI111	9195	3.27
				Back slope	HI112	30,000	10.66
				Foot slope	HI113	42,200	14.99
				Toe slope	HI114	71,410	25.37
	Mena valley	Depression		Outer	Va111	27,840	9.89
				Inner	Va112	13,360	4.75
				Outer leveled	Va211	8440	3.00
Colluvial deposits	Plain of Maryout Tableland	Series of Terraces	Pliocene Miocene formation	Terrace 1	PI111	9500	3.37
				Terrace 2	PI112	8825	3.14
				Terrace 3	PI113	9670	3.08
				Terrace 4	PI114	10,695	3.80
				Terrace 5	PI115	12,350	4.39
				Terrace 6	PI116	6780	2.41
Colluvial Aeolian deposits	Plain of Marmarica formation	Series of Terraces	Miocene formation	Terrace 1	PI211	2005	0.71
				Terrace 2	PI212	1230	0.44
				Terrace 3	PI213	1305	0.46
		Knop		Knop	PI311	1870	0.66
		Depression		Depression	PI411	1500	0.53

Sugar beet zone 1

Physiographic mapping units

Using the MapCalc operation the geomorphic mapping units were defined using the existing physiographic mapping units (Fig. 2 and Table 5).

TABLE 5. The geomorphic map legend sugar beet zone 1.

Environmental deposits	Landscape	Relief	Lithology	Landform	Unit	Area in Hectares	%
Marine deposits	Elongated hills	Extensive ridge	Pliocene formation	Summit	HI111	1480	4.10
				Back slope	HI112	9225	25.55
				Foot slope	HI113	7080	19.61
				Toe slope	HI114	11,675	32.33
	Mena valley	Depression		Outer	Va111	4910	13.59
				Inner	Va112	1740	4.82

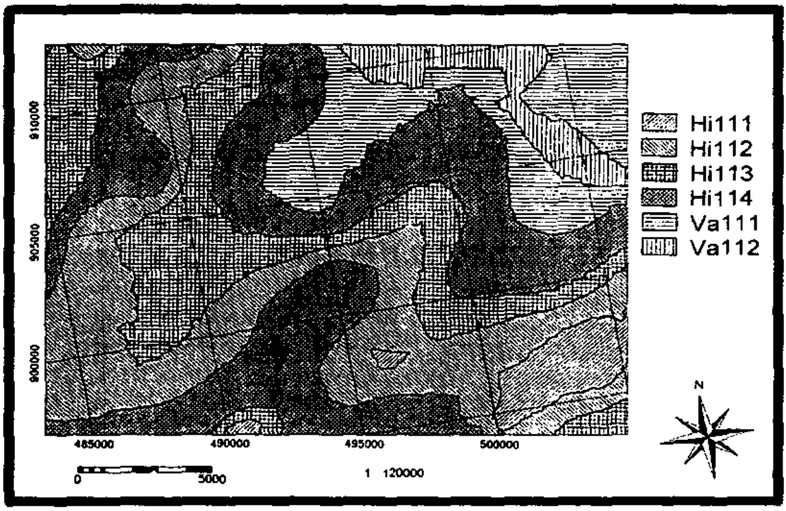

Fig. 2. The geomorphic mapping units of the case study .

Land qualities

According to Erian *et al.* (1999) and Yacoub (1999), the Analysis of Variance (ANOVA) was carried out between the physiographic mapping units and the soil properties (such as effective soil depth, soil salinity, and calcium carbonates) evaluated in 2003. The data in the Table 6 indicate that the effective soil depth measurements and the total calcium carbonate % are the soil properties that differentiates the 5 geomorphic mapping units (groups). Also, the data indicates that the EC measurements of the three layers and the EC of weighted layer of 0-60 cm depth are not a soil properties that differentiate the 5 geomorphic mapping units (groups). Therefore, the Kriging method was used to interpolate the effective soil depth and calcium carbonate %, and the moving surface method was used to interpolate the EC values of the three layers and the EC of weighted layer of 0-60 cm depth.

TABLE 6. The results of ANOVA table of the soil properties year 2003.

Variable	Source of variation	Sum of Squares	df	Mean Square	F calc.	F0.1 table	Sig.
Effective soil depth	Between Groups	15722.6	4	3930.6	5.31	3.565	0.001
	Within Groups	67348.7	91	740.1			
	Total	83071.3	94				
EC layer 1	Between Groups	846.9	4	211.7	1.065	3.565	0.379
	Within Groups	17899.6	91	198.9			
	Total	18746.5	95				
EC layer 2	Between Groups	842.2	4	210.5	1.254	3.565	0.294
	Within Groups	15282.5	91	167.9			
	Total	16124.7	95				
EC layer 3	Between Groups	411.8	4	102.9	0.787	3.565	0.536
	Within Groups	11767.5	91	130.7			
	Total	12179.3	95				
EC layer Of 60 cm	Between Groups	757.4	4	189.4	1.137	3.565	0.344
	Within Groups	15151.2	91	166.5			
	Total	15908.6	95				
CA layer 1	Between Groups	4180.1	4	1045.0	17.508	3.565	0.000
	Within Groups	5431.6	91	59.7			
	Total	9611.7	95				
CA layer 2	Between Groups	5577.6	4	1394.4	17.108	3.565	0.000
	Within Groups	7416.9	91	81.5			
	Total	12994.5	95				
CA layer 3	Between Groups	8221.6	4	2055.4	21.195	3.565	0.000
	Within Groups	8824.5	91	96.9			
	Total	17046.1	95				

EC: Electrical Conductivity (Salinity) in dS/m at 25°. CA: Calcium Carbonate % .

Effective soil depth

A total of 95 observation points were selected during March 2003 to cover the case study area through grid system with intervals of 1000 m. Using the attribute operation, the effective soil depth point map was created. The values of the effective soil depth point's map were ranged between 60 to 150 cm and the average was 120.4 cm. The standard deviation was 26.4 cm. The Kriging method was used to interpolate the effective soil depth. Table 7 shows the parameters and R^2 of each one.

TABLE 7. The effective soil depth model parameters of the five models and their goodness of fitting.

Models	Parameters			Goodness of fitting semi-variogram (R^2)
	Nugget	Sill or slope	Range	
Spherical	10	725	2050	-0.631
Exponential	10	745	850	-0.692*
Gaussian	50	725	900	-0.648
Power	470	0.0036	1.30	-0.495
Wave	450	720	650	-0.595

* The most fitting module

The parameters of the best fitting model were used to calculate the effective soil depth point values map as the following definition:

Map Kriging Ordinary (depth, sub area, exponential (10.0, 745.0, 850.0), 10000, 1, 8, 14, average, 0.0, 1000).

The result of applying Kriging shows that the values of the raster map ranged from 61.2 to 149.7 cm. The mean, the median, and the dominant values were 122.97, 122.8 and 138.4 cm, respectively. The standard deviation was 12.55 cm. Dependent raster value map of the estimated error was created directly when applying Kriging estimation. The result shows that the values of the raster error map ranged from 9.96 to 33.7 cm. The mean, the median, and the predominant values were 21.89, 21.79 and 21.94 cm, respectively.

Using the slicing operation, the rated classes of effective soil depth were created Fig. 3. The result shows that 820 Ha (8.68% of the total area) classified as moderate deep soil (60-90 cm depth), 2905 Ha (30.66% of the total area) classified as deep soil (90-120 cm depth), 5750 Ha (60.66% of the total area) classified as very deep soil (more than 120 cm depth).

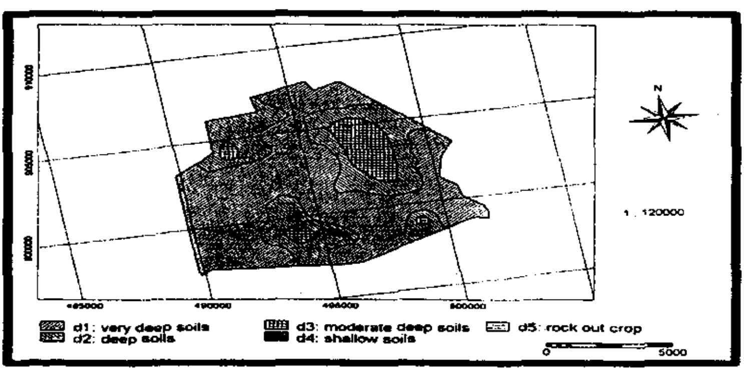

Fig. 3. Effective soil depth classes.

Carbonate accumulation

A total of 95 observation points were taken during March 2003 to cover the case study area in grid system with intervals of 1000 m. using the attribute operation, the total calcium carbonate point maps were created for the surface layer (0-30 cm depth), first subsurface layer (30-60 cm depth), and second subsurface (more than 60 cm depth). The values of the total calcium carbonate % point's map of surface layer were ranged from 5.5 to 46.8% and the average was 21.24%. The standard deviation was 9.67%. The values of the total calcium carbonate % point's map of the first subsurface layer ranged between 10.7 to 55.3% and the average was 24.77%. The standard deviation was 11.25%. The values of the total calcium carbonate % point's map of the second subsurface layer ranged between 6.1 to 63.8% and the average was 25.98%. The standard deviation was 24.3%. The Kriging method was used to interpolate the effective soil depth point map. Table 8 shows the parameters of the tested models and R^2 of each one. The parameters of the best fitting models of the three layers were used to calculate the total calcium carbonate % point values maps of the three layers as the following definition:

Surface layer = Map Kriging Ordinary (Ca layer1, sub area, exponential (10.0, 166, 6000), 10000, 1, 8, 14, average, 0.0, 1000).

First subsurface layer = Map Kriging Ordinary (Ca_layer2, sub area, Power (35.0, 0.0185, 1.0), 10000, 1, 8, 14, average, 0.0, 1000).

Second subsurface layer = Map Kriging Ordinary (Ca_layer3, sub area, exponential (25.0, 295, 5650), 10000, 1, 8, 14, average, 0.0, 1000).

TABLE 8. The effective soil depth model parameters of the five models and their goodness of fitting.

Calcium carbonates	Models	Parameters			Goodness of fitting semi-variogram (R^2)
		Nugget	Sill or slope	Range	
Surface layer 0-30 cm	Spherical	20	148	11500	0.893
	Exponential	10	166	6000	0.896*
	Gaussian	35	146	5500	0.894
	Power	40	0.015	1.00	0.885
	Wave	20	.149	2650	0.883
First subsurface layer 30-60 cm	Spherical	30	200	11,000	-0.587
	Exponential	15	235	6300	-0.445
	Gaussian	45	200	5250	-0.246
	Power	35	0.0185	1.0	-0.824*
	Wave	50	200	2650	-0.574
Second subsurface layer > 60 cm	Spherical	35	250	9650	0.944
	Exponential	25	295	5650	0.945*
	Gaussian	60	250	4650	0.679
	Power	40	0.028	1.00	0.741
	Wave	65	220	1950	0.766

* The most fitting module

The result shows that the values of the raster map of surface layers ranged from 8.48 to 41.95 %. The mean, the median, and the domain values were 21.40, 18.77 and 18.57% respectively. The result of first subsurface layer shows that the values of the raster map ranged from 15.67 to 49.96 %. The mean, the median, and the dominant values were 24.36, 21.45 and 20.89%, respectively. The result of second subsurface layer shows that the values of the raster map ranged from 11.77 to 56.26 %. The mean, the median, and the dominant values were 25.92, 21.66 and 21.59%, respectively. Dependent raster value maps of the estimated error of the three layers were created directly when applying Kriging estimation. The result shows that the values of the raster error map of the surface layer were ranged from 4.12 to 7.15%. The mean, the median, and the dominant values were 5.09, 5.07 and 5.1%, respectively. The result shows that the values of the raster error map of the first subsurface layer were ranged from 6.9 to 8.96%. The mean, the median, and the domain values were 7.74, 7.16 and 7.15%, respectively. The result shows that the values of the raster error map of the second subsurface layer were ranged from 6.38 to 10.1%. The mean, the median, and the dominant values were 7.48, 7.45 and 7.49%, respectively.

Using MapCalc operation, the differences between the surface layer and the first subsurface layer, and also the differences between the first subsurface layer and the second subsurface layer were created. The two differences value map can be classified using the slicing operation to obtain the calcic horizon maps. Fig. 4 & 5 show that 7145Ha (75.37% of the total area) classified as non-calcic horizon, 2335 Ha (24.63% of the total area) classified as calcic horizon.

Salt affected areas

A total of 95 observation points were taken during March 2003 to cover the case study area in grid system with intervals of 1000 m. using the attribute operation, the EC values of first subsurface layer point map were created. The values of the EC value point's map were ranged between 0.10 to 95.85 dS/m and the average was 6.10 dS/m. The standard deviation was 13.91 dS/m. The result of applying moving surface shows that the values of the raster map ranged from 0.10 to 95.98 dS/m. The mean, the median, and the dominant values were 8.17, 4.08 and 2.76 dS/m, respectively. The standard deviation was 10.07 dS/m. Using the slicing operation, the rated classes of Salic horizon were created. The result shows that 8105 Ha (85.5% of the total area) classified as non-salic horizon, 1375 Ha (14.5% of the total area) classified as salic horizon.

Also, using the slicing operation the rated classes of soil salinity were created. The result shows that 1790 Ha (18.88% of the total area) classified as non-saline soils < 2 dS/m, 2835 Ha (29.90% of the total area) classified as slightly saline soils 2-4 dS/m, 2235 Ha (23.58% of the total area) classified as moderate saline soils 4-8 dS/m, 1065 Ha (11.23% of the total area) classified as strong saline soils 8-16 dS/m, 1555 Ha (10.41% of the total area) classified as very strong saline soils >16 dS/m.

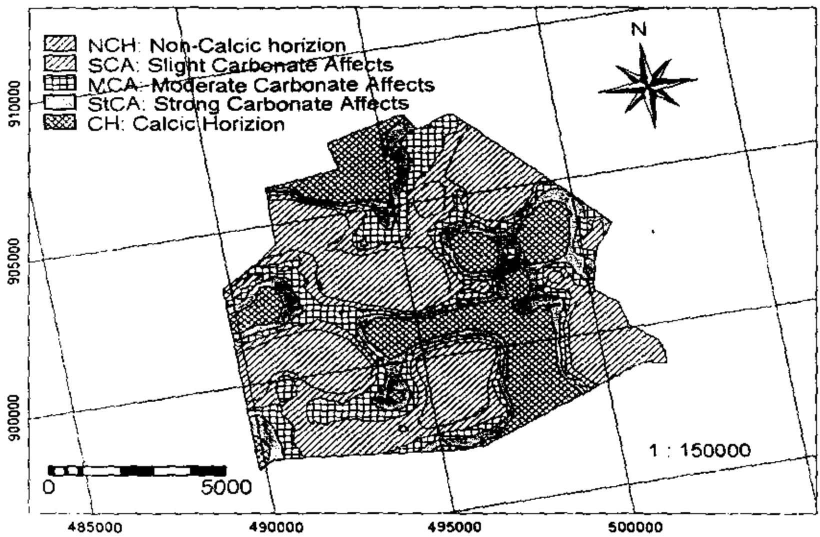

Fig. 4. The classified map of the differences value map between surface layer and the first sub-surface layer .

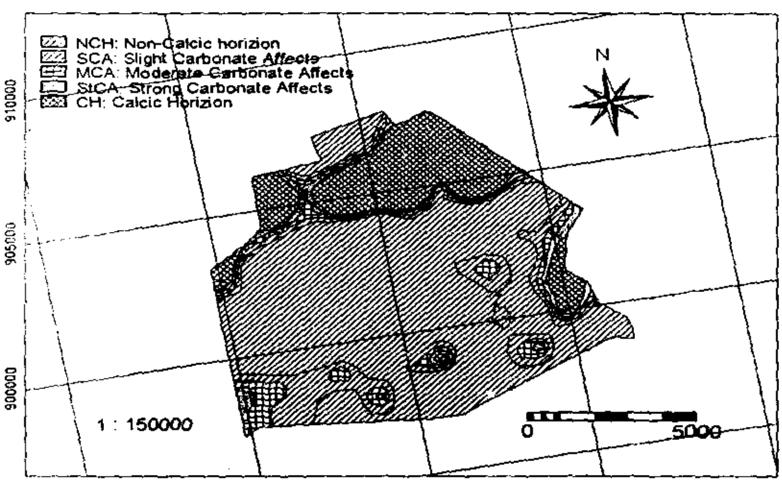

Fig. 5. The classified map of the differences value map between first sub-surface layer and the second sub-surface layer.

Soil mapping units

Using the cross operation between the effective soil depth classes, the salt contents, and the Calcic accumulation, hot spot areas map was created (Fig. 6). The result shows that, 40 Ha (0.43% of the total area) was classified as Aquic and saline areas, 780 Ha (8.23% of the total area) was classified as aquic 1335 Ha (14.08% of the total area) was classified as saline areas, 1210 Ha (12.76% of the total area) was classified as calcic areas, 6115 Ha (64.5% of the total area) was classified as non-affected areas. The hot spot map was crossed with the geomorphic map to create the physiographic and soil map, Table 9 shows the different physiographic and soil - mapping units.

TABLE 9. The physiographic and soil mapping units of the studied area.

Soil mapping units	Area in hectares	Mapping area	Area %	Kind of mapping unit
Hi111_Typic_Torriorthents	75	75	100.00	Consociation
Hi112-Aquic Torriorthents	251	2583	9.58	
Hi112-Typic Haplocalcids	119		4.55	
Hi112-Typic Haplosalids	37		1.41	
Hi112-Typic Torriorthents	2176		83.04	Consociation
Hi113-Aquic Haplocalcids	78	2289	3.39	
Hi113-Aquic Torriorthents	181		7.90	
Hi113-Calcic Haplosalids	3		0.14	
Hi113-Typic Haplocalcids	116		5.09	
Hi113-Typic Haplosalids	388		16.93	
Hi113-Typic Torriorthents	1523		66.55	Complex
Hi114-Aquic Haplocalcids	178	3601	4.93	
Hi114-Aquic Torriorthents	96		2.67	
Hi114-Calcic Haplosalids	380		10.57	
Hi114-Typic Aquisalids	11		0.30	
Hi114-Typic Haplocalcids	498		13.82	
Hi114-Typic Haplosalids	98		2.72	
Hi114-Typic Torriorthents	2340		64.99	Complex
Va111-Calcic Haplosalids	457	932	49.00	Association
Va111-Typic Haplocalcids	475		50.95	

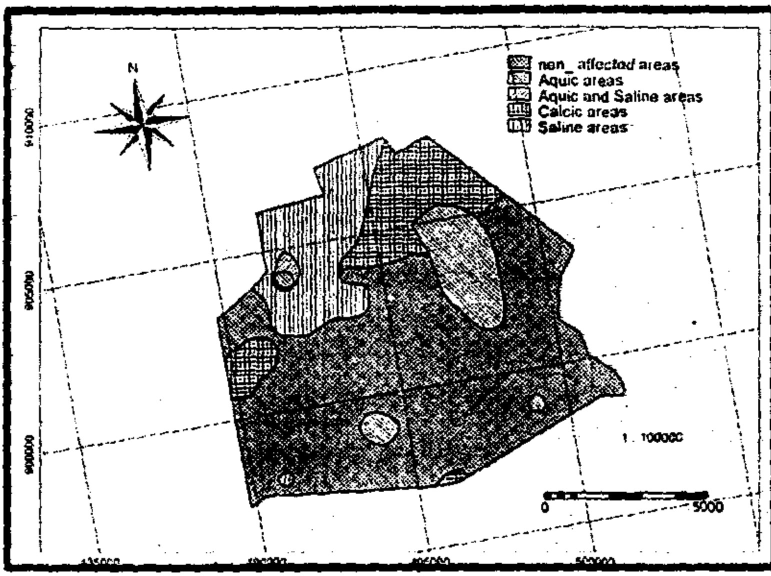

Fig. 6. The result of crossing in term of hot spot areas.

TM analysis monitoring waterlogging areas

The result of applying the maximum likelihood classification to the map list of the TM bands 1, 2, 3, 4, 5, and 7 of December 1999 shows that about 615 feddans were classified as Waterlogging areas cover 1.37% of the total area of the case studied area. The maximum likelihood classification to the map list of the TM bands 1, 2, 3, 4, 5, and 7 of August 1997 was achieved. The result indicates that about 600 feddans were classified as waterlogging areas cover 1.35% of the total area of the case studied area. The crossing facility of ILWIS.3.11 between the waterlogging areas in both 1997 – 1999 years was achieved and then crossed with the physiographic mapping units (Table 10).

TABLE 10. The results of crossing the geomorphic mapping units and the waterlogging areas in both years 1997 and 1999.

Mapping units		Year 1997 and year 1999			
		Waterlogging area		Non-Waterlogging area	
		Hectares	%	Hectares	%
Ridge	Hil11	---	---	15	100
	Hil12	---	---	85	100
	Hil13	2	1.59	65	98.41
	Hil14	80	16.27	400	83.73
	Total	82		656	
Mena Valley	Val11	75	15.64	410	84.36
	Val12	2	2.11	90	97.89
	Total	77		500	

The results of crossing operation show that, the flat and almost flat areas (Hi114, Va111 and Va112) were affected by water logging in both years, but they slightly decreased in mapping unit Hi113. The summit and back slope areas were not affected. This result is logical due to the deep seepage from higher areas, and seepage from irrigation canals which is high than the cultivated areas.

Land degradation assessment

1997-2003 *differences*

The data of Erian *et al.* (1999) were considered and value maps for effective soil depth and salinity for 1997 were carried out. Using the MapCalc operation the total differences of the effective soil depth and salinity were created and the differences of each year was calculated.

Rating degradation status

The degradation status of different soil qualities such as effective soil depth and soil salinity per year were calculated by the following formula:

The differences per one year= (year1997-year2003)/5.

Then using the slicing operation according to FAO (1978), the effective soil depth and salinity status per year was rated. The result of land degradation status due to waterlogging shows that, there is 6330 hectares (66.77% from the total area) classified as improved areas, 800 hectares (8.45% from the total area) classified as non-severe areas, 545 hectares (5.73% from the total area) classified as slight severe areas, 470 hectares (4.94% from the total area) classified as moderate severe areas, and 1335 hectares (14.11% from the total area) classified as high severe areas.

The result of the land degradation status due to salinization shows that, there is 5660 hectares (59.71% from the total area) classified as improved areas, 20 hectares (0.23% from the total area) classified as non-severe areas, 1730 hectares (18.26% from the total area) classified as slight severe areas, 855 hectares (9.00% from the total area) classified as moderate severe areas, 740 hectares (7.83% from the total area) classified as high severe areas, and 470 hectares (4.97% from the total area) classified as very high sever areas.

The extend of land degradation severity %

The extent of land degradation severity was calculated by the following formula:

The extent of land degradation severity = (year1997-year2003)/year1997.

By using the slicing operation according to FAO (1978), the extent of land degradation severity % of the effective soil depth and salinity were rated. The result of land degradation extent due to waterlogging shows that, there is 340 hectares (3.61% from the total area) classified as improved areas, 6785 hectares (71.57% from the total area) classified as non-severe areas, 1355 hectares

(14.52% from the total area) classified as slight severe areas, and 995 hectares (10.50% from the total area) classified as moderate severe areas.

The result of the land degradation extend due to salinization shows that, there is 3508 hectares (40.15% from the total area) classified as improved areas, 2 hectares (0.02% from the total area) classified as non-severe areas, 5570 hectares (58.77% from the total area) classified as slight severe areas, and 100 hectares (1.06% from the total area) classified as moderate severe areas.

Overall degradation severity

Waterlogging (physical degradation)

The overall waterlogging severity was calculated and rated according to GLASOD by crossing the effective soil depth classes of the total period and each year with the physiographic mapping units. Table 11 shows the overall degradation severity of the waterlogging (physical degradation) on the effective soil depth.

TABLE 11. The overall severity of waterlogging (physical degradation) on effective soil depth.

mapping units	Severity classes	severity total period classes		severity each one year classes		severity differnces classes		GLASOD	
		area ha	%	area ha	%	area ha	%	Classes	Code
Hi111	improve area	75	100,00	75	100	0	0	non severe	non severe
	non change areas	0	0,00	0	0,00	0	0,00		
	slight severe areas	0	0,00	0	0,00	0	0,00		
	moderatye severe areas	0	0,00	0	0,00	0	0,00		
	high severe areas	0	0,00	0	0.00	0	0.00		
	very high severe areas	0	0,00	0	0,00	0	0,00		
total		75	100	75	100	0	0		
Hi112	improve area	2235	86,58	2095	81,14	-140	-5,42	non severe	non severe
	non change areas	20	0,69	160	6,13	140	5,42	non severe	non severe
	slight severe areas	10	0,42	50	1,97	40	1,55	infrequent	slight-Pw1.1
	moderatye severe areas	10	0,4	50	1,93	40	1,55	infrequent	Slight-Pw2.1
	high severe areas	170	6,65	230	8,83	60	2,32	infrequent	Medium-Pw3.1
	very high severe areas	140	5,28	0	0	-140	-5,42	infrequent	Medium-Pw4.1
total		2585	100	2585	100	0	0,00		
Hi113	improve area	1615	70,53	1455	63,6	-160	-6,99	non severe	non severe
	non change areas	40	1,84	200	8,8	160	6,99	non severe	non severe
	slight severe areas	30	1,25	130	5,4	100	4,37	infrequent	slight-Pw1.1
	moderatye severe areas	25	1,08	130	5,9	105	4,59	infrequent	Slight-Pw2.1
	high severe areas	350	15,17	375	16,3	25	1,09	infrequent	Medium-Pw3.1
	very high severe areas	230	10,13	0	0	-230	-10,04	common	High-Pw4.2
total		2290	100	2290	100	0	0,00		
Hi114	improve area	2400	66,68	2145	59,61	-255	-7,08	non severe	non severe
	non change areas	70	1,91	325	9,05	255	7,08	non severe	non severe
	slight severe areas	50	1,41	295	8,13	245	6,81	common	slight-Pw1.2
	moderatye severe areas	55	1,57	230	6,45	175	4,86	infrequent	Slight-Pw2.1
	high severe areas	650	18,05	605	16,76	-45	-1,25	infrequent	Medium-Pw3.1
	very high severe areas	375	10,38	0	0	-375	-10,42	common	High-Pw4.2
total		3600	100	3600	100	0	0,00		
Va111	improve area	650	69,78	555	59,88	-95	-10,22	non severe	non severe
	non change areas	20	2,31	115	12,43	95	10,22	non severe	non severe
	slight severe areas	15	1,38	70	7,84	55	5,91	common	slight-Pw1.2
	moderatye severe areas	15	1,72	60	6,24	45	4,84	infrequent	Slight-Pw2.1
	high severe areas	165	17,96	130	13,81	-35	-3,76	infrequent	Medium-Pw3.1
	very high severe areas	65	6,85	0	0	-65	-6,99	common	High-Pw4.2
total		930	100	930	100	0	0,00		

Salinization (chemical degradation)

The overall degradation severity of soil salinity was calculated and rated by crossing the severity classes of each year and the total period with the geomorphic mapping units. Table 12 shows the overall degradation severity of the salinization (chemical degradation) on soil salinity indicator.

TABLE 12. The overall severity of salinization (chemical degradation) on soil salinity indicator.

mapping units	Seventy classes	severity total period classes		severity each one year classes		severity differnces classes		GLASOD	
		area ha	%	area ha	%	area ha	%	Classes	Code
Hi111	improve area	75	100	75	100	0	0	non severe	non severe
	non change areas	0	0.00	0	0.00	0	0 00		
	slight severe areas	0	0.00	0	0.00	0	0 00		
	moderatye severe areas	0	0.00	0	0.00	0	0 00		
	high severe areas	0	0.00	0	0.00	0	0.00		
	very high severe areas	0	0.00	0	0.00	0	0.00		
total		75	100	75	100	0	0		
Hi112	improve area	1875	72.59	1875	72.61	0	0.00	non severe	non severe
	non change areas	0	0	0	0	0	0.00	non severe	non severe
	slight severe areas	145	5.66	560	21.68	415	16.05	frequent	Medium-Cs1 3
	moderatye severe areas	280	10.74	120	4.57	-160	-6.19	common	Medium-Cs2.2
	high severe areas	140	5.29	30	1.14	-110	-4.26	infrequent	Medium-Cs3.1
	very high severe areas	145	5.72	0	0	-145	-5.61	infrequent	Medium-Cs4.1
total		2585	100	2585	100	0	0.00		
Hi113	improve area	1475	64.5	1475	64.44	0	0.00	non severe	non severe
	non change areas	0	0	0	0	0	0.00	non severe	non severe
	slight severe areas	60	2.49	305	13.62	245	10.70	common	slight-Cs1.2
	moderatye severe areas	145	6.4	135	5.64	-10	-0.44	infrequent	Slight-Cs2.1
	high severe areas	105	4.47	195	8.43	90	3.93	infrequent	Medium-Cs3.1
	very high severe areas	505	22.14	180	7.87	-325	-14.19	frequent	Very High-Cs4 3
total		2290	100	2290	100	0	0.00		
Hi114	improve area	2215	61.56	2210	61.36	-5	-0.14	non severe	non severe
	non change areas	0	0	10	0.34	10	0.28	non severe	non severe
	slight severe areas	340	9.39	675	18.75	335	9.31	common	slight-Cs1.2
	moderatye severe areas	270	7.58	225	6.25	-45	-1.25	infrequent	Slight-Cs2 1
	high severe areas	70	1.89	215	6.02	145	4.03	infrequent	Medium-Cs3 1
	very high severe areas	705	19.59	265	7.28	-440	-12.22	frequent	High-Cs4.2
total		3600	100.01	3600	100	0	0.00		
Va111	improve area	30	3.09	30	2.99	0	0.00	non severe	non severe
	non change areas	0	0	0	0	0	0.00	non severe	non severe
	slight severe areas	35	3.71	190	20.72	155	16.67	frequent	slight-Cs1.2
	moderatye severe areas	80	8.61	380	40.49	300	32.26	very frequen	High-Cs2.4
	high severe areas	75	8.22	305	32.88	230	24.73	frequent	High-Cs3.3
	very high severe areas	710	76.38	25	2.92	-685	-73.66	dominant	Very High-Cs4.5
total		930	100.01	930	100	0	0 00		

Conclusion

The geostatistical interpolation tools in GIS environment are vital in assessing the spatial- temporal variability of major land degradation types. The study revealed that during the period 1997 to 2003 waterlogging and salinization on sugar beet zone 1 of west Nubariya increased. The overall severity of water logging on effective soil depth classified as follows: non-severe areas covered 7130 hectares (75.22% of the total area), slight severe areas covered 50 hectares (0.54% of the total area), medium severe areas covered 1940 hectares (20.44% of the total area), and high severe areas covered 360 hectares (3.80% of the total area). The overall severity of salinization on soil salinity classified as follows: non-severe areas covered 5680 hectares (59.93% of the total area), slight severe areas covered 1720 hectares (18.15% of the total area), medium severe areas covered 1215 hectares (12.80% of the total area), and high severe areas covered 865 hectares (9.12% of the total area). This land degradation rate might be due to inadequate drainage system and the use of drainage water (low quality) for flooding irrigation. Also, the irrigation schedule in the area was inadequate due to insufficient irrigation water and some problems in the irrigation canals design.

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تقييم شدة تدهور الأراضى باستخدام Ordinary - Kriging بغرب النوبارية – مصر

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تمثل منطقة بنجر السكر (٨٠٠٠٠ فدان) أحد مناطق الاستصلاح الجديدة في منطقة غرب النوبارية منذ ١٩٨٩. حيث تواجه التنمية الزراعية بها تدهور أراضى ناشئ عن الملوحة و يزيد فيها المناطق الغدقة. و يهدف هذا البحث إلى تطبيق Ordinary Kriging لتقدير شـــدة تدهور الأراضي بطريقة كمية لمنطقة بنـجر السكر الأولى حيث تتضمن الدراسة مـــا يـــلي:

١- تحليل نموذج الارتفاع الرقمي وتحديد الوحدات الجيومورفولوجية السائدة.

٢- تحديد الصفات الأرضية المحددة وإنتاج الخرائط الأرضية الرقمية للخواص الأرضية المختلفة.

٣- تحديد شدة تدهور الأراضي باستخدام طريقة GLASOD ، FAO بين اعوام ١٩٩٧ – ٢٠٠٣ .

أوضحت الدراسة أن استخدام Ordinary Kriging كأداة من خلال منظومة المعلومات الجغرافية مفيد جدا في تحديد حدود الوحدات الأرضية بكفاءة عالية للمتغيرات الأرضية لكافة أنواع التدهور السائدة. وقد أشارت النتائج أن التدهور الناتج من تأثير ظهور الماء على السطح على نقص العمق الفعال كما يلي: ٧١٣٠ هكتار (٧٥,٢٢٪) لم تتأثر و تدهور بسيط في ٥٠ هكتار (٠,٥٤٪) و تدهور متوسط فى ١٩٤٠ هكتار (٢٠,٤٤٪) و تدهور مرتفع في ٣٦٠ هكتار (٣,٨٠٪) . كما أشارت النتائج أن التدهور الناتج من تأثير الملوحة على ملوحة التربة كما يلي: ٥٦٨٠ هكتار (٥٩,٩٣٪) لـــم تتأثر و تدهور بسيط في ١٧٢٠ هكتار (١٨,٥١٪) و تدهور متوسط في ١٢١٥ هكتار (١٢,٨٠٪) و تدهور مرتفع في ٨٦٥ هكتار (٩,١٢٪).

ويرجع زيادة معدل التدهور إلى عدم كفاية الصرف بالمنطقة والسلوك السيئ من المزارعين لاستخدامهم ماء الصرف الرديء لري محاصيلهم ، كما يرجع أيضا إلى طول مناوبات الري ووجود عيوب في تصميم شبكة الري.