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MONITORING OF ENVIRONMENTAL SENSITIVITY TO DESERTIFICATION IN SOME AREAS AT WEST OF DELTA, EGYPT

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ABSTRACT

Current study aimed at classifying the environmental sensitivity to desertification using quantitative indices of soil, groundwater, erosion, and vegetation qualities. In addition to monitor the changing trends of the environmental sensitivities regarding their intensity and quality with time. Two studied areas were chosen to model soils of West of Delta. The first located at Sugar beat area over 21300 faddans while the second located at El-Bostan area over 14800 faddans. A comparison between their sensitivity qualities was performed during a period of 25 years starting in 1990 till 2015. Using an ETM image, DEM was processed in which slope gradient was extracted. Field investigations were undertaken. Soil mapping units were sampled at representative profiles. Laboratory analyses were carried out for collected soil samples. MEDALUS model published by the European Commission (Kosmas *et al.,* 2003) was used for sensitivity evaluation, in addition to some modification done by Desert Research Center (DRC) staff (Hegazi *et al.,* 2009). Results of calculating the environmental sensitivity areas (ESAs) for desertification indicated that Sugar beat area was classified as moderate sensible where ESIs ranged between 1.327-1.374 over 38.0% in 1990, while being between 1.354-1.386 over 38.3% in 2015. Meanwhile, the moderate ESIs at El-Bostan vary between 1.313-1.357 over 39.9% in 1990, which surpass to be between 1.335-1.373 above 41.5% in 2015. Studied areas were partially classified as very sensitive and sensitive to desertification. It was grown up at Sugar beat as accounted for 9.1% in 1990 and 13.4% in 2015 of the total area. While it was completely renovated into moderate sensitive at El-Bostan due to ground leveling and existence of sufficient vegetation cover. Percentages of sensitivity classes at Sugar beat in 1990 found to be very close to corresponding values in 2015, but with different spatial distributions. Further, the study achieved more positive changes of El-Bostan sensitivity than occurred in Sugar beat which had more intensive limitations *i.e.* shallow profile depth, saline groundwater as sea water intrusion, soil salinization, and difficulty of leveling due to ground hardness as affected by high lime content rather than rock exposures. It can be concluded that implementing maps of sensitivity to desertification is rather useful in the newly reclaimed desert areas as they give more likely quantitative trend for frequency of sensitivity. Applied agricultural systems affect negatively on increase the environmental sensitivity to desertification in some locations at both of studied areas. Therefore, it is necessary to re-evaluate current practices and/or land uses to prevent that degradation.

Key words: Desertification, environmental sensitivity indices, soil quality, sugar beat area, El-Bostan area, West of Delta.

INTRODUCTION

Desertification is recognized as a process of land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. As land degradation implies the reduction of the resource potential of the landscape through different processes (UNCCD, 1999 and 2002). The need to assess sustainable land use requires an addressing to the degradation issue and associated risks using

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proper methods according to the locally dominant degradation processes. It is important to identify and describe the driving forces leading to land degradation to understand the phenomenon at a local scale. An environmental sensitive area to desertification (ESA) could be considered as a spatially delimited area in which some key aspects related to its sustainability are unbalanced with a particular environment (Kosmas *et al.*, 2003).

Success in combating desertification requires assessment and mapping of desertification forces in arid and semi-arid environments. The first attempt for assessment and mapping the desertification process was presented by FAO/UNEP (1984). This study was carried out based on data collected under the project Global Assessment of Soil Degradation (GLASOD) indicated that 19.5% of dry lands of the world have been affected by soil degradation. However, it should be mentioned that the GLASOD estimates are mainly based on expert judgments that are necessarily subjective.

It has been widely investigated and documented that over the last several decades the Mediterranean region has been subjected to major changes in land uses and covers (Brandt and Thornes, 1996; Kosmas *et al.*, 1999; Balabanis *et al.*, 2000; Burke and Thornes, 2004). That was a result of the relocation of people, the abandonment of farms and the intensification of agriculture. MEDALUS method (Kosmas *et al.*, 1999) present an algorithm used in identifying regions that are environmentally sensitive to desertification. ESAs to desertification can be analyzed in terms of various parameters such as landforms, soil, geology, vegetation, climate and human actions. Each of these parameters is grouped into various uniform classes and a weighting factor is assigned to each class. According to that model, four layers are evaluated: soil quality, climate quality, vegetation quality and management quality. Desert Research Center (DRC) staff incorporated some significant parameters related to soil salinity, drainage, rock fragments, erosion, runoff and groundwater, which are considered as local circumstances affecting the sensitivity to desertification in the Egyptian agroecological zones (Hegazi *et al.*, 2009).

The western fringe of Nile Delta was introduced into land reclamation during the sixtieth of the last century. Rapid evolution was obviously monitored of land uses at the region during the last 25 years. Sugar beat and El-Bostan areas were selected into the current study as representative models for agrarian expansions at west of Delta during that period. Changes occurred in the studied areas during the recent decades in land use and land cover have been induced mostly by man and resulted in acceleration of different degradation processes. On the other hand, many descriptive investigations were carried out, however the quantification of the land degradation issue is clearly missed. Therefore, the present study is devoted to quantify the change of the environmental sensitivity to desertification in the compared locations at West of Delta region. The objective was to construct spatial and temporal comparative models for assessing desertification qualities between two timing points in the studied areas. Chosen factors for modeling the environmental sensitivity to desertification include soil quality, erosion quality, groundwater quality and vegetation quality. The environmentally sensitive areas (ESAs) and corresponding indices (ESIs) were assessed.

MATERIALS AND METHODS

Studied Areas

For assessing the desertification sensitivity in the current study, two sites representing the newly reclaimed locations at West of Delta region were selected; (1) Sugar beat area located at west of Nubaria and (2) El-Bostan area located at east of Wadi El-Natrun (map 1.a). Generally, both of selected areas at West Delta region have a typical semi-arid climate characterized by hot dry summer and rainy warm winter.

Sugar beat area

It is represented by villages Nos. 26, 27 and 28 which extend over 21300 faddans. Geographically, it is located between 30° 42' 28"-30° 45' 42" N and 29° 26' 16"-29° 30' 31" E (map 1.b-c). Its elevation ranges from 44 – 60 m a. s. l. with almost flat to undulating topography.

Soils found throughout the area were formed of late Pleistocene calcareous sediments, sometime mixed with gypsi-ferrous materials or sand. As well marine limestone coastal beach ridges were formed by successive high sea levels. Holocene aeolian sand mixed with fluvial loam sediments are most noticeable in the southern part of the area with altering Pliocene calcareous sandstone beds.

As agrarian reclamation started in 1985, so Sugar beat is rather older than El-Bostan area regarding agricultural land use. The area irrigated mainly by pumped Nile water through El-Nasr canal. Some areas irrigated using groundwater through scattered shallow to deep artesian wells. Nowadays, intensive land use led to rapid water Table rising to be within 1 m of the surface in some parts of the area causing water logging and secondary salinization.

El-Bostan area

It belongs to the third stage of land reclamation at El-Bostan sector which extends over 75000 faddans. From which, the studied area was chosen to include Gaber Ben Hian and Abu Bakr El-Sedeek villages over 14800 faddans. It is bounded between 30° 28' 17"-30° 34' 37" N and 30° 12' 40"-30° 18' 53" E (map 1.d-e). Its elevation ranges from 24 – 40 m a.s. l. with almost flat to undulating topography. Geologically, as the area is located west of the Nile Delta and east of Wadi El-Natrun, its soils were developed from Pleistocene and Holocene deposits having widely distribution and essentially formed of sands and gravels. Geomorphologically, three landforms characterizing the area namely; wind blown sand deposits, deltaic stage of various river terraces and Wadi El-Natrun complex.

The considered area is irrigated mainly using pumped Nile water through El-Bostan canal. Some scattered orchards are irrigated from dominant shallow groundwater. Soils have loose structure and low organic matter content which make them very susceptible to wind erosion (Biroudian *et al.*, 2006). The natural vegetation habitats found to be typical as found in the Western Desert of Egypt *i.e. Artemisia monosperma*, Pityranthus *tostuosus, Aristida pliniosa,* and other common perennial species.

Sensitivity Indices

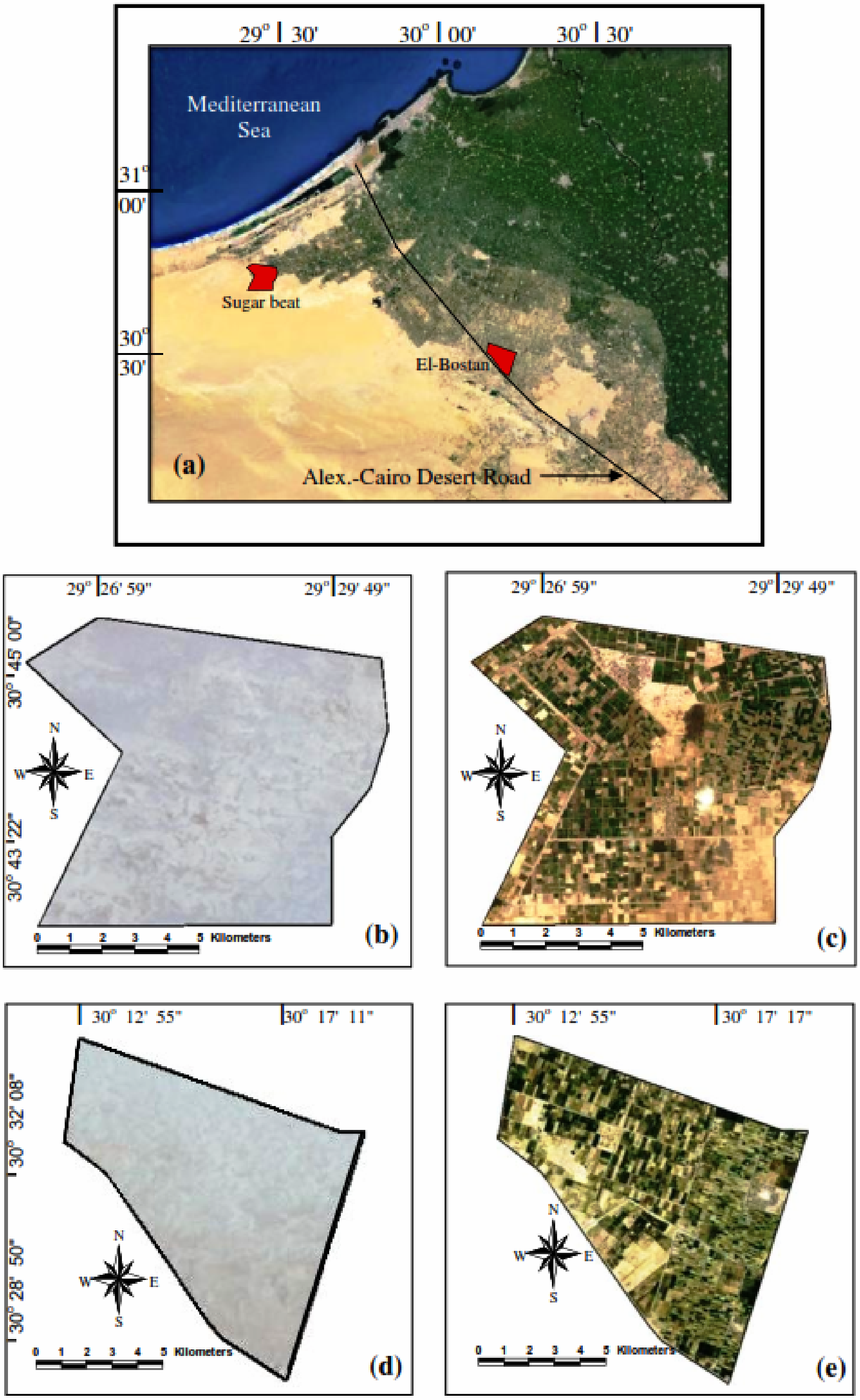
The Environmental Sensitivity Index (ESI) of an area to desertification can be seen as the result of the interactions among elementary factors (information layers) that are differently linked to direct and indirect degradation or desertification phenomena. Four quality indices were selected and computed to assess the environmental sensitivity to desertification in the investigated areas after Kosmas *et al.* (2003) and Hegazi, *et al.* (2009). The indices selected are soil quality index (SQI), groundwater quality index (GQI), erosion quality index (EQI) and vegetation quality index (VQI). The climatic quality index was neglected as the two studied locations have similar arid desert climate. Fig. 1 illustrates the main flow chart of concepts and studied steps performed in the present study.

In the original MEDALUS approach four main indicators have been used to assess the desertification intensity of an area. They are soil, climate, vegetation and management, where each main factor includes some sub-indicators. Meanwhile, the main deteriorating factors in the studied areas are waterlogging and soil erosion processes which are not directly used in the original MEDALUS model. Therefore, some additional factors are needed to be incorporated in current study according to Hegazi *et al.* (2009) *i.e.* erosion quality and groundwater quality. As well some sub- indicators of soil quality *i.e.* salinity, drainage and rock fragments.

A quantitative classification scheme with values ranging from 1 to 2 has been applied throughout the model for individual indices as well as the final classification of Desertification Sensitive Areas (DSAs). The value 1 was assigned to areas of least sensitivity and the value 2 was assigned to areas with the most. Values between 1 and 2 reflect relative vulnerability.

Mapping soil quality index (SQI)

Soil is the dominant factor of the terrestrial ecosystems in arid and semi arid zones. Seven soil parameters were considered related to parent material, soil depth, soil texture, slope gradient, soil salinity, drainage and rock fragments, following Kosmas *et al.* (2003) and Hegazi *et al.* (2009). Weighting factors were



Map. 1. LANDSAT images of the studied locations at West of Delta

(a) General location – (b/c) Sugar Beat 1990 -2015- (d-e) El-Bostan 1990-2015.

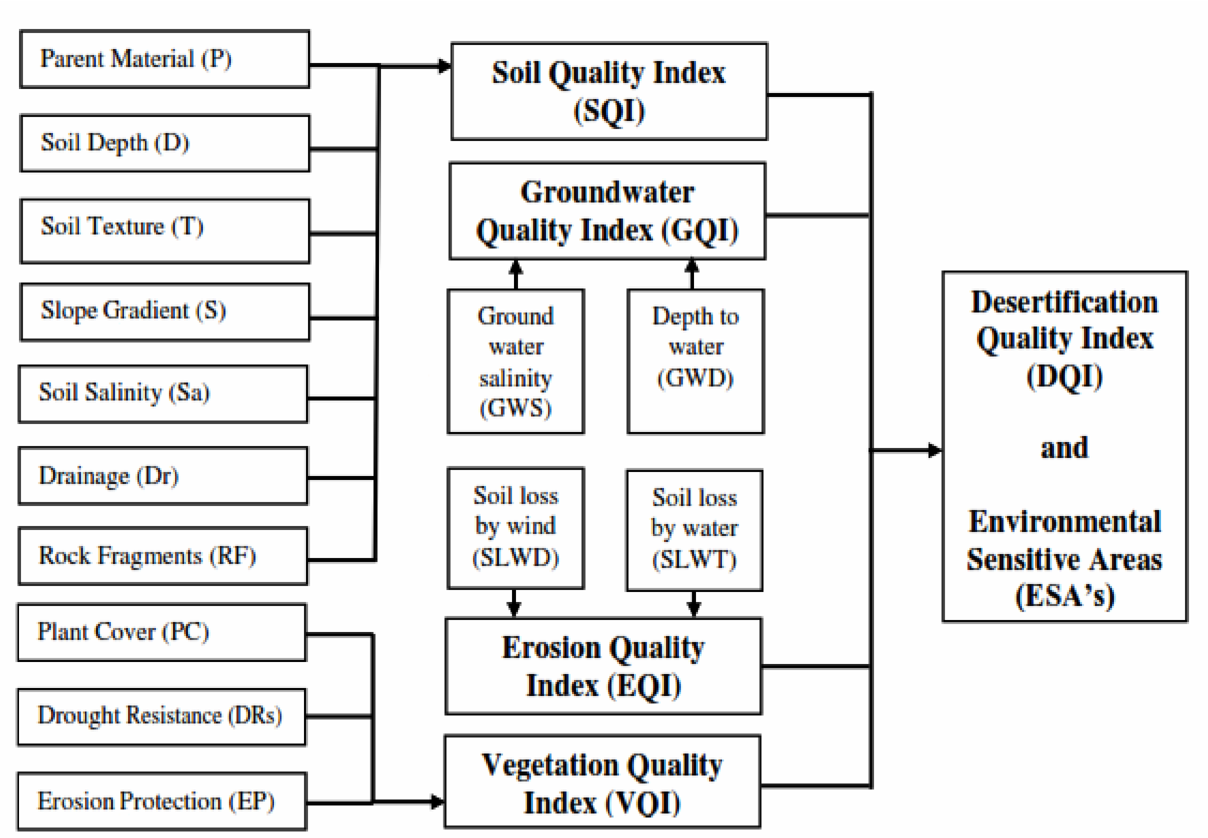


Fig. 1. Flow chart of mapping environmentally sensitive areas (ESAs)

assigned to each category of the considered parameters, on basis of European Commission (1999). According to International ESI Atlases (2005) the Soil Quality Index (SQI) was computed on basis of the following equation:

$$\mathbf{SQI= (Ip \times Id \times It \times Is \times Isa \times Idr \times Irf)^{1/7}}$$

Where:

Ip= Index of parent material, Id= Index of soil depth, It = Index of soil texture, Is= Index of slope gradient, Isa=Index of salinity, Idr= index of drainage, Irf= Index of rock fragment.

Mapping groundwater quality index (GQI)

The second water source for irrigation in the areas under studying is groundwater. So, it is necessary to add GQI to the current model due to that deterioration occurs in some locations at the studied areas as affected by rising of rather saline groundwater. Therefore, it is evaluated in terms of two aspects; groundwater depth and salinity. Suggested arithmetic equation for GQI calculation as follows:

$$\mathbf{GQI= (Iwd \times Iws)^{1/2}}$$

Where:

Iwd = Index of ground water depth, Iws= Index of ground water salinity.

Mapping erosion quality index (EQI)

In current study, soil erosion is considered as an expression of total soil loss to indicate the sensitivity to desertification. Quantities of soil loss from the studied areas by water estimated by Universal Soil Loss Equation (USLE), whereas, soil loss by wind was estimated using Wind Erosion Equation (WEE) during the periods 1980-1990 and 2005-2015. Index of soil loss by water (Islwr) and index of soil loss by wind (Islwd) are calculated, respectively and used to determine the erosion quality index (EQI) according to Kosmas *et al.* (2003) as the following equations:

$$\text{Islwr= (soil loss by water)}^{1/5}$$

$$\text{Islwd= (soil loss by wind)}^{1/5}$$

$$EQI= (Islwr \times Islwd)^{1/2}$$

Where:

Islwr= Index of soil loss by water, Islwd= Index of soil loss by wind.

Mapping vegetation quality index (VQI)

It was evaluated in terms of three aspects; plant cover, erosion protection and drought resistance. An ETM satellite images were classified and field validation was performed to convert the unsupervised classes to vegetation type. Rating values for these parameters were adapted on the basis of Observatory of the Sahara and Sahel (OSS, 2004). VQI was classified as mentioned in the European Commission (1999) and calculated using the following equation:

$$VQI= (Ipc \times Idrs \times Iep)^{1/3}$$

Where:

Ipc= Index of plant cover, Idrs = Index of drought resistance, Iep= Index of erosion protection.

Mapping environmentally sensitive areas (ESAs) to desertification

The sensitivity to desertification expressed as environmental sensitivity index (ESI) was finally evaluated by integrating all data concerning physical environment as follows:

$$ESI = (SQI \times GQI \times EQI \times VQI)^{1/4}$$

According to the calculated different quality indices, ARC-GIS is used to deduce classes of sensitivity map. Classification of (DSI) was done according to the values of Medalus project (European Commission, 1999) as shown in Table 1.

Data Collection and Processing

Available data and information related to soils, plant cover, erosion and groundwater required to fulfill distinguishing severity of desertification were collected for both of studied areas, (IFAD, 1992) and (BADP, 1995). For present study, a total of 15 and 12 soil profile locations were identified at Sugar beat and El-Bostan areas, respectively to represent soil mapping units of each. Field investigations were carried out on the basis of guidelines for soil description, FAO (2006) including definition of physiographic features, detailed pedo-morphological descriptions of soil profiles with assessing effective soil profile depths. Representative soil samples were compiled for further laboratory analysis to determine soil texture and salinity according to USDA (2014).

A mosaic of LANDSAT ETM+ and SRTM images for studied areas were processed using the ERDAS system (IMAGINE 8.6, 2001). Images were used for vegetation cover calculations and slope gradient extraction. Computational and map editing functions were performed using Arc GIS 9.2 (ESRI, 2006) to find out the environmental sensitivity areas (ESA's).

Table 1. Classes of desertification sensitivity indices (DSI)

Classes	DSI	Description
1	< 1.20	Non affected areas to desertification
2	1.20 - 1.30	Low sensitive areas to desertification
3	1.31 - 1.40	Moderate sensitive areas to desertification
4	1.41 - 1.50	Sensitive areas to desertification
5	> 1.50	Very sensitive areas to desertification

RESULTS AND DISCUSSION

Soil Quality Index (SQI)

Soils of the area under consideration at Sugar beat were originated from different materials, including Pleistocene marine coastal limestone ridges, Holocene aeolian sand dune and Pliocene calcareous sandstone beds. Five soil mapping units could be differentiated in the area based on the variations in profile depth, soil texture and topography (map 2-A). The area was dominated over 26.4% of the total area by the unit "deep to moderately deep moderately coarse-textured soils sometimes finer at surface with almost flat topography". Meanwhile, soils of the selected location at El-Bostan area were originated form wind blown sand deposits, Deltaic stage of various river terraces and Wadi El-Natrun complex (map 2-B). In accordance with differences in profile depth, texture and topography, four soil units may be distinguished. They dominated over 37.7% of the total terrain by the unit "deep coarse textured soils with undulated topography" (map 2-B).

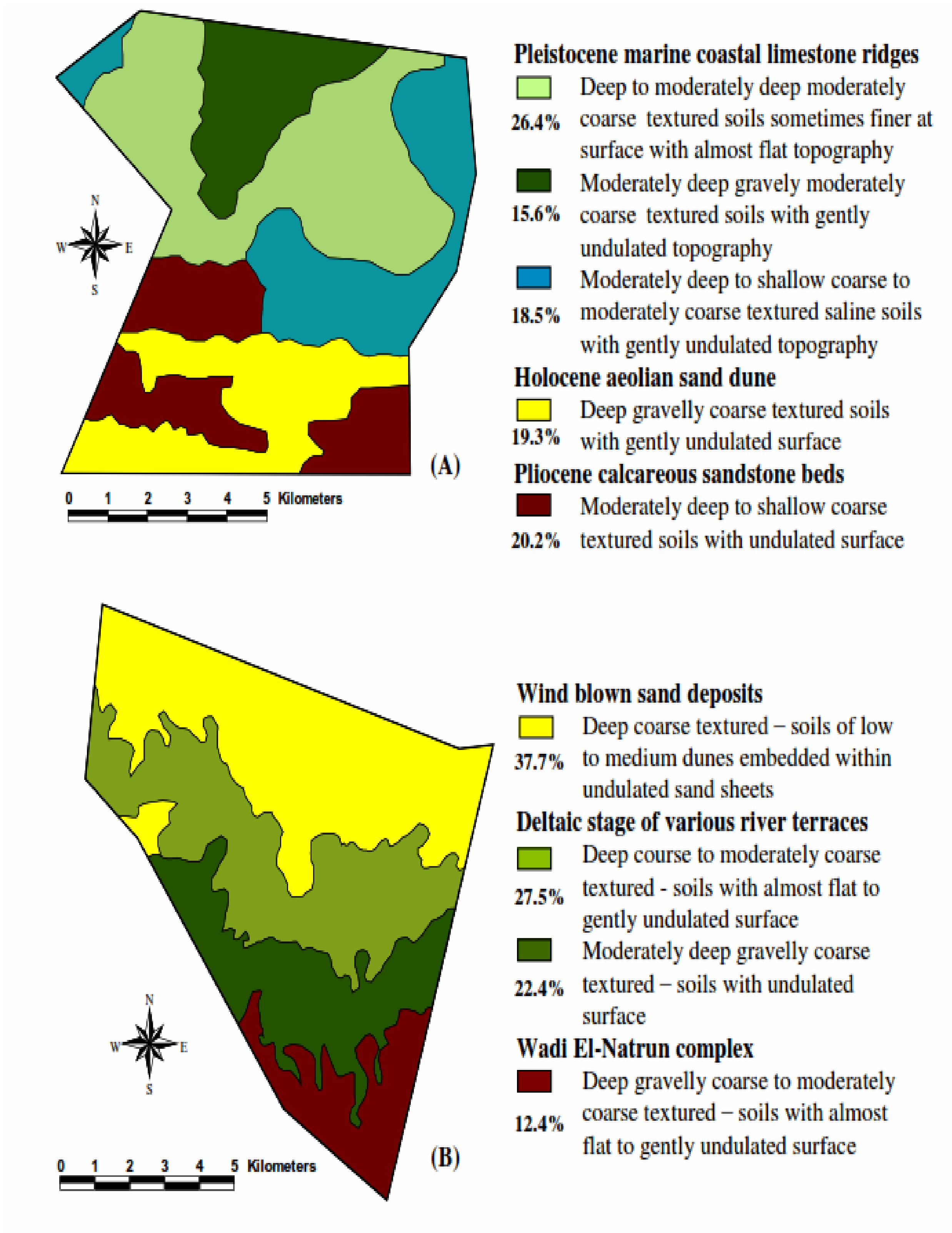
Soil parent materials were classified regarding their sensitivity to desertification in Sugar beat and El-Bostan areas as summarized in Tables 2 and 3. Results show the variability of parent material nature either inside or between the studied sites. While the moderately coherent marine limestone and friable sandstone characterized by moderate sensitivity class cover 60.5% (12887 faddans) of Sugar beat, its frequency is limited only over 12.7% in El-Bostan (1835 faddans). Rest of the studied area at Sugar beat splits parent material between the coherent (20.2%) and the soft to friable (19.3%) attaining good and poor sensitivity classes, respectively. Poor parent material which originated from soft to friable materials is dominated El-Bostan over 87.6% of the total area (12965 faddans), indicating more sensitivity to the desertification processes. It may be outlined that the southern portions at West of Delta include more sensitive parent material than the northern ones. Soils of both studied locations were originated from certain parent materials doesn't change with time, thereupon, data revealed concerning parent material sensitivity are similitude at 1990 and 2015.

Tables 2 and 3 show that soils in the considered areas at 1990 are mostly characterized either by a deep to moderately deep soil depth (map 2), reflecting good to moderate sensitivity to desertification. In particular, Sugar beat soils characterized by deep and moderately deep depths over 32.5% (6923 faddans) and 48.2% (10255 faddans), respectively. Shallow soil depth which indicates high sensitivity to desertification is confined only at Sugar beat over 19.3% (4122 faddans). El-Bostan soils are mostly characterized by deep profile depth over 76.6% (11485 faddans). Meanwhile, those soils characterized by moderately deep profiles do not exceed more than 22.4% (3315 faddans) of the whole area at El-Bostan, located mainly at the western portion.

Under land use practices over 25 years, soil profile depth of Sugar beat area at 2015 is worthily evoluted towards more sensitivity to desertification (Tables 2 and 3). Shallow soils were grow up to 36.4% (7753 faddans) due to water Table rising, simultaneously with obvious decrease in moderately deep soils to 32.1% (6624 faddans). Neglec Table deference of soil profile depth at El-Bostan area with no affection on sensitivity classification.

Coarse textured soils dominated El-Bostan area over 80.1% of all soils (11847 faddans) as shown in map (2B) and Table (3), expressing most sensitivity to desertification. Coarse textured soils were brought by wind blown weathered sands. Rest of the area is exhibited by moderately coarse soil texture with less sensitivity. Soil texture of Sugar beat area could be nearly divided to coarse texture over 48.8% (10383 faddans) and moderately coarse above 54.2% (10916 faddans), which characterized by high and moderate sensitivity to desertification, respectively (map 2A and Table 2).

It could be outlined that vicinity of studied areas from north of the western desert was important factor for the dominance of sensitive soil textural classes. Even though, soils of both studied locations were exposed to different agricultural practices during the last 25 years, particle size distributions of the soil primary components have very tiny changing inside the same texture classes. Hence, the same sensitivity for desertification are given for studied areas at 2015 regarding soil texture (Tables 2 and 3).



Map. 2. Soil mapping units at (A) Sugar beat and (B) El-Bostan area, West of Delta

Table 2. Parameters of soil quality and assigned scores at Sugar beat area.

Soil quality parameters	Class	Description	1990			2015		
			Area (%)	Area (fad.)*	Score	Area (%)	Area (fad.)*	Score
Parent Material	**1**	Coherent (Hard limestone layer, non-friable sandstone)	20.2	4303	1.0	20.2	4303	1.0
	2	Moderately coherent (Marine limestone deposits, sandy formation)	60.5	12887	1.4	60.5	12887	1.4
	3	Soft to friable (Aeolian)	19.3	4111	1.8	19.3	4111	1.8
Soil Depth	**1**	Deep (> 100 cm)	32.5	6923	1.42	32.5	6923	1.35
	2	Moderately deep (50 - 100 cm)	48.2	10255	1.88	31.1	6624	1.62
	3	Shallow (25 - 50 cm)	19.3	4122	1.94	36.4	7753	1.94
Soil Texture	**1**	Moderately coarse (SL,LS,SCL)	51.2	10916	1.66	51.2	10916	1.66
	2	Coarse (S)	48.8	10383	1.92	48.8	10383	1.92
Slope Gradient	**1**	Flat to gently undulated (< 6%)	26.4	5623	1.15	79.8	16997	1.25
	2	Gently undulated to undulated (6-18%)	53.4	11374	1.33	20.2	4303	1.42
	3	Undulated to sloping (18-35%)	20.2	4303	1.85	--	--	--
Soil Salinity	**1**	Slightly saline (2-4 dSm^{-1})	61.3	13056	1.14	38.1	8115	1.20
	2	Moderately saline (4-8 dSm^{-1})	20.2	4303	1.42	39.5	8413	1.48
	3	Saline (8-16 dSm^{-1})	18.5	3941	1.75	22.4	4771	1.82
Drainage	**1**	Well drained	45.7	9734	1.18	45.7	9734	1.18
	2	Imperfectly drained	54.3	11566	1.28	35.8	7625	1.32
	3	Poorly drained	--	--	--	18.5	3941	1.85
Rock Fragments	**1**	Stony (20-60%)	34.9	7433	1.33	19.3	4111	1.30
	2	Bare to slightly stony (< 20%)	65.1	13866	1.96	80.7	17189	1.90

*Faddan = 4200 m^2

Table 3. Parameters of soil quality and assigned scores at El-Bostan area

Soil Quality Parameters	Class	Description	1990			2015		
			Area (%)	Area (fad.)	Score	Area (%)	Area (fad.)	Score
Parent Material	1	Moderately coherent (Marine limestone deposits, sandy formation)	12.4	1835	1.5	12.4	1835	1.5
	2	Soft to friable (Aeolian)	87.6	12965	2.0	87.6	12965	2.0
Soil Depth	1	Deep (> 100 cm)	77.6	11485	1.71	77.6	11485	1.71
	2	Moderately deep (50 - 100 cm)	22.4	3315	1.98	22.4	3315	1.98
Soil Texture	1	Moderately coarse (SL,LS,SCL)	19.9	2952	1.70	19.9	2952	1.70
	2	Coarse (S)	80.1	11847	1.95	80.1	11847	1.95
Slope Gradient	1	Flat to gently undulated (< 6%)	12.4	1835	1.24	62.3	9220	1.12
	2	Gently undulated to undulated (6-18%)	27.5	4070	1.55	37.7	5580	1.62
	3	Undulated to sloping (18-35%)	60.1	8894	2.0	--	--	--
Soil Salinity	1	Slightly saline (2-4 dSm^{-1})	65.2	9649	1.10	65.2	9649	1.10
	2	Moderately saline (4-8 dSm^{-1})	22.4	3315	1.33	34.8	5150	1.42
	3	Saline (8-16 dSm^{-1})	12.4	1835	1.60	--	--	--
Drainage	1	Well drained	87.6	12964	1.0	65.2	9649	1.12
	2	Imperfectly drained	12.4	1835	1.54	34.8	5150	1.62
Rock Fragments	1	Stony (20-60%)	12.4	1835	1.24	3.5	518	1.36
	2	Bare to slightly stony (< 20%)	87.6	12964	1.88	96.5	14282	1.94

Slope gradient of Sugar beat and El-Bostan areas, as shown in Tables 2 and 3 were classified into three classes at 1990 concerning desertification sensitivity, then reduced towards less sensitivity into two classes at 2015. The majority (53.4%) of Sugar beat area over about 11374 faddans, situated northwards is characterized by a gently undulated to undulated slopes, inducing moderate sensitivity to the desertification process. Followed by flat to gently undulated over 26.4% (5623 faddans), then undulated sloping above 20.2% (4303 faddans) indicating low and high sensitivity, respectively. In 2015, leveling processes affect positively in reducing sensitivity to desertification. Where the slope gradient mostly ranges between flat to gently undulating, covering area representing 78.8% (16997 faddans) of the total studied terrain at Sugar beat.

Most of El-Bostan area was characterized in 1990 by undulated surface (map 2-B) where 60.1% (8894 faddans) of the total area had undulated slopping class, referring to high sensitivity to desertification (Table 3). Obviously, the area got less sensitive in 2015 to desertification as being reclaimed and leveled, where 62.3% of the total area (9220 faddans) became flat to gently undulated (Table 3). Meanwhile, an area representing 27.5% is characterized by a gently undulated to undulated landscape.

In general, it can be outlined that the studied areas attain more rugged landscape causing more sensitivity to most desertification processes in 1990. Applied leveling processes of ground surface at the areas under consideration, which required for reclamation, shifted soil mapping units (map 2) to more flatness indicating less sensitivity to desertification in 2015.

Obvious contrast was achieved between studied areas regarding their behavior of sensitivity evolution concerning soil salinity during the period 1990-2015. In general, soil salinity has been raised at Sugar beat area between that period in response to excess irrigation with rather saline water. Sometimes values of soil salinity raised inside the same class, hence, their classification persist even they became higher. However, slightly saline soils reduced from 61.3% (13056 faddans) to 38.1% (8115 faddans) of the total area. Against that increasing of moderately saline soils from 20.2% (4303 faddans) to 39.5% (8413 faddans) at 1990 and 2015, respectively as indicated in Table 2 in which more sensitivity to desertification is demonstrated. Miner increment of saline soil's areas was occurred from 18.5% (3941 faddans) to 22.4% (4771 faddans). Data in Table 3 show that the majority of El-Bostan soils over 65.2% (9649 faddans) of the total area keep belonging to the slightly saline class in both of 1990 and 2015, which indicate low sensitivity to desertification. Meanwhile, saline soils in 1990 stretched over 12.4% (1835 faddans) were decreased gradually and became moderately saline in 2015. This may be attributed to leaching processes using pumped Nile water through El-Bostan canal, as supported by dominant coarse soil texture.

Sensitivity to desertification at Sugar beat regarding drainage was classified into two classes in 1990. Well drained soils occupy 45.7% (9734 faddans) and imperfect drained ones cover 54.3% (11566 faddans) of the total terrain (Table 2). Some locations at Sugar beat area suffering from poor drainage which resulted in water Table rising. The application of excess irrigation water and existing of hardpan or compact layers due to high lime content affect negatively the soil drainage. Thus, some imperfect drained soils transformed into poorly drained ones over 18.5% (3941 faddans) of the total area, which mean more sensitivity to desertification. The same situation with less severity conditions occurred at El-Bostan area. Table 3 indicates that most of the studied soils were well drained over 87.6% (12964 faddans) in 1990. In 2015, careless of design appropriate irrigation system led to extension of the imperfect drained soils growing up from 12.4% (1835 faddans) to 34.8% (5150 faddans) of the total area. In conclusion, the amount of applied irrigation water, soil texture and occurrence of consolidated subsurface layers, are controlling drainage status in the studied areas.

Surface rock fragments influence the sensitivity to desertification due to its capacity to conserve soil water and protect the soils from erosion. From the data in Table 2 it is clear that Sugar beat was classified in 1990 into two classes regarding rock fragments, stony over 34.9% (7433 faddans) and bare to slightly stony over 65.1% (13866 faddans). AttribuTable to weathering processes associated to agricultural practices, the surface rock fragments were degraded. Thus, 80.7% (17189 faddans) of the area got classified as bare to slightly stony in 2015. The sensitivity to desertification was maximized in El-Bostan area in relation to rock fragments. It was dominated by bare to slightly stony class at both 1990 and 2015 over 87.6% (12964 faddans) and 96.5% (14282 faddans), respectively as shown in Table 3.

Soil quality index (SQI) at Sugar beat area was calculated as shown in map (3.1). Data reveal that good soil quality in 1990 characterize 38.2% of the total area, which grow up in 2015 to be 50.3% referring to least sensitivity to desertification. At the same time, moderate soil quality decreased from 50.7% to 36.5%, in 1990 and 2015, respectively. Only miner change occurred to areas of low quality class from 11.1% to 13.2% during the same period which covering shallow and rugged landscaped soils. Soil quality maps illustrate how the influences of land use during 25 years leading the area towards more sensitivity to desertification in some locations and less sensitivity at others. Areas of low soil quality have been shifted partially in 2015 due to shallowness of profile depth, poor drainage and salinization which refer to more sensitivity to desertification. Due to same reasons, the moderate quality soils which exhibit the majority of studied area in 1990 were degraded in some locations at 2015 to be more sensitive.

Moderate changes in soil qualities have been detected at El-Bostan between 1990 and 2015 (map 4.1). Soils of good and moderate qualities extended from 50.1% and 34.2% in 1990 to 55.8% and 38.9% in 2015, respectively. While soils of low quality decreased significantly from 15.7% at 1990 to 5.4% at 2015.

In conclusion, it doesn't make a sense to compare the percentages of a certain sensitivity class between 1990 and 2015. Meanwhile, the comparison should be done between the locations of corresponding sensitivity classes and their qualities affecting the desertification, which have been changed with time under land uses.

Groundwater Quality Index (GQI)

Water aquifer system of the studied areas gained considerable changes during the period 1990-2015. Three classes of sensitivity to desertification could be differentiated in Sugar beat area at 1990 regarding groundwater depth (Table 4). These were dominated by deep class over 55.1% (11736 faddans) expressing high sensitivity. Shallow and moderate classes stretched over 18.5% (3941 faddans) and 26.4% (5623 faddans), respectively. Shallow groundwater which indicates least sensitivity was consumed completely at 2015 with the contribution of rapid water pumping. Moreover moderate class was transformed partially into deep one because of same condition. Hence, deep groundwater extends to occupy the majority of the area in 2015 over 81.5% (17359 faddans) due to the unsafe consumption. On the other hand, groundwater with low salinity was dramatically decreased from 61.3% (13056 faddans) in 1990 to 24.4% (5623 faddans) in 2015 due to unbalanced consumption. That was compensated by serious increase of moderately saline area from 38.7% (8243 faddans) to 55.1% (11736 faddans), in addition to emerge a new quality of high saline groundwater over 18.5% (3941 faddans).

The same deterioration was achieved at El-Bostan area between 1990 and 2015 regarding both of groundwater depth and salinity (Table 5). Shallow groundwater was totally consumed in 2015. Simultaneously as deep class has progressed from 37.7% (5580 faddans) in 1990 to 65.2% (9649 faddans) in 2015, expressing the majority of the area which led towards more sensitivity to desertification. Appearance of high saline groundwater over 12.4% (1835 faddans) in addition to decrease the area of low salinity groundwater from 65.2% (9650 faddans) to 37.7% (5580 faddans) are demonstrating how the area was exposed to more sensitivity to desertification with time.

These results were illustrated in map (3.2) where area of low quality groundwater class in Sugar beat was increased from 20.2% in 1990 to 54.3% in 2015. Moreover, good quality class was completely disappeared in 2015. On the other hand, map (4.2) emphasized the general deterioration of groundwater quality in El-Bostan area. Serious increase of low quality area from 18.9% to 55.3% versus general shrunk of good and moderate quality areas from 38.8% and 42.4% in 1990 to 18.5%and 26.2% in 2015, respectively. In conclusion, general deterioration occurred in groundwater depth and salinity maximized the sensitivity to desertification at studied areas.

Erosion Quality Index (EQI)

Wind and water erosion are affecting Sugar beat area while wind only is the erosional agent at El-Bostan area. General improvement could be noticed as shown in Tables 6 and 7 associated to decreasing the sensitivity to desertification regarding erosion. High quality class associated with less erosion at Sugar beat expanded from 20.2% (4303 faddans) in 1990 to 80.7% (17189 faddans) in 2015. Sharp evolution achieved at El-Bostan area during the same period. The absent high quality class in 1990 being the dominant in 2015. Whole studied area at El-Bostan is classified as high or moderate quality in 2015 as they represent 62.3% (9220 faddans) and 37.7% (5580 faddans). Low quality classes were entirely absent at the studied areas in 2015, which means transforming with time towards less sensitivity to desertification (maps 3.3 and 4.3). This perfection could be attributed to extensive plant coverage and wind fenders.

Table 4. Classes and corresponding scores of groundwater quality at Sugar beat area

Groundwater parameter	Class	Description	1990			2015		
			Area (%)	Area (fad.)	Score	Area (%)	Area (fad.)	Score
Groundwater depth	1	Shallow (< 25 m)	18.5	3941	1.15	--	--	--
	2	Moderate (25 – 50 m)	26.4	5623	1.65	18.5	3941	1.62
	3	Deep (> 50 m)	55.1	11736	1.92	81.5	17359	1.90
Groundwater salinity	1	Low (< 5000 ppm)	61.3	13056	1.05	26.4	5623	1.12
	2	Moderate (5000-10000 ppm)	38.7	8243	1.48	55.1	11736	1.50
	3	High (> 10000 ppm)	--	--		18.5	3941	1.98

Table 5. Classes and corresponding scores of groundwater quality at El-Bostan area

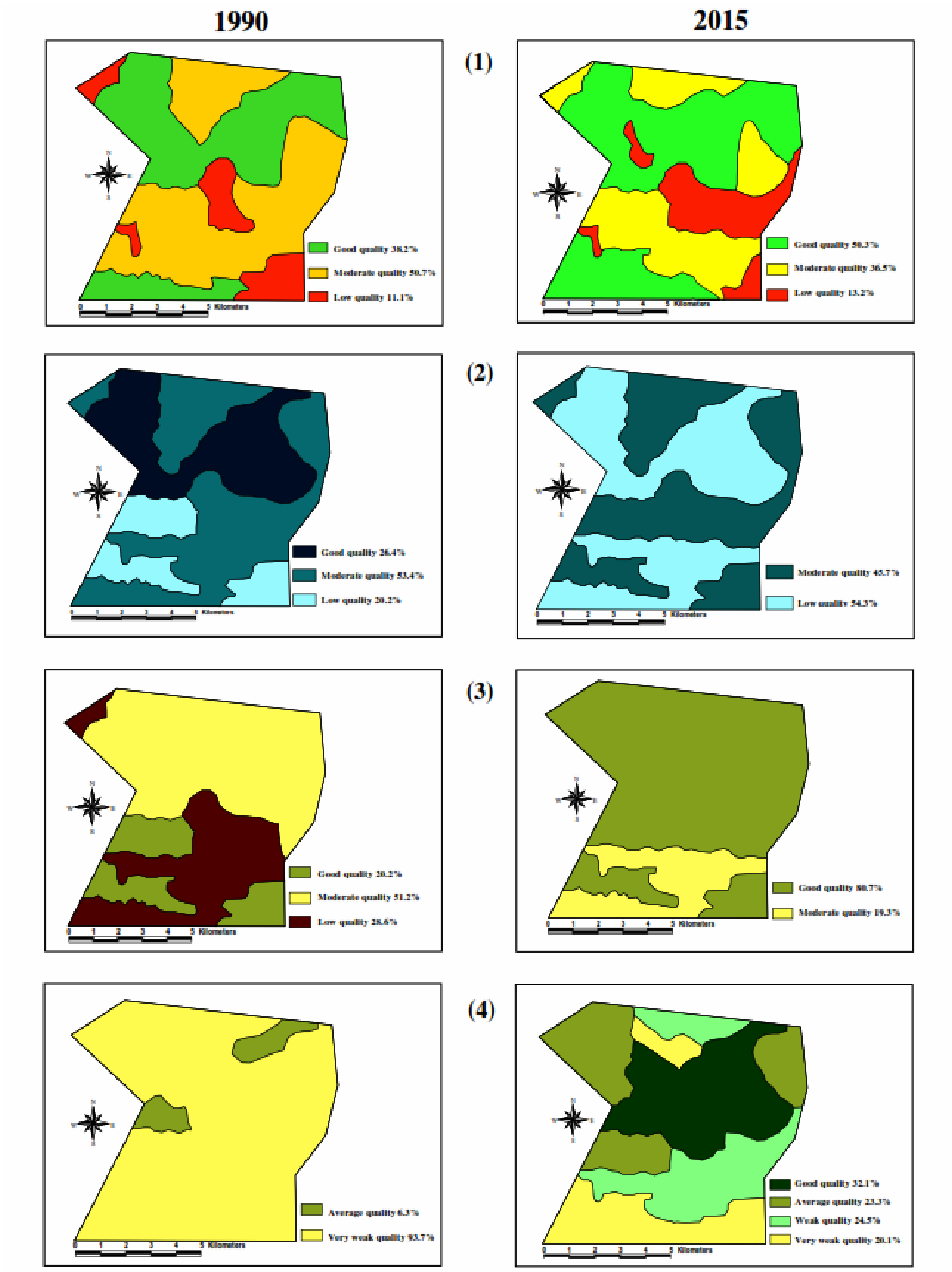
Groundwater parameter	Class	Description	1990			2015		
			Area (%)	Area (fad.)	Score	Area (%)	Area (fad.)	Score
Groundwater depth	1	Shallow (< 25 m)	12.4	1835	1.22	--	--	--
	2	Moderate (25 – 50 m)	49.9	7385	1.48	34.8	5150	1.50
	3	Deep (> 50 m)	37.7	5580	1.92	65.2	9649	1.98
Groundwater salinity	1	Low (< 5000 ppm)	65.2	9650	1.05	37.7	5580	1.20
	2	Moderate (5000-10000 ppm)	34.8	5150	1.58	49.9	7385	1.72
	3	High (> 10000 ppm)	--	--	--	12.4	1835	2.00

Table 6. Classes of soil erosion and calculated scores at Sugar beat area

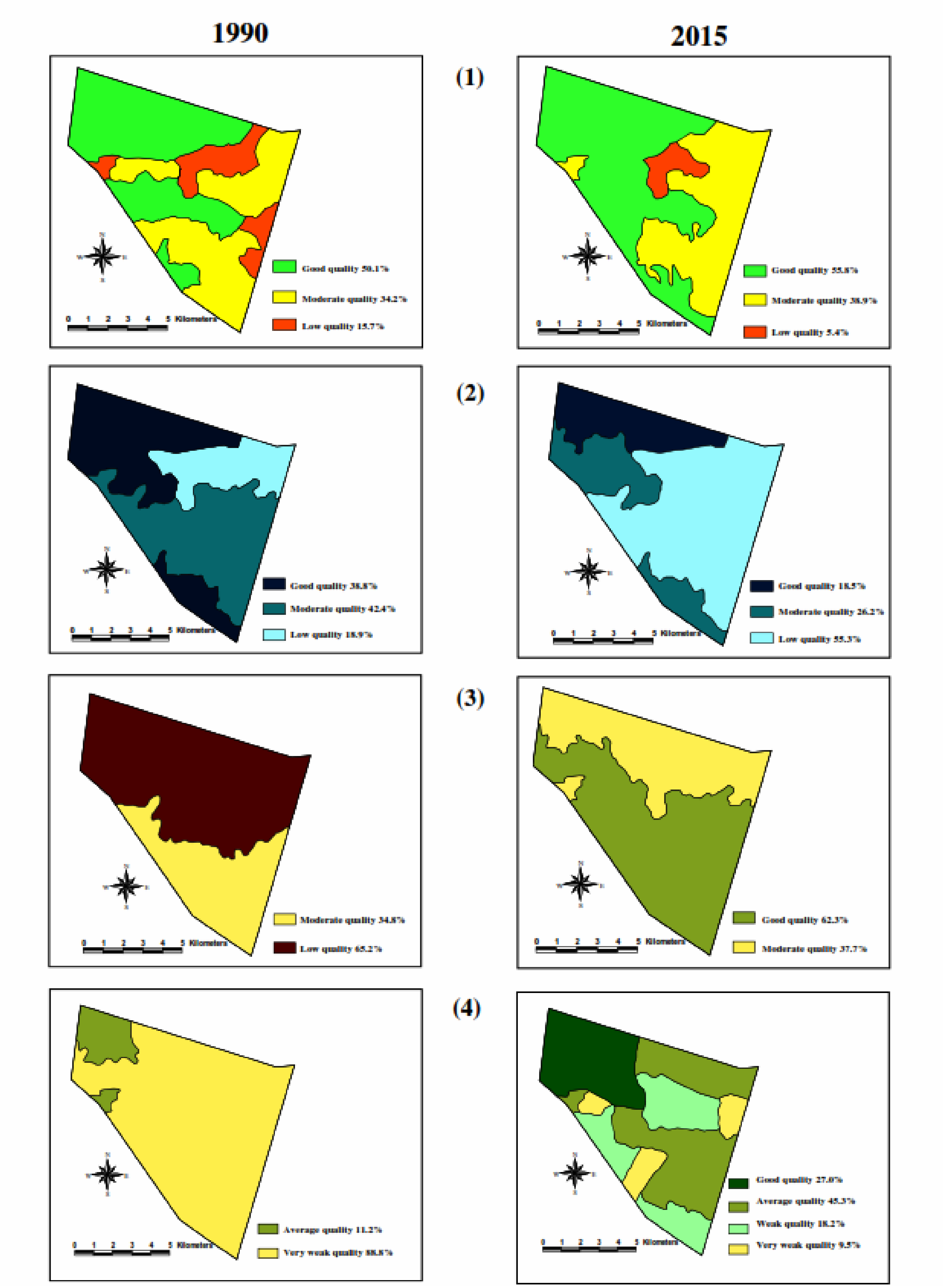
Class	Description	1990			2015		
		Area (%)	Area (fad.)	Score	Area (%)	Area (fad.)	Score
1	High quality (soil loss <10 Mg/h/y)	20.2	4303	0.85	80.7	17189	0.92
2	Moderate quality (soil loss 10-20 Mg/h/y)	51.25	10916	1.50	19.3	4111	1.56
3	Low quality (soil loss > 20 Mg/h/y)	28.55	6081	1.94	--	--	--

Table 7. Classes of soil erosion and calculated scores at El-Bostan area

Class	Description	1990			2015		
		Area (%)	Area (fad.)	Score	Area (%)	Area (fad.)	Score
1	High quality (soil loss <10 Mg/h/y)	--	--	--	62.3	9220	0.84
2	Moderate quality (soil loss 10-20 Mg/h/y)	34.8	5150	1.60	37.7	5580	1.58
3	Low quality (soil loss > 20 Mg/h/y)	65.2	9650	1.94	--	--	--



Map. 3. Comparison between desertification quality indices in 1990 and 2015 at Sugar beat area regarding (1) Soil, (2) Groundwater, (3) Erosion and (4) Vegetation



Map. 4. Comparison between desertification quality indices in 1990 and 2015 at El-Bostan area regarding (1) Soil, (2) Groundwater, (3) Erosion and (4) Vegetation

Vegetation Quality Index (VQI)

Tables 8 and 9 deal with the evaluation of sensitivity to desertification regarding vegetation. Data reveal clearly that plant cover at both of the studied areas were vividly changed from very low class in 1990 to low or high ones in 2015 due to agricultural expansions, which submit less sensitivity. Studied areas transformed to be more sensitive concerning drought resistance as characterized in 2015 by moderate, low and very low classes after been very high or high ones in 1990. This is may be attributed to spreading cereals and annuals. Concerning that issue El-Bostan area may be rather better than Sugar beat area due to attaining the largest area over 76.4% (11307 faddans) of the total area in 2015 within moderate sensitivity. This is attributed to the abundance of orchards in El-Bostan area. The reverse situation is noticed in Sugar beat where the majority over 45.5% (5474 faddans) is characterized by very low drought resistance class. Also vegetation type influence the erosion protection class at both of studied areas. Three classed were found for each area; moderate, low and very low at 2015. Very low class is the dominant at Sugar beat over 53.8% (11449 faddans), while the majority at El-Bostan area is characterized by low class over 66.4% (11307 faddans).

Vegetation quality indices were concluded as shown in maps (3.4) and (4.4) for the considered areas, respectively. Both of areas were aggressively occupied by very weak vegetation quality class in 1990, expressing high sensitivity to desertification. It covered 93.7% and 88.8%, respectively at Sugar beat and El-Bostan. Good, average, weak and very weak vegetation quality classes are nearly balanced over 32.1%, 23.3%, 24.5% and 20.1%, respectively of Sugar beat total studied area in 2015. Meanwhile, Average vegetation quality class which mostly restricted for orchards is the foremost at El-Bostan over 45.3% of the total area. Rest of the area is occupied by good, weak and very weak classes over 27.0%, 18.2 and 9.5%, respectively.

Geographic locations of the studied areas influence the vegetation quality which contributes to the desertification sensitivity. El-Bostan with its southern location is more situated to orchards due to deep soils, low lime content and subsequent absence of hard layers, in addition to its location far from probabilities of sea water intrusion. Meanwhile, Sugar beat is mush suited to cereals and annuals due to shallowness of soils resulting in weak vegetation type quality.

Environmental Sensitivity Areas (ESAs)

Desertification Sensitivity Indices (DSIs) were computed on basis of MEDALUS project methodology, using SQI, GQI, EQI and VQI values. Table 10 shows the output of the calculations, whereas map 5 demonstrates the geographical extension of each Environmental Sensitive Areas (ESAs). Distributions of the sensitivity values over the studied regions are clearly related to their general physiographic characteristics, which play a strong determining role on the built model configuration regarding used elements and parameters. Critical and fragile areas show the lower qualities for the different indices, while potential and non affected areas express the higher qualities (lower indices).

Studied areas at Sugar beat and El-Bostan classified within wide range of different sensitivity classes either in 1990 or 2015. Over prevailing areas, both of them were characterized as "moderate sensitive to desertification" which called the fragile areas, as their moderate quality soils are protected by good quality vegetation. Regarding Sugar beat, the moderate ESIs ranged between 1.327-1.374 over 38.0% in 1990, while being between 1.354-1.386 over 38.3% in 2015. Meanwhile, the moderate ESIs at El-Bostan vary between 1.313-1.357 over 39.9% in 1990, which surpass to be between 1.335-1.373 above 41.5% in 2015.

Considerable areas of each investigated site lie within the class of "non sensitive to desertification". These were degraded in Sugar beat from 24.2% in 1990 to 22.7% in 2015, while they upgraded at El-Bostan during the same period from 17.6% to 25.2%. On the other hand, it is clear that the studied areas were partially classified as very sensitive and sensitive to desertification. Very sensitive area to desertification located within critical class and considered vulnerable to high desertification sensitivity. It was grown up at Sugar beat as

Table 8. Vegetation quality indices at Sugar beat area

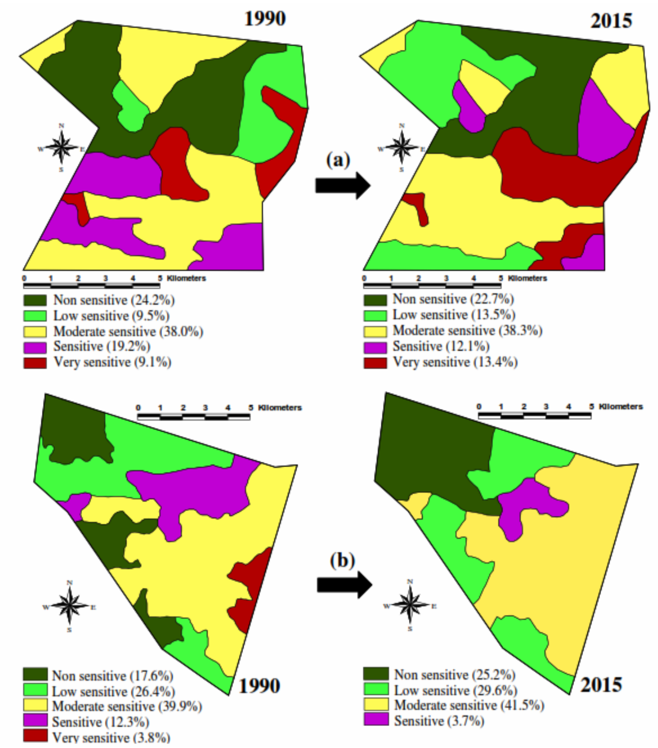
Vegetation parameter	Class	Description	1990			2015		
			Area (%)	Area (fad.)	Score	Area (%)	Area (fad.)	Score
Plant cover	1	High (> 40%)	--	--	--	61.3	13056	1.0
	2	Low (10-40%)	--	--	--	38.7	8243	1.7
	3	Very low (< 10%)	100	21300	2.0	--	--	--
Drought resistance	1	Very high (*Tamarix nilotica*)	--	--	--	--	--	--
	2	High (*Attriplex halimus*)	3.5	746	1.4	--	--	--
	3	Moderate (Perennials, Orchards)	1.7	362	1.5	36.05	7678	1.4
	4	Low (Cereals, vines)-	--	--	--	18.5	3941	1.8
	5	Very low (Annuals)	--	--	--	45.45	5474	2.0
Erosion protection	1	High (Wetlands with shrubs)	--	--	--	--	--	--
	2	Moderate (Mound shrubs)	--	--	--	10.0	2130	1.4
	3	Low (Perennials, Orchards)	5.2	1108	1.6	26.06	7678	1.7
	4	Very low (Annuals)	--	--	--	53.75	11449	2.0

Table 9. Vegetation quality indices at El-Bostan area

Vegetation parameter	Class	Description	1990			2015		
			Area (%)	Area (fad.)	Score	Area (%)	Area (fad.)	Score
Plant cover	1	High (> 40%)	--	--	--	65.2	9650	1.0
	2	Low (10-40%)	--	--	--	34.8	5150	1.6
	3	Very low (< 10%)	100	14800	2.0	--	--	--
Drought resistance	1	Very high (*Tamarix nilotica*)	--	--	--	--	--	--
	2	High (*Attriplex halimus*)	3.5	518	1.3	--	--	--
	3	Moderate (Perennials, Orchards)	--	--	--	76.4	11307	1.4
	4	Low (Cereals, vines)-	--	--	--	17.4	2575	1.7
	5	Very low (Annuals)	--	--	--	6.2	917	2.0
Erosion protection	1	High (Wetlands with shrubs)	--	--	--	--	--	--
	2	Moderate (Mound shrubs)	--	--	--	12.0	1776	1.2
	3	Low (Perennials, Orchards)	3.5	518	1.5	66.4	11307	1.6
	4	Very low (Annuals)	--	--	--	11.6	1717	2.0

Table 10. Environmental sensitive indices (ESIs) and areas (ESAs) in the studied locations at West of Delta

Class	Description	Studied area	Year	DSI	Area (%)	Area (fad.)
1	Non sensitive areas to desertification	Sugar beat	1990	1.023-1.123	24.2	5155
			2015	1.094-1.164	22.7	4835
		El-Bostan	1990	1.012-1.088	17.6	2605
			2015	1.056-1.109	25.2	3212
2	Low sensitive areas to desertification	Sugar beat	1990	1.237-1.271	9.5	2024
			2015	1.255-1.291	13.5	2876
		El-Bostan	1990	1.203-1.240	26.4	3907
			2015	1.235-1.263	29.6	3567
3	Moderate sensitive areas to desertification	Sugar beat	1990	1.327-1.374	38.0	8094
			2015	1.354-1.386	38.3	8158
		El-Bostan	1990	1.313-1.357	39.9	5905
			2015	1.335-1.373	41.5	7222
4	Sensitive areas to desertification	Sugar beat	1990	1.431-1.367	19.2	4090
			2015	1.460-1.498	12.1	2577
		El-Bostan	1990	1.404-1.433	12.3	1820
			2015	1.444-1.471	3.7	799
5	Very sensitive areas to desertification	Sugar beat	1990	1.545-1.558	9.1	1938
			2015	1.557-1.582	13.4	2854
		El-Bostan	1990	1.522-1.537	3.8	562
			2015	1.533-1.557	0.0	0



Map. 5. Environmental sensitive areas (ESAs) for desertification in (a) Sugar beat (1990-2015), and (b) El-Bostan (1990-2015) at West of Delta

accounted for 9.1% in 1990 and 13.4% in 2015 of the total area. While it was completely renovated into moderate sensitive at El-Bostan due to ground leveling and existence of sufficient vegetation cover. Obtained results indicate a clear degrading trend of the critical and non affected areas at Sugar beat area along the study period. Whereas, an opposite trend is noticed at El-Bostan area through enlarge the non sensible area while critical one was dropped off.

It was helpless to monitor the absolute percentage of sensitivity changing over the whole area of each case study, while shifting of a sensitivity class location according to altered qualities or intensity with time have to be considerably assessed. However, percentages of sensitivity classes at Sugar beat in 1990 found to be very close to corresponding values in 2015, but with different spatial distributions. It was incorrectly expected that land use has great positive effects on sensitivity degrees at Sugar beat due to its earliest reclamation and long period of agricultural practices than El-Bostan. Further, the study achieved obviously more changes of El-Bostan sensitivity than occurred in Sugar beat. That was because limitations found in El-Bostan have less intensity than those found at Sugar beat *i.e.* shallow profile depth, saline groundwater as sea water introgen, soil salinization, and difficulty of leveling due to ground hardness as affected by high lime content rather than rock exposures.

Considerable areas are susceptible to a high to very high desertification sensitivity. The study emphasized that higher sensible areas to desertification have been shifted with time to other locations guided by the degradation / improvement occur in the investigated parameters at both of the studied areas. Action measures are essential for the sustainable agricultural projects located in the desert due high desertification sensitivity.

Conclusion

Assessment of desertification sensitivity is rather important to plane combating actions and to improve the employment of natural resources. The merely quantitative aspect of desertification sensitivity demonstrates a clearer image of the risk state, thus, reliable priority actions can be planned. It may be pointed out that precise determination of the desertification sensitivity at desert areas are needed to identify the risk magnitude and causes of degradation in problematic areas. Current research considered two models of newly reclaimed land located at the western border of West of Delta region. They rather differ in their physiographic characteristics, which led to noticeable variations partially in their response to desertification issue along 25 years of land use from 1990 till 2015. The majority of the studied areas are moderately sensitive due to satisfactory vegetation cover, ground leveling in addition to improvement in some soil qualities. However, as various environmental conditions may control the desertification sensitivity, some locations within the investigated areas may be exposed to relatively less sensitivity to desertification.

Applied agricultural systems affect negatively the environmental sensitivity to desertification in some locations at both of studied areas. Therefore, it is necessary to re-evaluate current practices and/or land uses to prevent that degradation.

It can be concluded that the quantitative approach for assessing the desertification is rather important for planning sustainable development programs. Desertification sensitivity index demonstrates a clearer vision of risk state, thus, reliable priority actions can be planned. Some work still remains needed to be carried out to assess the reliability of the sensitivity maps and to refine the values of ESA assigned to the different classes of sensitivity by field validation.

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يهدف البحث إلى تصنيف نوعية الحساسية البيئية للتصحر باستخدام طرق التحليل الكمي لمعلومات بعض الدلائل النوعية للصفات والخصائص البيئية، كدليل نوعية التربة Soil Quality Index (SQI) ودليل نوعية الماء الجوفى Groundwater Quality Index (GQI) ودليل نوعية التعرية Erosion Quality Index (EQI) بالإضافة لدليل نوعية الغطاء النباتى Vegetation Quality Index (VQI)، مع محاولة رصد تغير نوعية وشدة الحساسية البيئية للتصحر مع الزمن، أختيرت منطقتين للدراسة بإقليم غرب الدلتا الأولى تمتد على مساحة ٢١٣٠٠ فدان بمنطقة بنجر السكر والثانية تمتد على مساحة ١٤٨٠٠فدان بمنطقة البستان، وذلك لمقارنة نوعية الحساسية البيئية للتصحر بكل منهما خلال فترة زمنية قدرها ٢٥ عام من ١٩٩٠ وحتى ٢٠١٥، تم تقسيم الأراضي طيفيا باستخدام Unsupervised classification وحساب درجات الميل بناءا على نموذج الارتفاعات الرقمى DEM بكل منطقة. وخلال الدراسة الحقلية تم إستيفاء البيانات الحقلية اللازمة، وتجميع عينات التربة من قطاعات الأراضى الممثلة لوحدات التربة السائدة بمناطق الدراسة، مع إجراء التحليلات المعملية اللازمة لتقدير صفات التربة الطبيعية والكيميائية. تم تطبيق نظام الجمعية الدولية لمكافحة التصحر (كوزماس وآخرون، ٢٠٠٣) لتقييم الحساسية البيئية للتصحر مع إجراء بعض التعديلات وفقا لما تم إقراره بمركز بحوث الصحراء (حجازى وآخرون، ٢٠٠٩)، حيث تم حساب أدلة نوعية الحساسية البيئية للتصحر DSI مع تصنيف أراضى مناطق الدراسة وفقا لدرجة استجابتها لعناصر التصحر، مع مقارنة نوعية الاستجابة البيئية للتصحر بمناطق الدراسة في الوقت الحالي (٢٠١٥) باستجابها للتصحر في (١٩٩٠) في محاولة لدراسة تأثير الاستخدام الأرضي على تغير درجة ونوعية استجابة بيئة مناطق الدراسة لعناصر التصحر مع الزمن، أكدت النتائج على سيادة الحساسية البيئية المتوسطة للتصحر بكلتا منطقتى الدراسة عند ١٩٩٠ و٢٠١٥، حيث تراوح دليل الحساسية البيئية بين ١,٣٢٧-١,٣٧٤ ليشمل ٣٨,٠% من إجمالي المساحة ببنجر السكر فى ١٩٩٠ بينما تراوح بين ١,٣٥٤-١,٣٨٦على مساحة ٣٨,٣% فى ٢٠١٥، وتراوح دليل الحساسية المتوسطة بمنطقة البستان بين ١,٣١٣-١,٣٥٧ في ١٩٩٠ ليغطى مساحة ٣٩,٩% زادت إلى ٤١,٥% في ٢٠١٥ حيث تراوح دليل الحساسية بين ١,٣٣٥-١,٣٧٣، كما أكدت النتائج على وجود مساحات بكلتا المنطقتين ذات استجابة مرتفعة لعناصر التصحر، حيث تأثرت تلك الاستجابة المرتفعة بالاستخدام الأرضى على نحو سلبي ببنجر السكر وإيجابي بالبستان، منطقة بنجر السكر زاد ما تشغله الحساسية المرتفعة من ٩,١% إلى ١٣,٤% ما بين ١٩٩٠و٢٠١٥ على الترتيب دلالة على زيادة تدهور بعض الأراضي، وفى تحسن واضح تحولت كافة الأراضي شديدة الحساسية للتصحر بمنطقة البستان في ٢٠١٥ إلى أراضى متوسطة الحساسية نظرا لعمليات تسوية سطح التربة وتكثيف التغطية النباتية بالمنطقة، في العموم تدهورت نسب ما تشغله كل من الأراضي عديمة الحساسية وشديدة الحساسية للتصحر بمنطقة بنجر السكر بنقص الأولى وزيادة الثانية خلال فترة الدراسة، بينما تحسنت تلك النسب بزيادة مساحة الأراضي الغير الحساسة للتصحر واختفاء الأراضي شديدة الحساسية بمنطقة البستان. وأعزى ذلك لشدة وطأة محدات الاستخدام الأرضي ببعض مساحات منطقة بنجر السكر والتي تمثلت في ضحالة عمق القطاع الأرضي، تملح الماء الجوفي نتيجة السحب الغير آمن وتداخل ماء البحر، صعوبة تسوية سطح التربة بسبب صلابة الطبقات السطحية وانتشار التكشفات الصخرية، وأوضحت النتائج أنه ليس كافيا مقارنة نسب ما تشغله درجات الحساسية للتصحر خلال فترة الدراسة بل يتحتم رصد تباين التوزيع المكانى لدرجة ونوعية الحساسية البيئية للتصحر بكل منطقة مع الزمن تحت تأثير مستوى التحسن/التدهور في المتغيرات البيئية تحت الدراسة الأمر الذى يتحكم فيه جودة إدارة الاستخدام الأرضي، وقد حاولت الدراسة إلقاء الضوء على الأهمية التطبيقية لرصد تغير نوعية حساسية البيئة للتصحر خلال ٢٥ عاما من الاستخدام الأرضي عن طريق الدراسة الكمية وحساب أدلة الحساسية للتصحر بالمناطق المدروسة، وذلك من خلال التوصية بضرورة إعادة تقييم كافة أوجه الاستخدام الأرضي بالمساحات التي تأثرت سلبيا نتيجة ارتفاع مستوى الحساسية البيئية للتصحر تحت تأثير الأنظمة الحالية للاستغلال الزراعي.

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