Spatial Distribution of Soil Sensitivity to Desertification in The West Delta Lands (Egypt)

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ABSTRACT

Desertification is one of the most important problems facing arid and semi-arid regions, whether it is caused by irresponsible human activity or due to natural conditions or both. The objectives of the study were to assess the environmental sensitivity of desertification in the western delta region using a Mediterranean Mathematical Model (MEDALUS). Where the sensitivity of the land to desertification is deduced in this model using geographic information systems through the integration of spatial data of soil characteristics, vegetation cover, climate and management obtained from field visits and laboratory analyzes and then entered into the ArcGIS10.3 program base to derive a map of desertification sensitivity. This map was used by Stakeholders and decision-makers to propose a list of interventions that may contribute to alleviating desertification problems in the region and thus ensure their sustainable use. The results indicated that the sensitivity to desertification in the western delta region is distributed by 88% of medium sensitivity (i.e., 3,405.69 km), while the areas with high sensitivity to desertification represent 12% of the total area (i.e., 462.68 km). The results also indicated that low rainfall and poor soil properties are a determining factor in areas highly sensitive to desertification in the western Delta.

Keywords: Soil Quality, Climate Quality, Vegetation Cover Quality, and Management Quality.

INTRODUCTION

Desertification is a major problem in arid and semi-arid regions, where water is the main determinant in the process of agriculture, and soil use. The land sensitivity to desertification is a set of indicators that represent a potential risk of desertification, and it is the end result of many interactions between a set of factors, including environmental change. And human activities (Batterbury and Warren, 2001; Moghanm and Belal 2018).

About 15 percent of the world's population (more than 100 countries) of more than six billion people are affected by desertification (Adger et al., 2000, Adger et al., 2001).

In the Mediterranean countries, different regions are sensitive to desertification, depending on the specific conditions of each region. Some areas show high sensitivity to low rainfall because they contain plants that show poor resistance to drought, have low vegetation, have gentle slopes, and major materials are highly corrosive (Ferrara et al., 1999).

The occurrence of desertification incorporates two components: human actions and natural ecosystems (World Meteorological Organization, 2005).

The MEDALUS scheme was designed and used by (Kosmas et al., 1999), and thereafter used in several studies to evaluate ESA, and from these studies (Basso et al., 2000, Gad and Lotfy, 2006, Contador et al., 2009, and Tombolini et al. al., 2016).

Symeonakis et al., 2016 that the ESA framework is the most widely applied indicator-based system for assessing land degradation and desertification primarily in the Mediterranean region.

Various studies monitored and assessed environmentally
sensitive areas (ESA) by using MEDALUS model in the Mediterranean region with acceptable results (Saleh et al., 2018, Lahlaoi et al. 2017).

MEDALUS is one of the methods used to assess the sensitivity of environments to desertification based on four main indicators: soil, climate, vegetation cover and management (Bouabid et al., 2010).

Desertification sensitivity is the extent to which the terrestrial environment responds to the adverse effect of natural or human activities.

In this context, arid and semi-arid regions, which cover about a third of the Earth's surface, are particularly threatened by desertification due to their high sensitivity to this phenomenon, as the dry climate and human pressures through intensive agriculture

The objectives of our work were to apply the MEDALUS model to assess the risks of desertification in the West Nile Delta region using geographic information systems and remote sensing tools, and to use this information as a basis for making the spatial distribution of different degrees of desertification sensitivity.

MATERIALS AND METHODS

Study area

The study area is located in the west Nile delta, north west of the Cairo city. It extends between latitudes 30° 20′ and 30° 50′ N, and longitudes 30° 10′ and 30° 50′E (Fig. 1). The Nile River in the east (Rosetta branch), the Cairo-Alexandria roads in the west the Noubaria canal in the north, and the Khatatba road in the south border. It lies over approximately 2458.60 km2 and according to Climatological Normals for Egypt, (2006) is characterized by an arid condition. The mean annual temperatures ranging from 7.2 to 34.3 °C and the mean annual precipitation ranging from 0 to 200 mm/year. According to Conoco (1987). The geological formations of the study area belonging to the *Quaternary* ages, as they include the following deposits: Nile silt deposits, Aeolian deposits, alluvial deposits, and deltaic deposits

The information extracted from a DEM (i.e., surface elevation, slope and slope direction) is used with the satellite images to increase their utility in physiographic soil mapping. The Landsat ETM+ images and the DEM were merged in the ArcGIS to obtain the physiographic units (Dobos et al., 2000).

Field work and laboratory analyses

For field work and locating soil Profiles, a map of the physiographic units with GPS was used for this purpose (Fig. 2). Fifteen soil profiles were created to represent the different physiographic units on the map, morphology was subsequently described, and representative samples were taken from each Profile, according to the soil survey manual (USDA 2012).

Soil samples that were collected air-dried were sieved through a 2 mm stainless steel sieve and stored in plastic bottles to be ready for the physical and chemical analyzes. The necessary analyzes were carried out to complete the study according to Estefan et al. (2013)

Land Desertification assessment

The MEDALUS model was used to determine the sensitivity of areas to desertification by calculating indicators that lead to land degradation and, ultimately, desertification.

Through the model, we can compile indicators and merge them into four quality layers that represent soil quality indicators (SQI), climate (CQI), vegetation cover (VQI) and management (MQI). The SQI and CQI reflect the environmental conditions, the Quality of Life Index (VQI) reflects human activities, and the MQI reflects the management effects of the region (Figure 3 and Table 1).

Classes and assigned weighting index for factors were calculated in detail by (Kosmas et al., 1999).

The desertification sensitivity index (DSI) was calculated and classified from the four previously computed indicators, using equation 1 and Table 2. The obtained values are to be entered in order to create a desertification-sensitive map of regions through spatial analysis of data using ArcGIS 10.3 software using inverse-weight deterministic interpolation (IDW) techniques.

$DSI = (SQI \times CQI \times VQI \times MQI)^{1/4}$ (1)

RESULTS AND DISCUSSION

Estimate quality indicators

The effect of soil characteristics related to environmental sensitivity to desertification is estimated by estimating the so-called the Soil Quality Index (SQI) depending on drainage condition, rock fragments (%), slope (%), soil texture class, soil depth (cm), and parent material type. Table 3 shows the weighted average of soil properties used in the calculation of the soil quality index. In general, the texture was sandy and sandy loam, and the depth of the Profiles was between 100 and 150 cm, except for Profile No. 12 (50 cm) and the slope was <6% and the percentage of rock fragments did not exceed 20 % except for Profiles No. 8 and 9 (average of 27%), while the drainage condition was Well to Moderately Well, except for Profile No. 12, it was Very Poorly

The results indicate as in Table (3,4) Figure (4) that the study area with high and medium soil quality index, areas of high quality (value <1.13) represent 95.80% of the total area (i.e., 3700.43 km), and the areas with medium soil quality index (value = 1.13 - 1.45) represent 4.20 % of the total area (i.e., 162.42 km2). Thus, the areas of high quality are prevalent in the study area.

The Climate Quality Index (CQI) is evaluated based on climate data as well as slope direction. The local climate varies from one place to another depending on the direction of the slope. Slope direction was inferred from a digital elevation model (DEM). The moderate climate index (1.50 - 1.80) was prevalent for most soil profiles in the study area, while it was low (> 1.80) for profiles No. 8,9,10 and 16.

Vegetation cover and management play an important role in combating desertification, the higher the vegetation cover, the less likely the soil will be exposed to erosion and vice versa, and the more there is good management, this well be the reason for the likelihood of desertification. The data indicate that the study area has a high quality of vegetation cover and management.

Soil Desertification

The previous four indicators were combined together to assess environmentally sensitive desertification areas, on the basis of the Computed Desertification Sensitivity Indicators (DSI). The results as shown in Table (5,6) and Figure (5) indicate three levels of sensitivity to desertification in the western delta region. It is noted that areas with medium sensitivity to desertification (second degree) represent the largest area at 86% of the study area, areas with medium sensitivity to desertification (third degree) represent the least area by 1.5%, while areas with high desertification sensitivity represent 12%.

CONCLUSION

Desertification is considered one of the biggest challenges in sustainable development in Egypt in general. This research should be considered as a case study related to methods for assessing and mapping sensitive areas of desertification (SAD). SAD monitoring was performed using the MEDALUS model supported by field assessments and laboratory analyzes. The results show that the MEDALUS model is a valuable tool for assessing the environmental sensitivity of desertification in arid and semi-arid regions such as the western delta in Egypt. The MEDALUS approach can also be applied in other regions, but after adding some other indicators. This increases the accuracy of the approach such as the water quality. The results indicated that 88% of the region is moderately sensitive to desertification, and 12% is highly sensitive. These results allow the identification of areas that require action to combat desertification. The approach used in this research can be used elsewhere in Egypt. The SAD map has proven to be a good source of information to assist local and national authorities in combating desertification in the West Delta region. We suggest that in order to alleviate desertification in the West Delta region, soil properties should be improved and water loss reduced through the use of appropriate agricultural rotations and attention to choosing the appropriate type of management.

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Table 1: Environmental properties related to desertification sensitivity indexes.

Quality index	Algorithms
SQI	SQI= (texture x parent material x rock fragment x depth x slope x drainage)$^{1/6}$
CQI	CQI= (rainfall x aridity x aspect) $^{1/3}$
VQI	VQI= (fire risk x erosion protection x drought resistance x vegetation cover)$^{1/4}$
MQI	MQI= (land use intensity x policy enforcement)$^{1/2}$

Table 2: Ranges and classes of desertification sensitivity index.

Range of values	Symbo	Desertification Sensitivity Degree	
1-1.17	N	non-threatened	Very LOW
1.18-1.22	P	Potential	LOW
1.23-1.26	F1	Fragile (1)	Moderate
1.27-1.32	F2	Fragile (2)	Moderate
1.33-137	F3	Fragile (3)	Moderate
1.38-1.41	C1	Critical (1)	High
1.42-1.53	C2	Critical (2)	High
1.53-2	C3	Critical (3)	High

Table 3: Site description and some soil characteristics to the representative soil profiles.

Profiles No.	Slope %	Land cover & use	Parent material	Drainage class	Depth cm	Texture class	fragment %
1	0.7	Groundnut	A.D	M.W	125	LS	0.4
2	1.8	Banana	A.D	W	120	S	1.8
3	1	Groundnut	Ae.D	W	120	S	1
4	2	potatoes	A.D	W	140	S	0.9
5	1.85	Fallow after Maize	A.D	W	100	SCL	1.7
6	2.06	Grape	A.D	W	120	LS	6.5
7	2.63	Maize	A.D	W	150	S	8
8	1.7	Grapes	A.D	M.W	100	S	26
9	1.58	Pomegranate	A.D	M.W	110	LS	28
10	1.47	Mango	A.D	W	100	S	12.5
11	2.46	Lemon	Ae.D	W	130	S	1.3
12	0.16	Fallow after Rice	Ae.D	V.P	50	LS	1.4
13	2	Tomato	Mix	M.W	150	LS	0.5
14	1.94	Orange	Mix	M.W	150	S	1
15	3.67	Orange	A.D	W	150	S	1.8
16	1.2	Mango	Ae.D	M.W	110	S	2.7

MW=Moderately Well Drain ,W=Well Drained, V. P=Very Poorly Drained ,Mix= mixed Aeolian and fluvial, Alluvial deposits=A.D, Aeolian deposit=Ae.D
S= sand, SI= silt, C= clay,L= loam, GR=Gravel

Table 4: Summarized results of the soil quality index in the study area.

class	Description	range	Area km2	Area %
1	High	<1.3	3700.43	95.80
2	Moderate	1.3 to 1.45	162.42	4.20
			3862.85	100.00

Table 5: Values of quality indexes for indicators used in calculating desertification sensitivity of the study area.

Profiles	SQI	Class	CQI	Classes	VQI	Class	MQI	Class	DSI	Classes
1	1.16	High	1.59	Moderate	1.34	High	1.41	High	1.365	F3
2	1.12	High	1.59	Moderate	1.34	High	1.22	High	1.307	F2
3	1.26	High	1.59	Moderate	1.34	High	1.22	High	1.345	F3
4	1.12	High	1.59	Moderate	1.34	High	1.22	High	1.307	F2
5	1.12	High	1.59	Moderate	1.37	High	1.41	High	1.363	F3
6	1.12	High	1.59	Moderate	1.37	High	1.22	High	1.315	F2
7	1.26	High	1.59	Moderate	1.37	High	1.22	High	1.353	F3
8	1.16	High	1.82	LOW	1.49	High	1.00	High	1.330	F3
9	1.16	High	1.82	LOW	1.49	High	1.00	High	1.330	F3
10	1.26	High	1.82	LOW	1.37	High	1.00	High	1.331	F3
11	1.26	High	1.59	Moderate	1.35	High	1.22	High	1.347	F3
12	1.41	Moderate	1.59	Moderate	1.35	High	1.41	High	1.437	C2
13	1.16	High	1.59	Moderate	1.35	High	1.41	High	1.367	F3
14	1.30	Moderate	1.59	Moderate	1.35	High	1.22	High	1.357	F3
15	1.26	High	1.59	Moderate	1.35	High	1.22	High	1.347	F3
16	1.30	Moderate	1.91	LOW	1.35	High	1.00	High	1.352	F3

Table 6: Summarized results of the sensitive area to desertification.

Range of values	Symbol	class	Area km2	Area %
1.27-1.32	F2	Fragile (2)	56.65	1.46
1.33-137	F3	Fragile (3)	3349.03	86.57
1.42-1.53	C2	Critical (2)	462.68	11.96
			3868.36	100.00

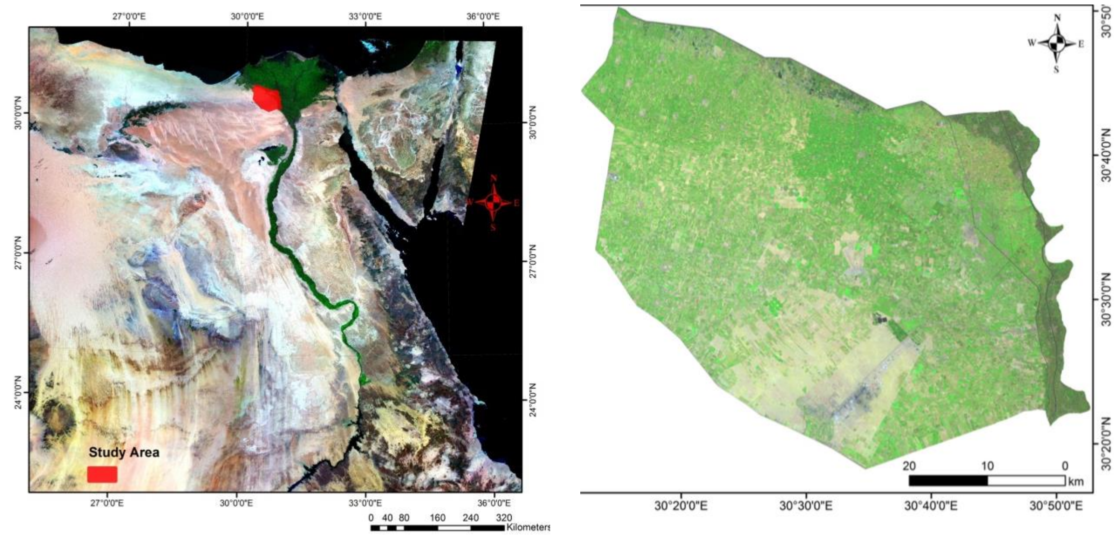

Figure 1: location of the study area

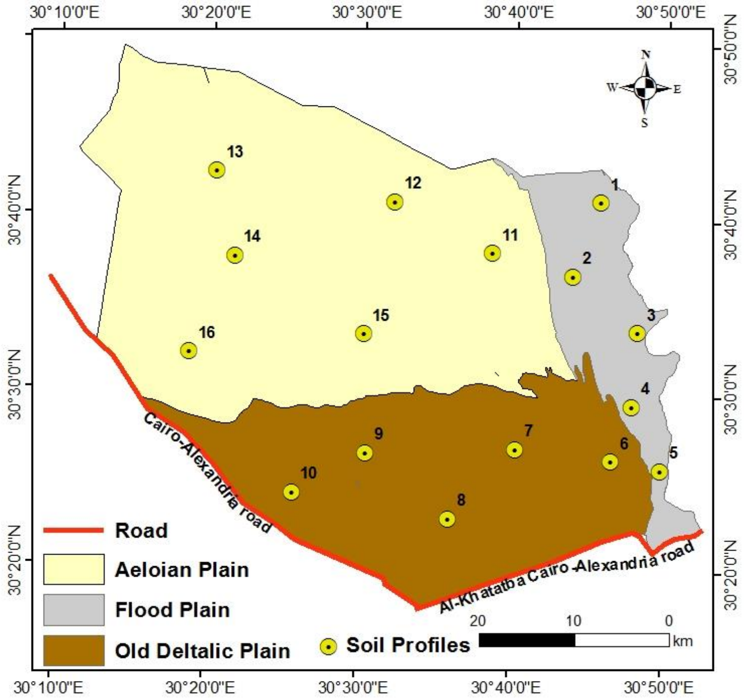

Figure 2: Soil profiles distributed according to the main landforms of the study area

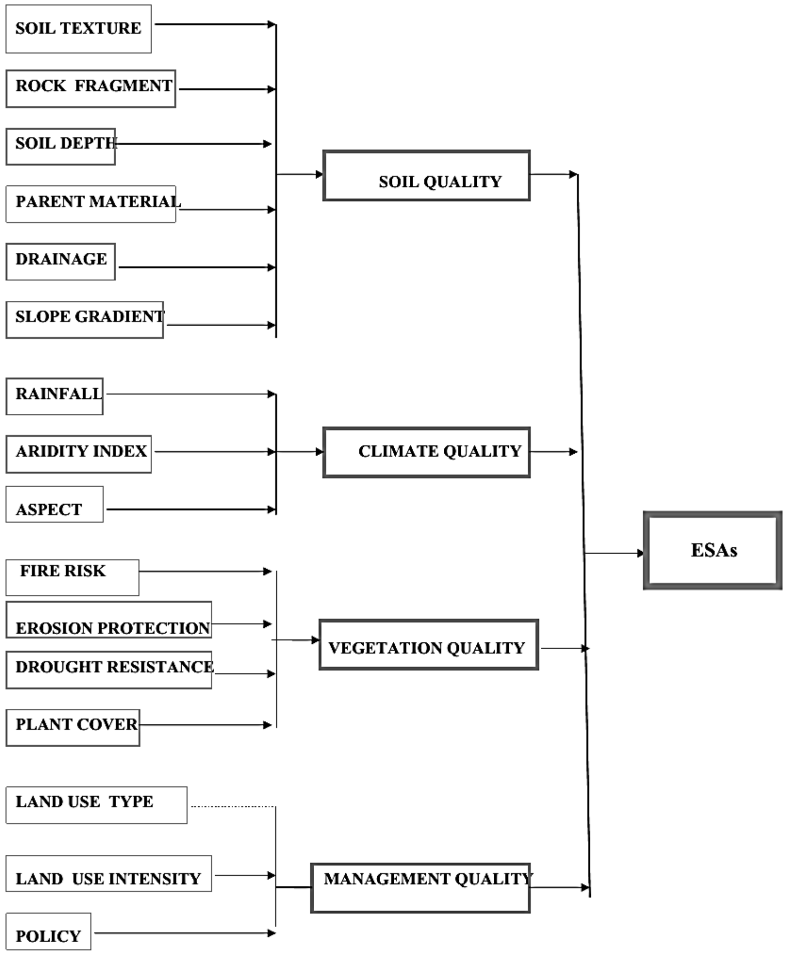

Figure 3: Outline for calculating the quality of indicators and sensitive areas of desertification

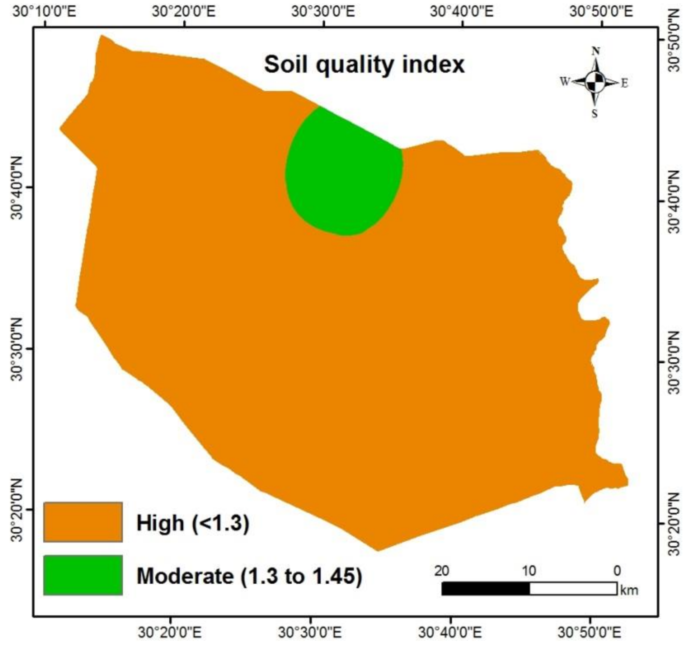

Figure 4: Spatial distribution of the soil quality index in the study area

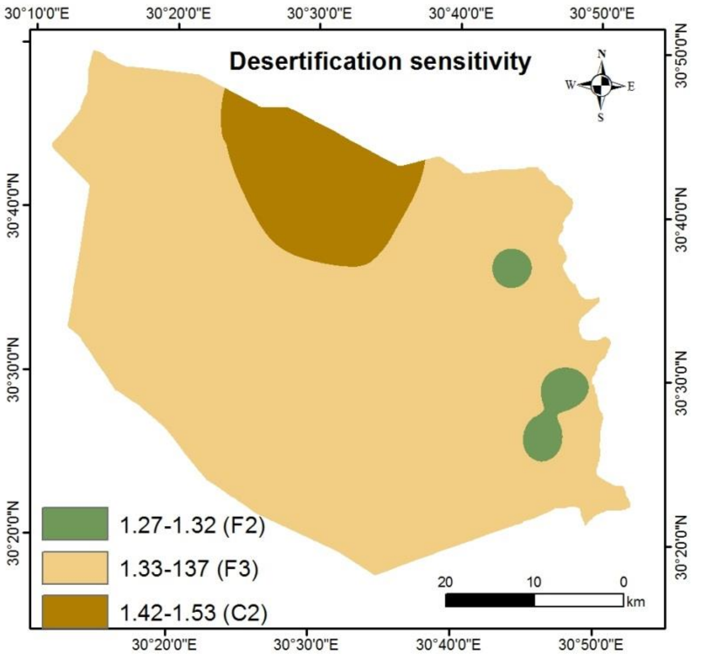

Figure 5: Spatial distribution of the sensitive area to desertification.

التوزيع المكاني لحساسية التربة للتصحر في أراضي غرب الدلتا (مصر)

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الملخــص العربي

يعتبر التصحر من أهم المشاكل التي تواجه المناطق القاحلة وشبه القاحلة سواء كان المتسبب النشاط البشري الغير مسئول أو بسبب الظروف الطبيعية أو الاثنين معا .كانت أهداف الدراسة هي تقييم الحساسية البيئية للتصحر في منطقة غرب الدلتا باستخدام نموذج رياضي خاص بمنطقة البحر الأبيض المتوسط .(MEDALUS) حيث يتم استنتاج حساسية الأرض للتصحر في هذا النموذج باستخدام نظم المعلومات الجغرافية من خلال دمج البيانات المكانية لخصائص التربة والغطاء النباتي والمناخ والإدارة والمتحصل عليها من الزيارات الميدانية والتحاليل المعملية ومن ثم ادخالها في قاعدة برنامج ArcGIS10.3 لاستنباط خريطة حساسية التصحر. تم الاستعانة بهذه الخريطة من قبل الجهات المعنية ومتخذي القرار لاقتراح قائمة بالتدخلات التي قد تساهم في التخفيف من مشاكل التصحر في المنطقة وبالتالي ضمان الاستخدام المستدام لها. اشارت النتائج إلى أن الحساسية للتصحر في منطقة غرب الدلتا موزعة بواقع 88٪ متوسطة الحساسية (أي 3،405.69 كم)، بينما تمثل المناطق ذات الحساسية العالية للتصحر 12٪ من المساحة الكلية (أي 462.68 كم). كما أوضحت النتائج أن انخفاض هطول الأمطار وخصائص التربة السيئة العامل المحدد في المناطق شديدة الحساسية للتصحر في غرب الدلتا.

الكلمات الاسترشادية: