Use of GIS and Remote Sensing for Environmental Sensitivity Assessment of North Coastal Part, Egypt.

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Abstract: Desertification is considered as an important problem facing arid and semi-arid regions, as Egypt. These processes are resulted either from human activities or adverse natural conditions. However, the combination of both is often applicable. The aim of this study is the identification of areas sensitive to desertification in the north coast of Egypt. Based on the MEDALUS approach and the characteristics of the study area regional model developed using GIS. Three main indicators of desertification, including: soil, vegetation and climate were considered. The several sub-indicators affecting the quality of each main indicator were identified. Based on the MEDALUS approach, each sub-indicator was quantified according to its quality and given a weighting of between 1 and 2. Arc-GIS 9.2 was used to analyze and prepare the layers of quality maps using the geometric mean to integrate the individual sub-indicator. ETM and SRTM satellite images, geologic and soil maps were used as main sources for calculating the Environmental Sensitivity Areas Index (ESAI) for desertification. The results show that the soil of the north coast is characterized mainly by high sensitive areas for desertification (44.01 % of the total area), distributed mostly in the north western coast and the northern part of Sinai, where the soil quality, climatic quality and vegetation quality are low, while, 9.37 % of the total area exhibit are sensitive. The areas of moderate sensitive to desertification revealed in the studied area, representing an area of 3834.577 Km2 (11.04 %) of the total area. The low sensitivity areas for desertification exhibit the whole area of the Nile Delta, as they represent 27.17 % of the total area (i.e. 9434.928 Km2). The low sensitivity for desertification is due to the good vegetation cover and soil quality. It can be concluded that implementing the maps of sensitivity to desertification is rather useful in the arid and semi arid areas as they give a more likely quantitative trend for frequency of sensitive areas. The integration of different factors contributing to desertification sensitivity may lead to plan a successful combating. The usage of space data and GIS proved to be suitable tools to rely on estimation and to fulfill the needed large computational requirements. They are also useful in visualizing the sensitivity situation of different desertification parameters.
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1. Introduction:

Desertification is defined in the first art of the convention to combat desertification as "land degradation in arid, semiarid and dry sub-humid areas resulting from climatic variations and human activities". Its consequence includes a set of important processes, which are active in arid and semi arid environment, where water is the main limiting factor of land use performance in such an ecosystem (UNEP, 1992). Desertification sensitivity can be defined, in this context, as the response of the environment, or part of it, to a change in one or more external factors (Batterbury and Warren, 2001). Environmental systems are generally in a state of dynamic equilibrium with external driving forces. Small changes in the driving forces, such as climate or imposed land use tend to be accommodated partially by a small change in the equilibrium and partially by being absorbed or buffered by the system (Tucker et al. 1991). Desertification of an area will proceed if certain land components are brought beyond the specific threshold, beyond which further change produces irreversible changes (Nicholson et al. 1998).

The MEDALUS method (Kosmas et al. 1999) identifies regions that are an environmentally sensitive area (ESAs). In this model, different types of 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 weighting factor is assigned to each class. Then four layers are evaluated soil quality, and management quality. After determined indices for each layer, the ESAs to desertification are defined by combining the four quality layer. All the data defining the four main layers are introduced in a regional geographical information system (GIS), and overlain in accordance with the developed algorithm which takes the geometric mean to compile maps of ESAs to desertification.

In order to implement the UNCCD (United Nation Convention to Combat Desertification, 1996) plane, it requires reliable and up-to-date information. Not only the real-time information, but also, the analysis and technical methodologies that integrate this information to generate environmental, soil, water geo-spatial database together with environmental sensitivity maps. In this context, the Egyptian government prepared the national action plane (NAP) in 2005 in order to identify the sensitive area to desertification. It was possible to subdivide the territory into four geographical areas on a basis of environmental farm Agro Ecological Zones characterized. Each of the Agro ecological Zones is characterized by specific environmental conditions. The Agro-ecological regions include the following;

1.**North Coastal Zone**
2.Nile Valley and Delta
3.The Inland Sinai and Eastern Desert
4.The Western Desert

The main aim was the assessment of most important factors affecting desertification in the study area (north coastal zone) by modifying MEDALUS system.

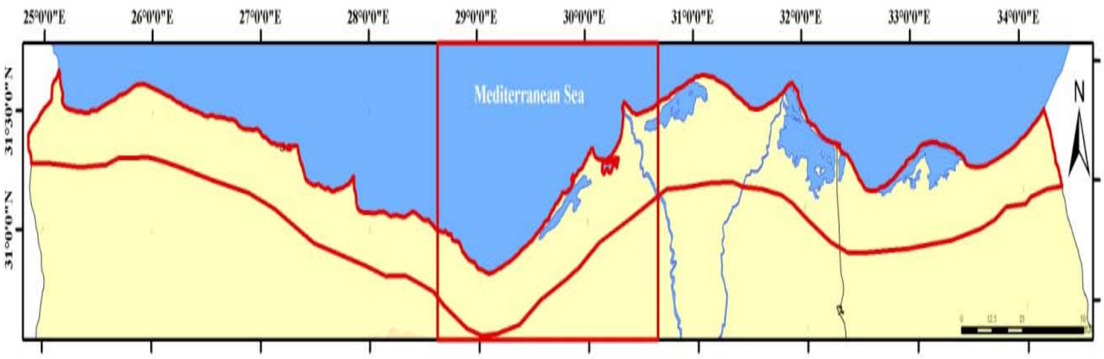

Figure (1). The area of study

2. Materials and methods

2.1. Study area

The study area represents the northern coastal zone of Egypt in a buffer zone of 20 Km from the coast line with the Mediterranean Sea. It extends from Rafah in the east on the border with Palestine to Al-Saloum in the west on the border with Libya (Figure, 1), representing an area of 32242.43 km^2. The mean annual temperature of the representative metrological stations (19 stations distributed in the whole area) reaches its maximum during July and August, then decreases gradually to their minimum in December and January, enjoys a typical Mediterranean climate, being strongly influenced by the presence of the sea. The rainy season starts in October to January are the rainiest months, and the dry season extends for seven months. The study area is suffering mostly from high to moderate relative humidity. The maximum relative humidity occurs at July and August. Different investigations indicate that the wind speed, at an altitude of 10 meters, range between 3.8 to 5.2 m/sec. The prevailing wind is mostly from the north however, 25% of windy day record southerly dusty warm storms. The later harm cultivation and causes soil water loss through its influence on increasing evapo-transpiration.

2.2. Methods

This study is based on multi concept data, thus the materials of different nature such as satellite data, thematic maps, ground truth geography and topographic data were used. Hybrid classification of ETM Landsat image (figure, 2) was the main mapping tools. Image analysis was made accordance with field observation. A number of 162 soil profiles representing the mapping units were studied. The soil sample was collected, analysed and classified to the level of the sub-great group according to (USDA, 2004). Arc-GIS, version 9.2 has been used as the main GIS software for producing geo-referenced maps.

This study used spatial analyses in a Geographic Information System (GIS) to assess and map the environmental sensitivity to desertification in the north coastal zone of Egypt depending upon the soils, climate, vegetation and management quality indices. Concerning the data required for estimating the Environmental Sensitivity to desertification, the indices of soils, vegetation, climate and management were computed. The main input data for calculating these indices include land surveying and laboratory analyses, Landsat ETM+ image (path 177 / row 39), Digital Elevation Model (DEM), climatic data and geological map of the studied areas (CONOCO, 1989).The satellite images were processed using the ERDAS IMAGINE 8.3 system. Different enhancement and classification techniques were tried to specify the optimal ones for the study purposes. Computational and map editing functions were performed using Arc-GIS 9.2 to find out the environmental sensitivity areas (ESA's) (figure, 3).

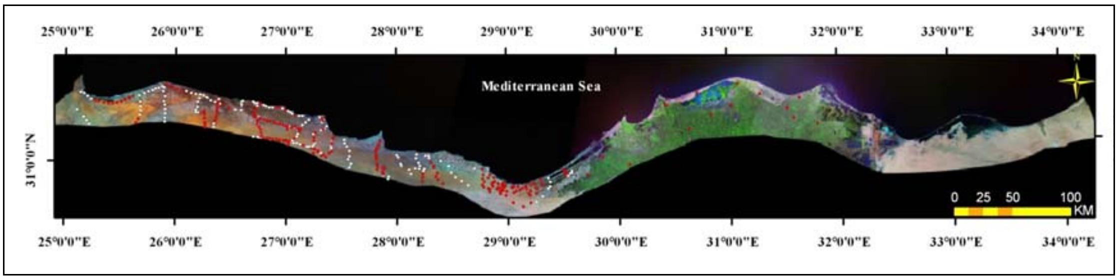

Figure (2) Location of the observation points plotted over Landsat satellite image

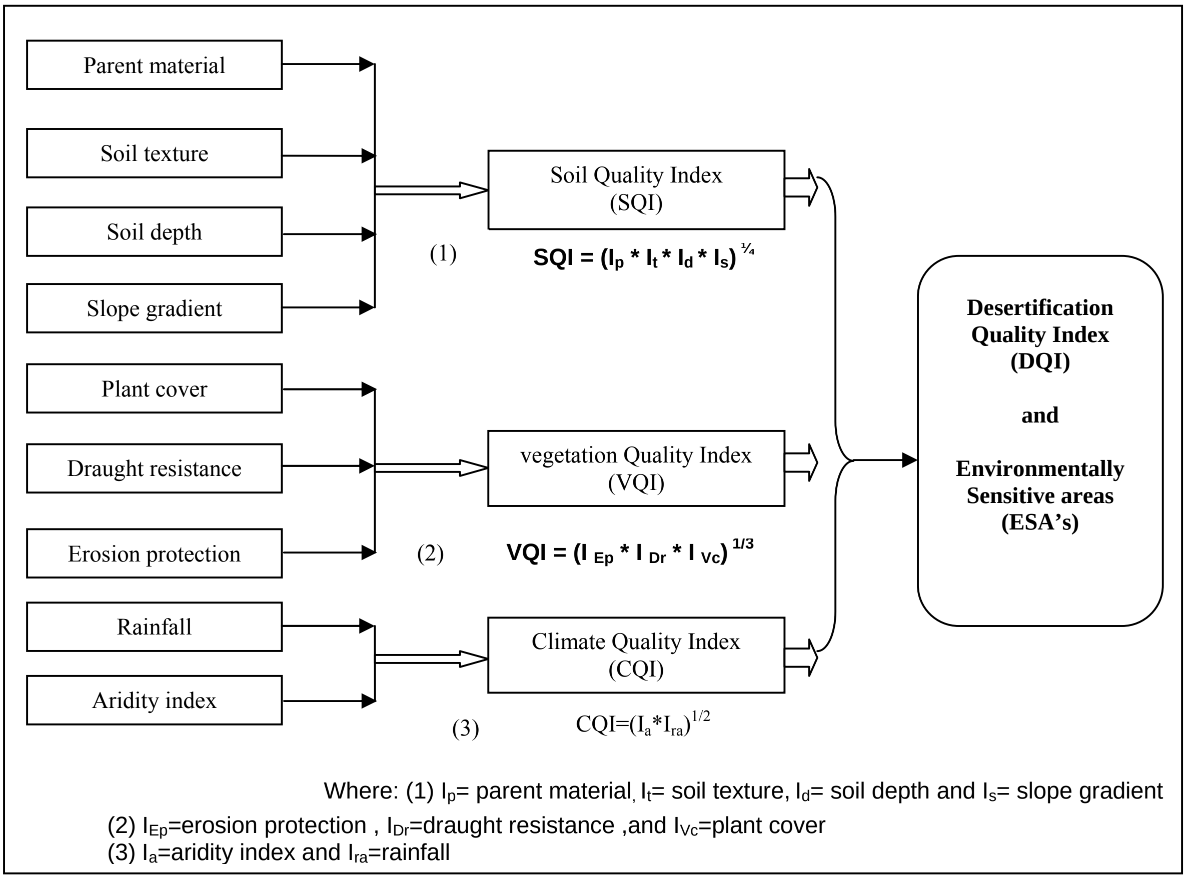

Figure (3) Flow chart of mapping Environmentally Sensitive Areas (ESA's)

The hypotheses used by the MEDALUS model for the identification of sensitive areas derive from research and field experiments activities. The model applies a geometrical average of the quality indices used in order to provide sensitivity diagnosis. The model implicitly assumes that each of the indices taken individually has only a limited capacity to influence the final value of the ESAs index and that only when several parameters have a high score, an area can be assigned to a high sensitivity class (Kosmas et al. 1999). The quality indices used for assessing the desertification sensitivity were calculated and displayed as GIS ready maps from which class areas were deduced, and then the Desertification Sensitivity Index (DSI) was calculated in the polygonal attribute tables linked with the geographic coverage using the spatial analyst tool in Arc GIS 9.2 software.

2.2.1. Mapping Soil Quality Index (SQI)

Soil is the dominant factor of the terrestrial ecosystems in the arid and semi arid and dry zones, particularly through its effect on biomass production (Basso et al, 1998). Four soil parameters, related to water availability and erosion resistance, were considered (I.e. parent material, soil texture, soil depth and slope gradient) following Medalu's project methodology (European Commission, 1999). Weighting factors were assigned to each category of the considered parameters, based on (Gad and Lotfy, 2007). The soil Quality Index (SQI) was computed based on the following equation:

$$SQI = (I_p * I_t * I_d * I_s)^{1/4}$$

Where Ip index of parent material, It indexed of soil texture, Id index of soil depth, Is indexed of the slope gradient). (Tables, 1 to 4) demonstrate the assigned indexes for different categories of each parameter. The soil Quality Index (SQI) was calculated based on the following equation, and classified according to categories shown in (table, 5).

Table (1) Classes and assigned weighting index for parent material

Class	Description	Score
Coherent: Limestone, dolomite, non-friable sandstone, hard limestone layer.	Good	1.0
Moderately coherent: Marine limestone, friable sandstone	Moderate	1.5
Soft to friable: Calcareous clay, clay, sandy formation, alluvium and colluvium	Poor	2

Table (2) Classes and assigned weighting index for soil depth

Class	Description	Score
Very deep	Soil thickness is more than 1 meter	1
Moderately deep	Soil thickness ranges from <1m to 0.5 m	1.33
Not deep	Soil thickness ranges from <0.5m to 0.25 m	1.66
Very thin	Soil thickness 0.15 m	2.00

Table (3) Classes and assigned weighting index for soil texture

Texture Classes	Description	Score	
		Areas dominated by water erosion	**Areas dominated by wind erosion**
Not very light to average	Loamy sand, Sandy loam, Balanced	1	1
Fine to average	Loamy clay, Clayey sand, Sandy clay	1.33	1.66
Fine	Clayey, Clay loam	1.66	2
Coarse	Sandy to very Sandy	2	2

Table (4) Classes and assigned weighting index for Slope gradient

Classes	Description	Score
< 6%	Gentle	1
6 – 18 %	Not very gentle	1.33
19 – 35 %	Abrupt	1.66
> 35 %	Very abrupt	2

Table (5) Classification of soil quality index

Class	Description	Range
1	High quality	>1.13
2	Moderate quality	1.13 to 1.45
3	Low quality	> 1.46

2.2.2. Mapping Vegetation quality index (VQI)

Vegetation quality was evaluated according to (Basso et al 2000) in terms of three aspects (i.e. erosion protection to the soils, drought resistance and plant cover) (table, 6). The mosaiced landsat satellite image (Fig. 2) is the main material used to map vegetation and plant cover classes. Rating values for erosion protection, drought resistance and vegetal cover classes were adapted based on (OSS, 2004). Vegetation Quality Index was calculated according to the following equation, while VQI was classified based on the ranges indicated in the (European Commission, 1999) (table, 7).

$$VQI = (I_{Ep} * I_{Dr} * I_{Vc})^{1/3}$$

Where: I_{Ep} index of erosion protection, I_{Dr} index of drought resistance and I_{Vc} index of vegetation cover).

c) Mapping Climatic quality index (CQI)

Climatic quality is assessed by using parameters that influence water availability to plants such as the amount of rainfall, air temperature and aridity, as well as climate hazards, which might inhibit plant growth (Thornes, 1995). Table (8) reveals the classification categories of climatic quality index according to (OSS, 2004). The Climate quality index is evaluated through the Aridity Index (AI), using the methodology developed by FMA in accordance with the following formula. In the current study, rainfall and evapotranspiration data on a number of 19 metrological stations were used to calculate the CSI as follows;

$$CQI = P/PET$$

Where: P is average annual precipitation, and ETP is average annual Potential Evapotranspiration.

2.2.3 Mapping Environmentally Sensitive Areas (ESA's) to Desertification

ArcGIS9 software was used to map ESA's to Desertification (Kosmas et al, 1999) by integrating all data concerning the soil and vegetation. Different quality indices were calculated and displayed as GIS ready maps from which class areas were deduced. The Desertification Sensitivity Index (DSI) was computed in the polygonal attribute tables linked with the geographic coverage based on the following equation;

$$DSI = (SQI * VQI * CQI)^{1/3}$$

Classification of (DSI) was done according to the values of Medalus project Mediterranean desertification and land use Manual (table, 9) (European Commission, 1999).

Table (6) Classes and assigned weighting index for different vegetation parameters

Class	Description	I_{Ep}	I_{Dr}	I_{Vc}
1	Perennial cultivation	1	1	1
2	Halophytes	1.33	1	1.33
3	Temporal and orchards, mixed with crop land	1.66	1.33	1.66
4	Saharan vegetation < 40%	2	1.66	1
5	Saharan vegetation > 40%	2	1	1

Table (7) Classification of vegetation quality index (VQI)

Class	Description	Range
1	Good	< 1.2
2	Average	1.2 to 1.4
3	Weak	1.4 to 1.6
4	Very weak	> 1.6

Table (8) Classification of Climatic quality index (CQI)

Class number	Climatic zone	P/PET	CQI
1	Hyper-Arid	< 0.05	2
2	Arid	0.05 – 2.0	1.75
3	Semi-Arid	0.20 – 0.50	1.50
4	Dry Sub-Humid	0.50 – 0.65	1.25
5	Humid	> 0.65	1

Table (9) Ranges and classes of desertification sensitivity index (DSI)

Classes	DSI	Description
1	> 1.2	Non affected areas or very low sensitive areas to desertification
2	1.2 < DSI < 1.3	Low sensitive areas to desertification
3	1.3 < DSI <1.4	Medium sensitive areas to desertification
4	1.3 > DSI <1.6	Sensitive areas to desertification
5	DSI > 1.6	Very sensitive areas to desertification

3. Results and Discussion:

The environmental sensitivity area to desertification is a complex concept to rationalize since, depending on the context. It can be caused by many different factors operating in isolation or in association (Rubio, 1995, Thornes, 1995, UNEP, 1992 and Basso et. al., 2000). ESAs can be considered, in general, as a specific and delimited entity in which environmental and socio-economical factors are not balanced or are not sustainable for that particular environment. The various types of ESA's to desertification can be distinguished and mapped by using certain key indicators for assessing the land capability to withstand further degradation, or the land suitability for supporting specific types of land use. The key indicators for defining ESA's to desertification, which can be used at a regional or national level, can be divided into four broad categories defining the qualities of soil, climate, vegetation, and land management (Kosmas et. al. 1999). The Environmental Sensitivity Index (ESI) to desertification of an area can also 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 (Basso et. al. 1998). Severe, irreversible environmental degradation phenomena could be resulted from a combination of poor management quality together with various combinations of critical environmental factors (soil, climate, and vegetation).

3.1 Soil Quality Index (SQI)

Soil is an essential factor in evaluating the environmental sensitivity of an ecosystem, especially in the arid and semi-arid zones. Soil properties related to desertification phenomena affect the water storage and retention capacity and erosion resistance.

3.1.1. Parent material

Parent material is considered a very important factor for determining the susceptibility to desertification. (Table, 10 and Figure, 4) represent the types, scores and areas of the parent materials of the northern coast of Egypt. The results show that 61.79 % of the study area (21454.32 Km^2) originated from coherent parent material. It dominates the eastern and western part of the study area. This type of parent material is the least susceptible to desertification and takes a score of 1.00 on the desertification sensitivity index. The moderately coherent parent material such as marine limestone and friable sandstone covers 3852.66 Km^2 representing 11.1 % of the study area. This type of parent material is moderately susceptible to desertification, and it takes a score of 1.5 on the desertification sensitivity index. The soils originated from soft to friable covers 27.12% (9415.03 Km^2). It dominates the northern part of Nile delta of the study area. This type of parent material is the most susceptible to desertification and takes a score of 2.00 on the desertification sensitivity index.

Table (10) Types and scores of the parent materials in the studied area

Type	**score**	**Area Km^2**	**Area %**
Coherent: Limestone, dolomite, non-friable sandstone, hard limestone layer	1.00	21454.32	61.79
Moderately coherent: Marine limestone, friable sandstone	1.50	3852.66	11.10
Soft to friable: Calcareous clay, clay, sandy formation, alluvium and colluvium	2.00	9415.03	27.12
Total		**34722.01**	**100.00**

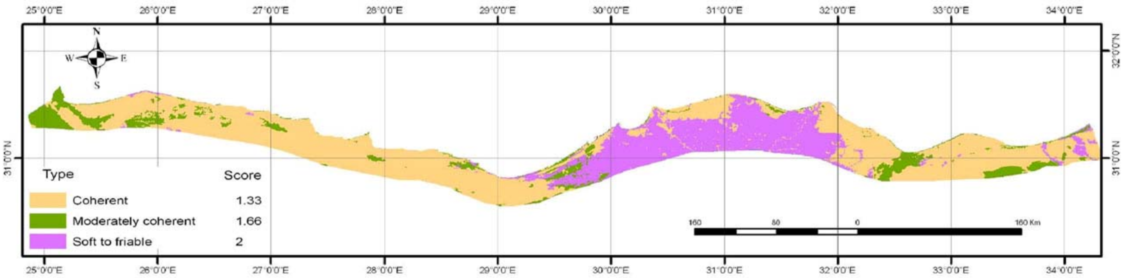

Figure (4) soil parent types and scores of the north coast of Egypt

3.1.2. Soil depth

Soil depth is a very important factor for determining the susceptibility to desertification, the deeper the soil the lesser sensitive to desertification and vice versa. As illustrated in (table, 11 and figure, 5) the very deep soil covers an area of 15295.11Km^2 representing 44.05 % of the total area. It dominates in the eastern and western part of the study area and represented by a score of 1.00 on the desertification sensitivity index. The moderately deep soil covers 27.12 % (9415.03Km^2) of the study area. This class dominates in the northern Nile delta part of the study area. The moderately deep soil takes a score of 1.33 on the desertification sensitivity index. Not deep soil is more susceptible to desertification than very deep and moderately deep soils. It covers an area of 3679.62 Km^2, representing 10.60 % of the study area. It is located in eastern Sinai and the most western part of the study area. The not deep soil takes a score of 1.66 on the desertification sensitivity index. The very thin soil is the most susceptible to desertification. It covers 11.10 % (3852.66 Km^2) of the study area. It is located in western Sinai, western Nile delta and western most part of the study area. The very thin soil takes a score of 2.00 on the desertification sensitivity index.

Table (11) distribution of soil depth classes and assigned scores in the studied area

Type	**score**	**Area Km^2**	**Area %**
Water bodies and urban	0.00	2479.58	7.14
Very deep	1.00	15295.11	44.05
Moderately deep	1.33	9415.03	27.12
Not deep	1.66	3679.62	10.60
Very thin	2.00	3852.66	11.10
Total		**34722.01**	**100.00**

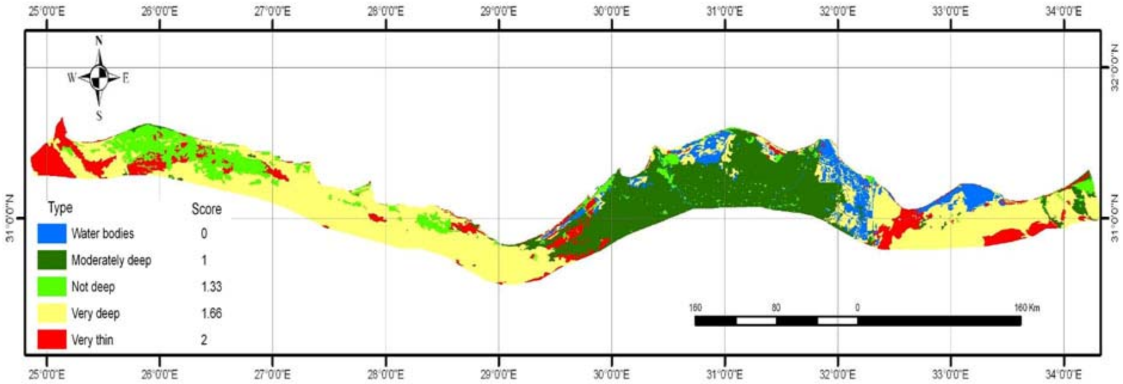

Figure (5) soil depth classes and scores of the northwestern coast of Egypt

3.1.3. Soil texture

Soil texture is a very important factor for determining the susceptibility to desertification, (table, 12 and figure, 6) represents the types, scores and areas of the soil texture the north coast of Egypt.

The soil is divided into four classes according to its texture not very light to average is least susceptible to desertification. It represents 21.29 % of the north coast of Egypt, and it covers an area of 7393.43Km^2. It dominates Nile delta part of the study area. It takes a score of 1.00 on the desertification sensitivity index. While, 20.48% (7111.32 Km^2) of the studied area is moderately susceptible to desertification, which classified as Fine to average soil texture. It dominates the northern Nile delta part of the study area and takes a score of 1.33 on the desertification sensitivity index. Nevertheless, the fine soil texture covers 27.12 % (9415.03Km^2) of the studied area. It is located in the north western part of Sinai and takes a score of 1.66 on the desertification sensitivity index. The rest of the studied area is classified as coarse soil texture, which is the most susceptible to desertification. It covers 23.97 % of the study area (8322.65 Km^2). It is located in the eastern Sinai and western coast of the study area and takes a score of 2.00 on the desertification sensitivity index.

Table (12) Distribution of soil texture classes and assigned scores in the studied area

Type	**score**	**Area Km2**	**Area %**
Water bodies and urban	0.00	2479.58	7.14
Not very light to average	1.00	7393.43	21.29
Fine to average	1.33	7111.32	20.48
Fine	1.66	9415.03	27.12
Coarse	2.00	8322.65	23.97
Total		**34722.01**	**100.00**

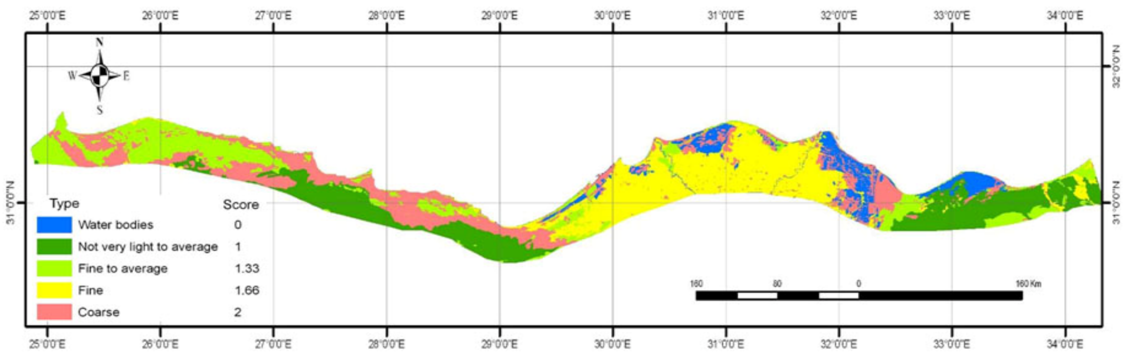

Figure (6) soil texture classes and scores of the northwestern coast of Egypt

3.1.4. Surface slope

Soil surface slope is very important factor for determining the susceptibility to desertification, (table 13 and figure, 7). The soil surface slope is divided into three classes. The Gently slope soil with surface slope of less than 6 % which is the least susceptible to desertification. It represents 27.12 % (9415.03.11Km^2) of the studied area. It dominates in the Nile delta part of the studied area and takes a score of 1.00 on the desertification sensitivity index. While, the majority 43.24 % of the studied area slope is located in the Gently undulating class where surface slope between 6 and 18 % which is moderately susceptible to desertification. It dominates the northern western coastal part and takes a score of 1.33 on the desertification sensitivity index. The rest of the studied area is classified as undulating soil with surface slope between 19 and 35 % which is the most susceptible to desertification. It covers 21.29 % of the study area covers 7393.43 Km^2. It is located in the western part of Sinai and eastern part of the northwestern coastal part and takes a score of 1.66 on the desertification sensitivity index.

Table (13) Distribution of slope classes and assigned scores in the studied area

Type	score	Area Km^2	Area %
Water bodies and urban	0.00	2900.54	8.35
< 6%	1.00	9415.03	27.12
6 – 18 %	1.33	15013.00	43.24
19 – 35 %	1.66	7393.43	21.29
Total		**34722.01**	**100.00**

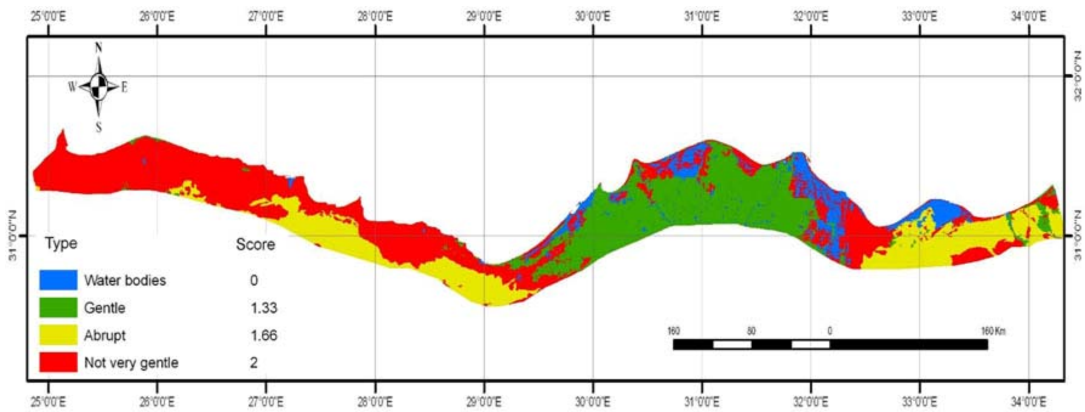

Figure (7) Surface slope classes and scores of the northwestern coast of Egypt

3.1.5. Soil Quality index

The soil quality index (SQI) was evaluated depend upon the drainage condition, rock fragments (%) slope gradient (%), soil texture class, soil depth (cm) and the parent material (Figure, 8 and table, 14). The layer of soil quality index of the studied area, indicate that the areas of high soil quality index (value <1.13) is found in large areas especially in the north western coast as it dominates an area of 14982.47 km^2 i.e. 43.15 % of the total area. The areas of moderate quality index (value = 1.13 – 1.45) represents 27.17% of the total area i.e. 9434.93Km^2 as it found mainly in the north coast of the Nile Delta. The areas of low soil quality index (value >1.45) represents 21.27 % of the total area i.e. 7386.66Km^2, it found mainly in the north coast of Sinai. The low soil quality dominates the areas which characterized by sandy texture, shallow depth and poor drainage soils.

Table (14) Soil Quality Index of the northwestern coast of Egypt

Class	Score	Description	Area%	Area Km^2
0	0	Water bodies and urban areas	8.40	2917.95
1	>1.13	High quality	43.15	14982.47
2	1.13 to 1.45	Moderate quality	27.17	9434.93
3	> 1.46	Low quality	21.27	7386.66
Total			**100**	**34722.01**

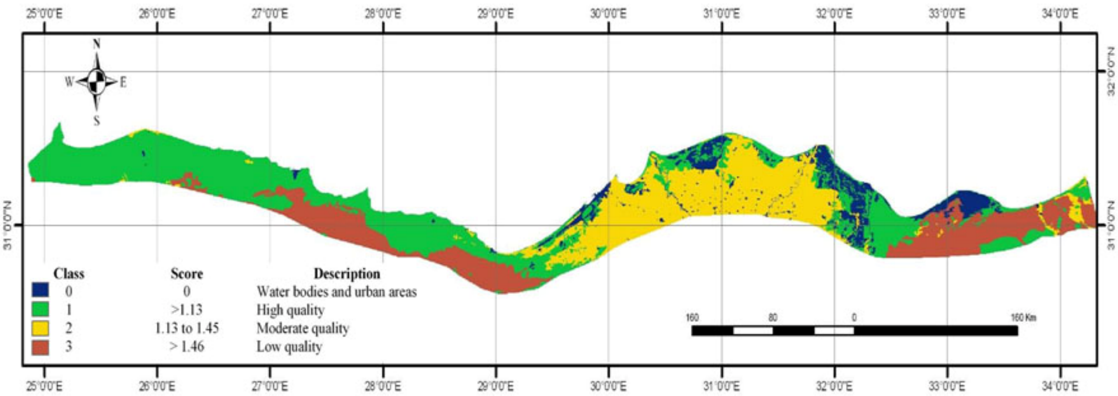

Figure (8) Soil Quality Index of the northwestern coast of Egypt

3.2. Vegetation Quality layers

The ETM satellite images were classified, and field validation was performed to convert the unsupervised classes to vegetation type. Different vegetation types were given score values evaluating vegetation cover type, erosion protection and drought resistance, and hence calculating the vegetation quality index (VQI).

3.2.1. Plant cover

Vegetation cover plays an important role in mitigating the effects of desertification and land degradation phenomena. The percentage of vegetation is a function of both man-made agriculture and natural vegetation coverage. The percentage of vegetation cover is a necessary input in a multi-criteria model to assess the vegetation quality index.

Hyperid classification of ETM images resulted in identifying a number of four vegetation classes. Each of these classes was given a score evaluating vegetation cover, erosion protection and drought resistance (Figure, 9 and table, 15).

Table (15) List of the vegetation covers categories and their area percentage

Vegetation cover %	Value	Area Km^2	Area %
Water bodies and urban areas	0.00	2900.54	8.35
Vegetation cover > 40%	1.00	9415.03	27.12
Vegetation cover (40 – 30 %)	1.33	3852.66	11.10
Vegetation cover (30 – 10%)	1.66	3258.66	9.39
Vegetation cover <10%	2.00	15295.11	44.05
Total		**34722.00**	**100.00**

As illustrated in (table, 15) 44.05% of the vegetation cover is very weak and sensitive to desertification. This category is distributed along the whole study area with higher concentration in the western section (northwestern part). Whilst, distributed as a few scattered areas in the middle section (northern Nile delta region) particularly in the sand dune areas and sabkhas. Nevertheless, the dense vegetation cover > 40% is representing a small area of 9415.03 km^2 (8.35%). This category occupies most of the middle section (northern part of the Nile Delta region) while it represents a minor area in the western section (northern western desert) and occupies a very minor area in the eastern section (northern Sinai). The rest of the study area has vegetation cover between 40 and 10%, distributed in the whole study area.

Table (16) Vegetation resistance to drought

Type	Value	Area km^2	Area %	Drought Resistance
Water bodies and urban areas	0.00	2900.54	8.35	
Evergreen trees; Bedrocks; Bare soils	1.00	13267.69	38.21	Very high
Orchards; Deciduous trees	1.33	3258.66	9.39	High
Shrubs	1.66	7901.68	22.76	Moderate
Annual crops; Very low vegetated	2.00	7393.43	21.29	Low
Total		**34722.01**	**100.00**	

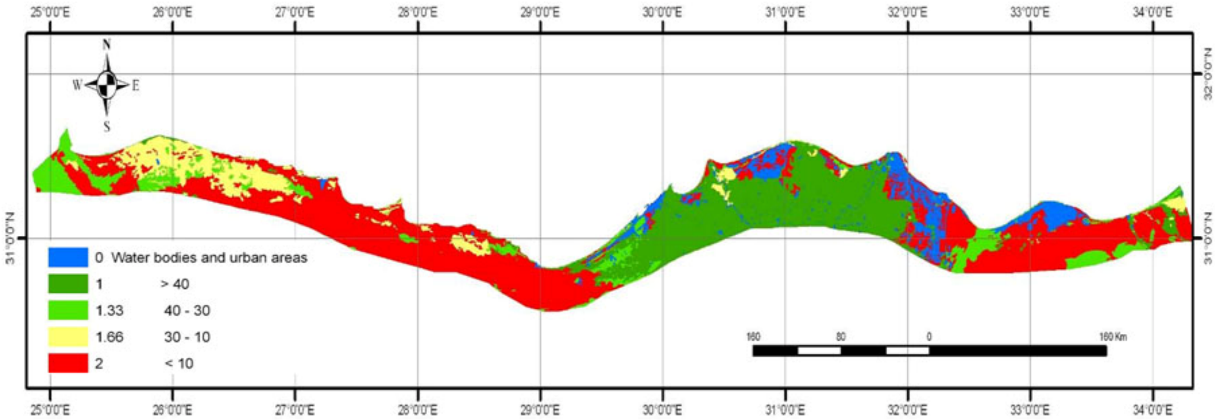

Figure (9) vegetation cover percentage of the northwestern coast of Egypt

3.2.2. Vegetation drought resistance

According to the universal standard classification for the susceptibility of vegetated land to drought and therefore its resistance, the study area in reflection to vegetation cover classified into five categories of drought resistance (Figure,10 and Table, 16).

Evergreen trees, bedrocks and bare soils; this category represents a significant area of about 38% of the study area. This category shows very high vegetation drought resistance with value of 1.0. It occupies most of the middle section (northern part of the Nile Delta region) and some areas in the western section (northern western coast). There are some scattered areas in the eastern section (northern Sinai) particularly the area of El-Tina plain and Wadi Al-Arish. Orchards and deciduous trees; this category occupies just 9% of the study area which is distributed in all the study area. This category shows high drought resistance with value of 1.33. The majority of this category is located in the western section (northern western desert) and few areas in the middle section around Lake El-Borouls and few areas near Rafah on the eastern border with Palestine. Shrubs; this category represents about 23% of the study area with moderate drought resistance of value of 1.66. The majority of this category occupies the western section (northern western desert). There are some areas of this category in the middle section around the coastal lagoons of Lake Manzala and lake Borouls. However, in the eastern section (northern Sinai) El-Tina plain and east of Suez Canal shows this moderate of drought resistance category. Annual crops and very low vegetated land; this category is the lowest category of drought resistance and it occupies 21% of the study area. This category is distributed in both the eastern and western sections (i.e. northern Sinai and north western desert). The terrain and geomorphological landforms in these two sections are the key constrains of this category to be low drought resistance.

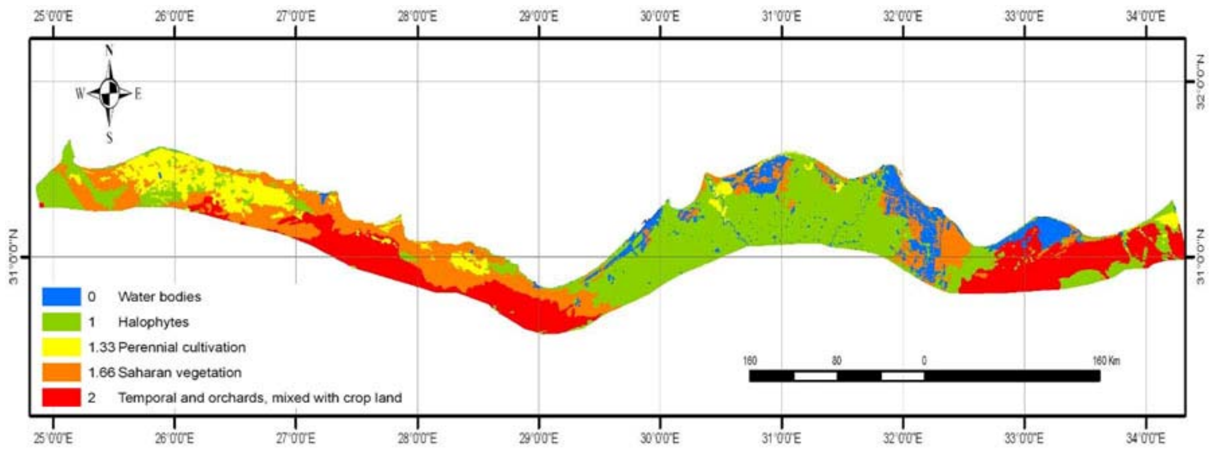

Figure (10) vegetation resistant to drought in the north coast of Egypt

3.2.3. Vegetation erosion protection

Vegetation erosion resistance shows how much land, and its vegetation cover is resistant to erosion. The study area in reflection to the vegetation cover shows five categories of erosion resistance (Figure, 11 and Table 17).

Evergreen trees and bedrocks; this category represents a significant area of about 27% of the study area. This category shows very high vegetation erosion resistance with value of 1.0. It occupies most of the middle section (northern part of the Nile Delta region) and some areas in the western section (northern western desert) particularly the area close to the border. There are some scattered areas in the eastern section (northern Sinai) particularly the area of El-Tina plain and Wadi Al-Arish. Shrubs; this category occupies just 11% of the study area which is distributed in all the study area. This category shows high erosion resistance with value of 1.33 which located in the eastern section (northern Sinai) and western section (northern western desert). There are minor areas in the middle section around Lake El-Borouls and in the area west Gamasa. Annual crops; this category represents about 9% of the study area with moderate drought resistance of value of 1.66. The majority of this category occupies the western section (northern western desert) and as some patches in the eastern section (northern Sinai) close to Rafah. Bare soils; this category is the lowest category of erosion resistance, and it occupies 44% of the study area. This category occupies most of the eastern and western sections (i.e. northern Sinai and north western desert). The terrain and geomorphological landforms in these two sections are the key constrains of this category to be low erosion resistance. There are a few scattered areas in the middle section (northern Nile Delta region) particularly, in the sand sheets and sand dune areas.

Table (17) erosion resistance of each vegetation category

Type	Value	Area km^2	Area %	Erosion resistance
Water bodies and urban areas	0.00	2900.54	8.35	
Evergreen trees; Bedrocks	1.00	9415.03	27.12	Very high
Shrubs	1.33	3852.66	11.10	High
Annual crops	1.66	3258.66	9.39	Moderate
Bare soils	2.00	15295.11	44.05	Low
Total		**34722.01**	**100.00**	

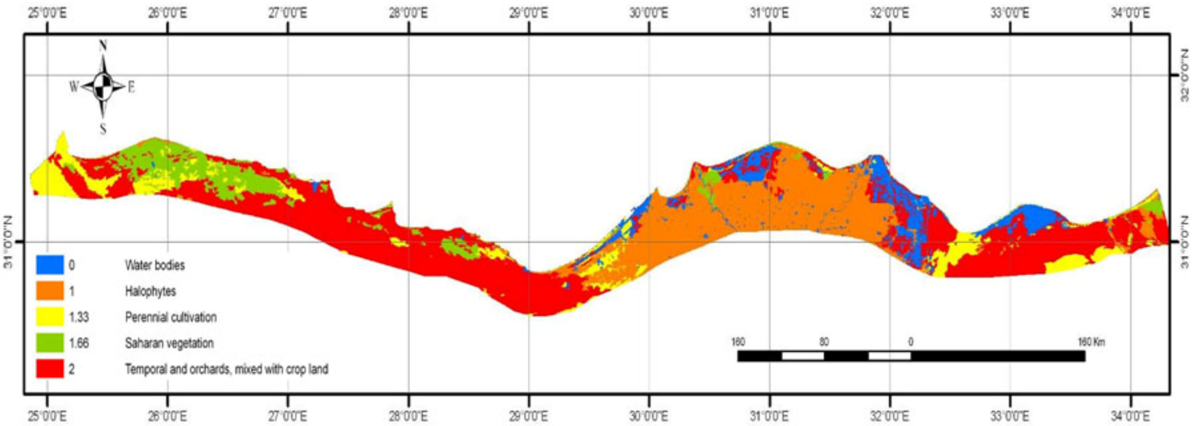

Figure (11) vegetation erosion protection in the north coast of Egypt

3.2.4. Vegetation Quality index

The plant cover (%), erosion protection, and drought resistance parameters were used for assessing the vegetation quality index (VQI). As illustrated in (figure, 12 and table, 18) the areas of low vegetation quality (Value <1.20) dominate creation parts near the northern lakes, it represents 8.40 % of the total area (i.e. 2917.95 Km^2), the moderate vegetation quality index (Value 1.2 – 1.4) dominates the north parts of the Nile Delta, it represents 27.17 % of the total area (i.e. 9434.93 Km^2). The weak (Value 1.4 – 1.6) and very weak sensitive vegetation index (Value >1.60) dominates the rest of the coast representing 11.04 and 52.38 % of the total area (i.e. 3834.58 and 18534.56 Km^2 respectively). The low vegetation index is due to the low density of plant cover.

Table (18) Vegetation Quality Index of the studied area

Class	Score	Description	Area %	Area Km^2
1	< 1.2	Good	8.40	2917.95
2	1.2 to 1.4	Average	27.17	9434.93
3	1.4 to 1.6	Weak	11.04	3834.58
4	> 1.6	Very weak	53.38	18534.56
Total			**100**	**34722.01**

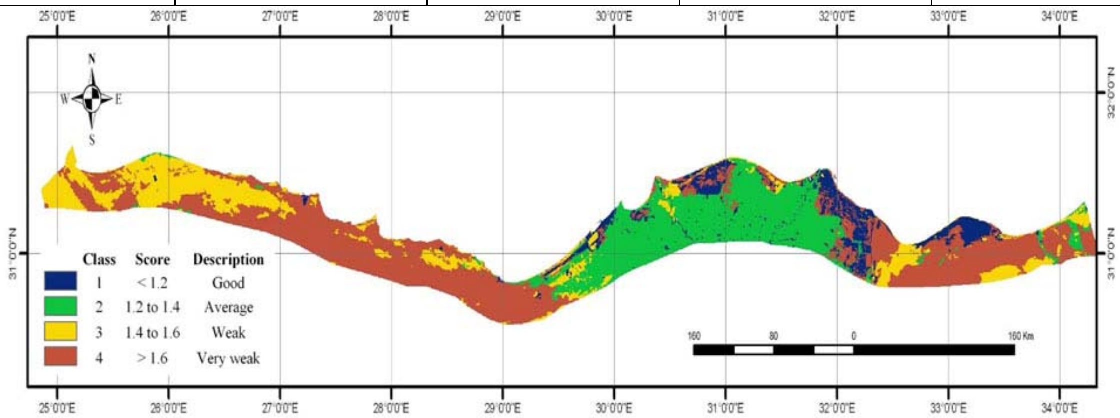

Figure (12) Vegetation Quality Index of the north coast of Egypt

3.2.5. Climatic Quality Index

Climate quality index (CQI) is assessed depend upon the amount of rainfall, aridity and slope aspect parameters. The amount of rainfall and aridity are the same in the studied area, but the microclimate is differ from place to another depend on the surface slope and slope aspect. The digital elevation model (DEM) of the depression was established and used for extracting the slope and aspect. The climatic quality index layer of the area refer that the northwestern coast of Egypt is characterized by a low (>1.80) climatic quality index.

3.3. Desertification sensitivity index of the north coast of Egypt

The abovementioned layers (soil, vegetation and climate indices) were driven together to assess the environmentally sensitive areas (ESA's) to desertification, on basis of the calculated desertification sensitivity index (DSI). As revealed from (figure, 13 and table 19) the high sensitive areas for desertification in the area (44.01 % of the total area) are found in north western coast and the northern part of Sinai, where the soil quality, climatic quality and vegetation quality are low.

The sensitive areas are found where the vegetation cover is low, it found in Sidi Barrani and El Salum areas where, the sensitive areas represent 9.37 % of the total studied. The areas of moderate sensitive to desertification, revealed in the studied area, representing an area of 3834.577 Km^2 (11.04 %) of the total area. The low sensitivity areas for desertification exhibit the whole area of the Nile Delta, as they represent 27.17 % of the total area (i.e. 9434.928 Km^2). The low sensitivity for desertification is due to the good vegetation cover and soil quality.

Table (19) Environmentally Sensitive Areas to desertification in the north coast of Egypt

Classes	DSI score	Description	area %	area Km^2
1	> 1.2	Non affected areas or very low sensitive areas to desertification	8.403747	2917.95
2	1.2 < DSI < 1.3	Low sensitive areas to desertification	27.17276	9434.928
3	1.3 < DSI <1.4	Medium sensitive areas to desertification	11.04365	3834.577
4	1.3 > DSI <1.6	Sensitive areas to desertification	9.371228	3253.879
5	DSI > 1.6	Very sensitive areas to desertification	44.00862	15280.68
Total			100	34722.01

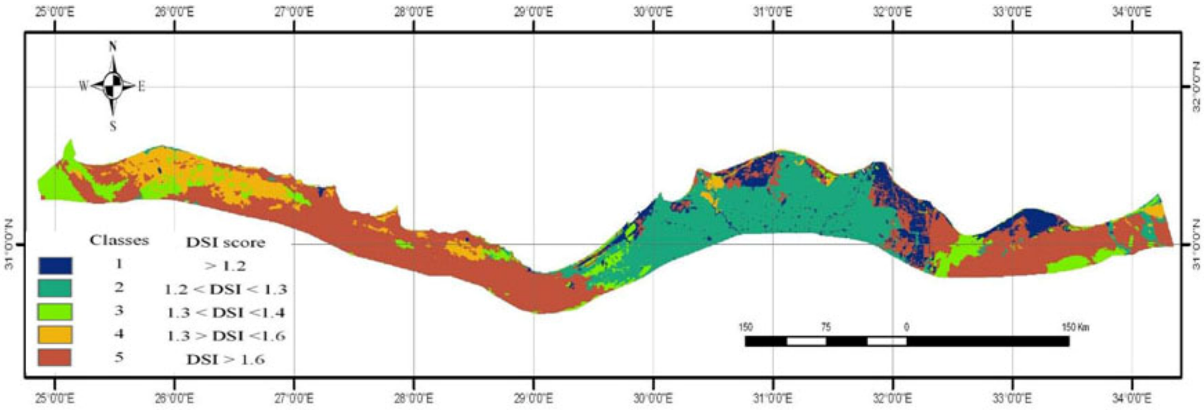

Figure (13) Environmentally Sensitive Areas to desertification in the north coast

4. Conclusions and Recommendations

It can be concluded that the assessment of desertification sensitivity is rather important to plane combating actions and to improve the employment of natural resources. Remote sensing, in addition to thematic maps, may supply valuable information concerning the soil and vegetation quality at the general scale. However, for more detailed scales, conventional field observation would be essential.

Remote sensing, in addition to thematic maps, may supply valuable information concerning the soil and vegetation quality. However, field validation is rather important for reliable information. The Geographic Information System (GIS) is a valuable tool to store, retrieve and manipulate the huge amount of data needed to compute and map different quality indices to desertification.

It can be recommended that mathematical modeling should be developed for the operational monitoring of different elements contributing in desertification sensitivity.

Multi scale mapping of ESA's are needed to point out the risk magnitude and causes of degradation in problematic areas.

The Egyptian north coast is susceptible to very high-to-high desertification sensitivity, however the Nile Valley is moderately sensitive because of its vegetation cover.

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4. References:

1- Basso F., Bellotti A., Bove E., Faretta S., Ferrara A., Mancino G., Pisante M., Quaranta, G., Taberner M., (1998). Degradation processes in the Agri Basin: evaluating environmental sensitivity to desertification at basin scale. Proceedings International Seminar on 'Indicator for Assessing Desertification in the Mediterranean'. Porto Torres, Italy 18 - 20 September. Edited by G. Enne, M. D'Angelo, C. Zanolla. Supported by ANPA via Brancati 48 - 00144 Roma. pp 131-145
2- CONOCO Inc. (1989). Startigraphic Lexicon and explanatory notes to the geological map of Egypt 1- 500,000, eds. Maurice Hermina, Eberhard klitzsch and Franz K. List, pp. 263, Cairo: CONOCO Inc., ISBN 3-927541-09-5.
3- Batterbury, S.P.J. and Warren. A. (2001). Desertification. in N. Smelser & P. Baltes (eds.) International Encyclopædia of the Social and Behavioral Sciences Elsevier Press. Pp. 3526-3529.
4- European Commission (1999). The Medalus project Mediterranean desertification and land use- Manual on key indicators of desertification and mapping environmentally sensitive areas to desertification, pp. 84, Eds. C. kosmas, M. Kirkby and N. Geeson, European environment and climate research program – Theme: Land resources and the threat of desertification and soil erosion in Europe (Project ENV4 CT 95 0119).
5- GAD, A. and LOTFY, I (2007). Combined GIS and Remote Sensing techniques in Mapping Desertification Sensitivity in the North of the Western Desert, Egypt, Paper submited to the Second National GIS Symposium in Saudi Arabia, Al-Khobar, Kingdom of Saudi Arabia, April 23-25, 2007 / Rabi II 6-8, 1428, http://www.saudigis.org/papers.aspx.
6- Kosmas C., Ferrara A., Briasouli H. and Imeson A. (1999). "Methodology for mapping

Environmentally Sensitive Areas (ESAs) to Desertification" Mediterranean desertification and land use (MEDALUS project), European Union 18882. pp:31-47 ISBN 92-828-6349-2.

7- Nicholson, S.E, C.J Tucker, and M.B Ba. (1998). "Desertification, Drought and Surface Vegetation: an example from the West African Sahel." Bulletin of the American Meteorological Society 79 (5): 815-829.

8- OSS (2004). Map of sensitivity to desertification in the Mediterranean basin- Proposal for the methodology for the final map, Rome: Observatory of the Sahara and Sahel (OSS).

9- Rubio, J. L. (1995). Opening conference- Desertification: evolution of concept. In Desertification in a European Commission-DG XIII, Brussel, pp. 5-14.

10- Tucker, C.J, Dregne, H.E, Newcomb WW (1991). "Expansion and Contraction of the Sahara Desert from 1980 to 1990" *Science* 253: 299-301.

11- Thornes J.B. (1995). Mediterranean desertification and the vegetation cover. In EUR 15415 - "Desertification in a European context: Physical and socio-economic aspects", edited by R.Fantechi, D.Peter, P.Balabanis, J.L. Rubio. Brussels, Luxembourg: Office for Official Publications of the European Communities. 169-194

12- UNEP(United Nation Environmental Program) (1992). World atlas of desertification, editorial commentary by N. Middleton and D.S.G. Thomas. Amold: London.

13- USDA, (2004). "Soil Survey Laboratory Methods Manual" Soil Survey Investigation Report No. 42 Version 4.0 November 2004.

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