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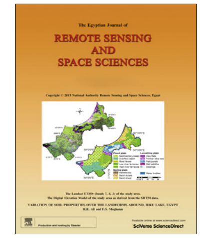

RESEARCH PAPER

Assessment of environmental hazards in the north western coast -Egypt using RS and GIS

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KEYWORDS

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Revised universal soil loss equation (RUSLE);
GIS;
Northern west coast

Abstract Soil erosion, salinity and sodicity hazards are serious problems in the northern west coast of Egypt and lead to reducing the soil quality and increasing the degradation of soil resources. Sidi Barrani and Al-Sallum regions are selected as study areas which are located from a longitude of 25°10′00″ to 26°55′00″East and from a latitude of 31°00′0″ to 31°37′30″ North. Erosion hazard was estimated using the 'Universal Soil Loss Equation' (USLE), which is a simple empirical model that is widely used for assessing long-term annual soil loss .The salinity and sodicity hazards were estimated based on FAO method as standard reference. The resultant map of annual soil erosion shows a maximum soil loss of 60 t h^{-1} y^{-1} with a close relation to foot slopes and wide units on the steep side-slopes (with high LS value) and the erodibility value reached to 0.1 t h^{-1} y^{-1}. Meanwhile sand beaches and sabkha units are characterized by high environmental hazards of both water erosion, salinity and sodicity, while in the overflow basin units are identified as low environmental hazards. The spatial environmental hazards assessment is conducted by using integrated GIS and RS which can serve as effective inputs in deriving strategies for sustainable land use planning and management.

Introduction

Soil erosion is defined as a ‘‘physical process with considerable variation globally in its severity and frequency’’ which is also dependent on various social, economic and political factors besides climatic factors. Soil erosion has become a seriously threatening problem to the agriculture and the natural environment (Pimental, 2009). Soil erosion is a hazard traditionally associated with agriculture in tropical and semi-arid areas and some of the associated problems which include loss of fertile topsoil for agriculture, productivity and sustainable agriculture (Morgan, 2005; Onyando et al., 2005). Salinity is one of

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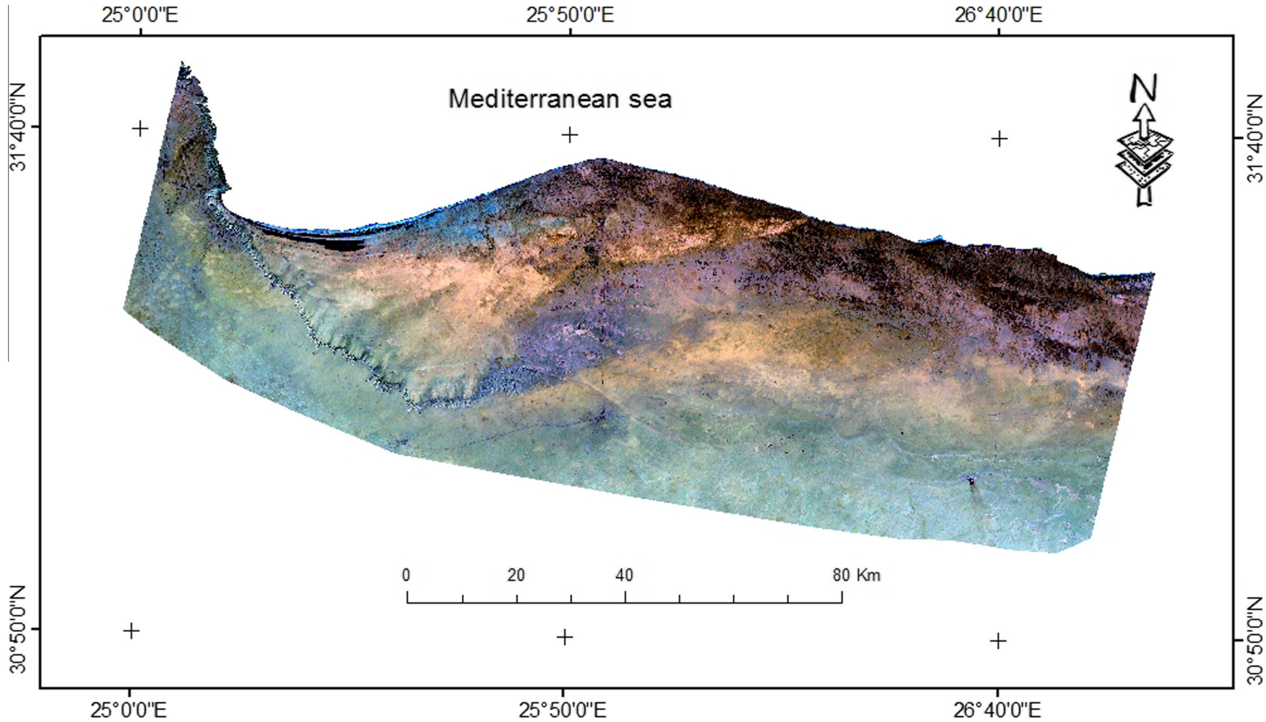

Figure 1 Location of the study area.

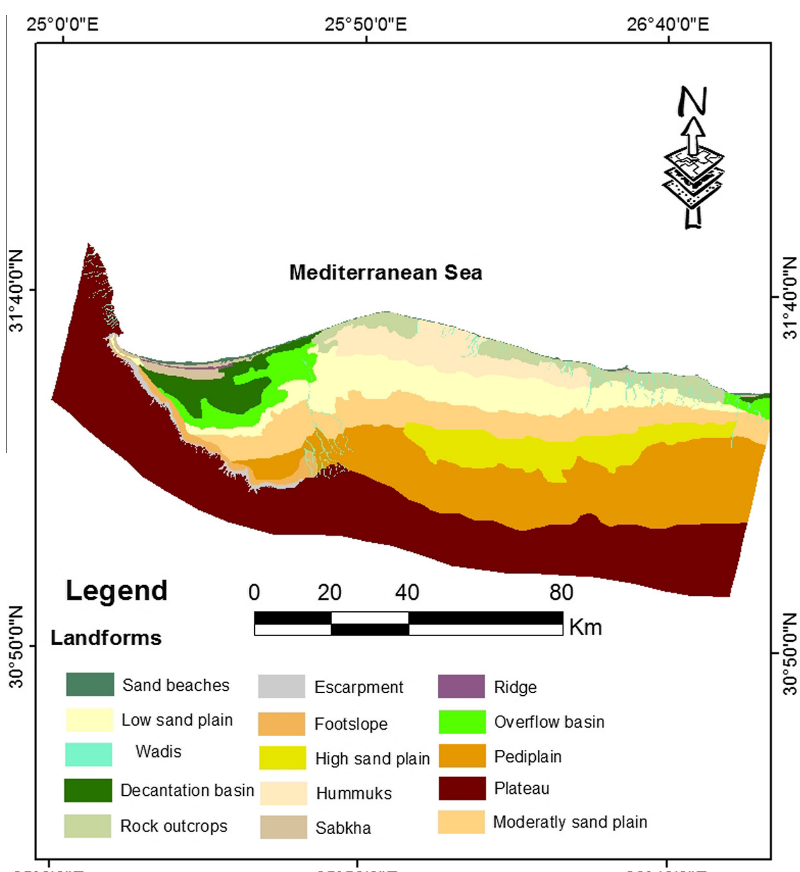

Figure 2 Landforms of the studied area.

the most widespread soil degradation processes on the Earth. Soluble salts restrict plant roots from withdrawing water from the surrounding soil, effectively reducing the plant's available water (Western Fertilizer Handbook, 1995; Bauder, 2001; Bauder and Brock, 2001; Hanson et al., 1999; USDA, 2002). Although water erosion is the dominant human-induced soil degradation process, an extent of 0.8 million km sq suffers from secondary salinization caused by land mismanagement, with 58% of these in irrigated areas alone, and nearly 20% of all irrigated land is salt affected (Ghassemi et al., 1995).The major empirical models to estimate soil erosion are the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965), the revised universal soil loss equation (RUSLE) (Renard et al., 1997), and the soil and water assessment tool (SWAT) (Neitsch et al., 2001. The Egyptian northern coastal zone suffered from moderate to severe water erosion hazards except in some areas concentrated in the eastern part of Egypt (Afifi and Gad, 2011). Water erosion risk is defined as the intrinsic susceptibility of a parcel of land to erosion caused by water. It is dependent on climate, landform and soil factors. Erosion hazard is a combination of risk and land use/management factors (Houghton and Charman, 1986). Soil losses models are the most satisfactory methods of soil erosion hazard assessment based on data of climate, soil erodibility, slope, slope length, vegetative cover and soil conservation practices (FAO, 1983). This work aims at mapping and assessing the environmental hazard using remote sensing data and GIS of the areas located between Sidi Barrani and Sallum north western coast of Egypt. Therefore maps of soil hazards are essential and can be a starting point of any regional intervention policy for soil erosion control and conservation.

Materials and methods

The investigated is located at the north western coast between latitudes 25°10′00″ to 26°55′00″East and from longitudes of 31°00′0″ to 31°37′30″North. It covers a total area of about 918222 hectares, it extended toward the western side of Egypt to the Libyan borders (Figure 1). The study area is characterized by extreme aridity and virgin soils, and huge storage of water resources. Topographically, the elevation of the area varies from 0 at the north to 249 m a.s.l.at the south of the

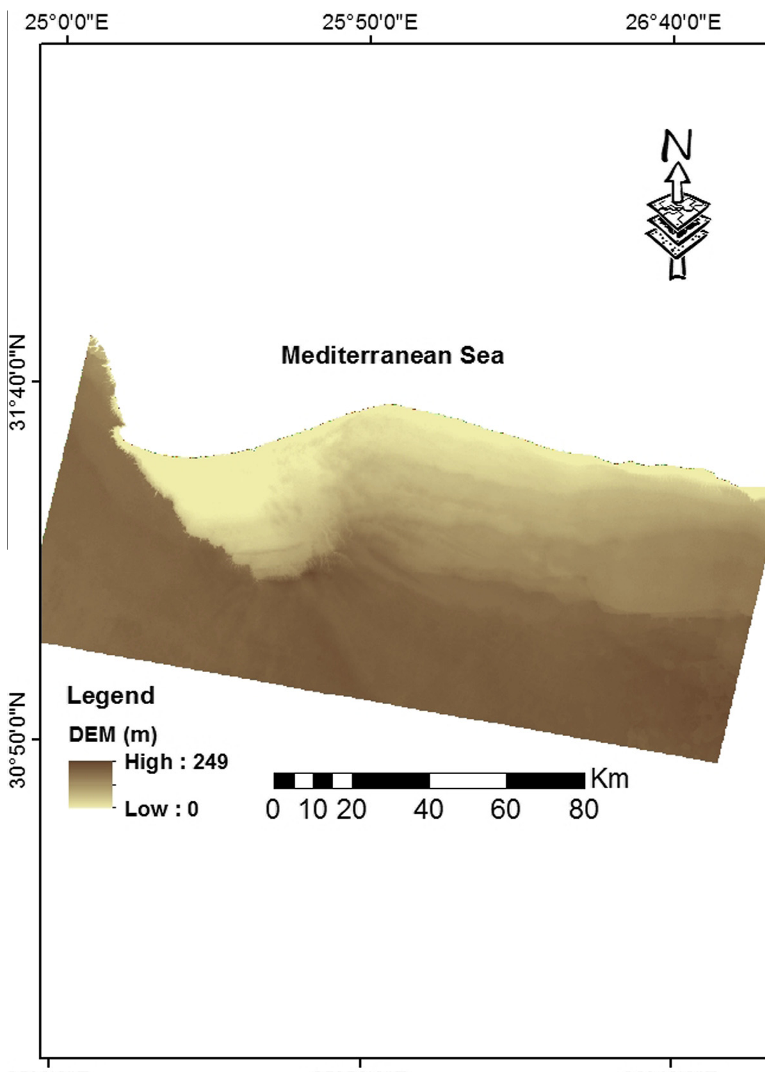

Figure 3 The digital elevation model of the study area.

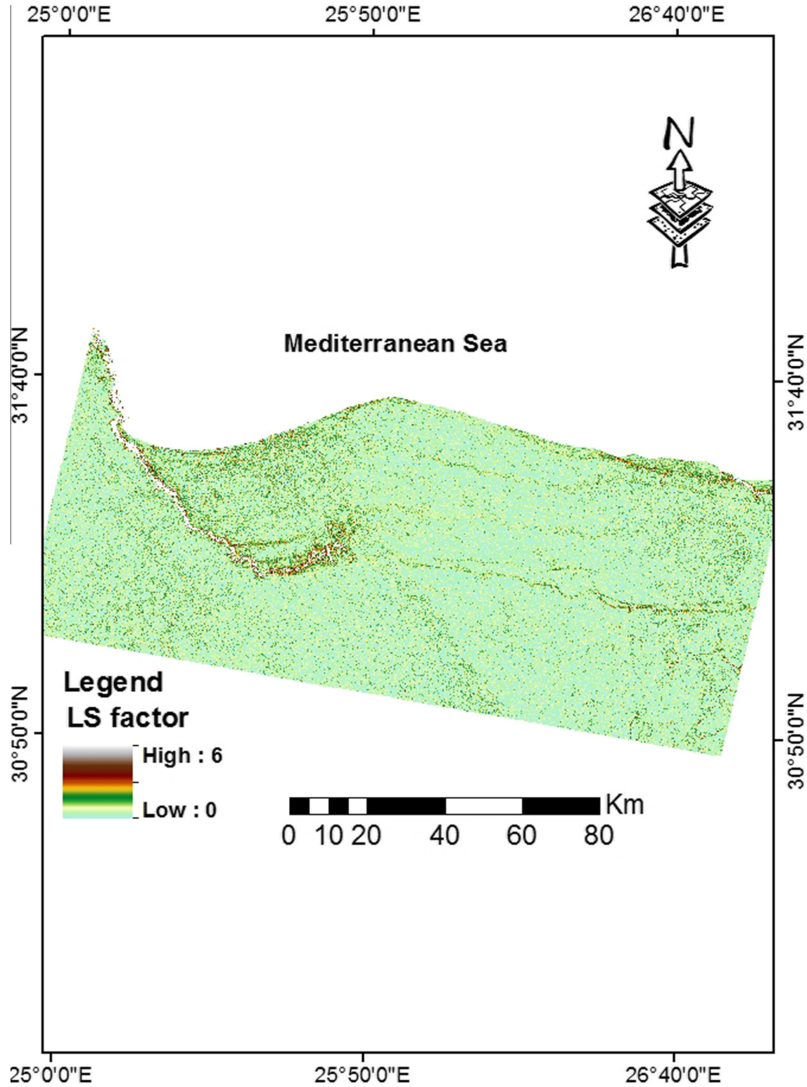

Figure 4 LS Factor of the study area.

studied area with general slope northward of land decreases from south to north. Its micro-relief varies considerably from almost flat to undulating with scattered escarpments A flat coastal zone is about 1–3 km wide. Some important wadis dissect the escarpment, especially southwest of Sidi Barrani.

Rainfall in the studied area ranges between 105.0 mm/y at El Sallum and 199.6 mm/y at Sidi Barrani and the average temperature ranges between high and low temperature of 18.1 and 8.1° C in the winter and 29.2 and 20° C in the summer, respectively. The main geological units in the investigated area are the Miocene and Quaternary deposits (MIMIR, 1981). Northwest cost dominated by coastal plan, elongated hills, first northern plateau, second northern plateau, southern plateau, Libyan plateau and the plain of the Maryout table land as a main geomorphologic mapping unit (Fawzy and Yacoub, 2005). The soils are mainly Torripsamments, Torriorthents and Calci/Paleorthids (FAO, 1970).

Fieldwork and laboratory analyses

Field studies and ground truth were carried out to identify the geomorphologic units as well as field observations of erosion features. Twenty-three soil profiles representing the different geomorphic units as well as seventeen test sites were selected for the validation of soil erosion model (USLE). During fieldwork, soil samples were collected and described using methods manual of the soil survey staff (2002). The soil samples were analyzed in the laboratory where particle size distribution, bulk density, percentage fine sand, silt, clay, and organic matter, pH, and electrical conductivity, etc. were carried out according to USDA (2004).

Environmental hazards in the studied area

This work focused on three factors soil salinity, soil sodicity and water erosion, to assess the environmental hazards of the studied area. The hazards of salinity and sodicity which lead to adverse conditions that affect the growth of most crops were evaluated and classified depending on their salinity and sodicity degrees (Gupta and Abrol, 1990; FAO, 1988; Richards, 1954).

Water erosion was assessed using RUSLE equation in a raster GIS environment for the calculation of specific factors and annual soil loss of the investigated area. The climatic data were derived from rainfall data collected from Egyptian Meteorological stations which included El-Sallum and Sidi Barrani stations. RUSLE was developed to incorporate new research since the earlier USLE publication in 1978 (Wischmeier and Smith, 1978). Agriculture Handbook 703 (Renard et al., 1997) is a guide to conservation planning with the RUSLE. The RUSLE method as showed:

$$A = R * K * LS * C * P$$

where: A = predicted soil loss (t h^{-1} y^{-1}) R = the rainfall erosivity factor, was calculated from the available agro climatologically data of El-Sallum and Sidi Barrani meteorological stations. R = 0.07397 * F1.847 1.72 when F < 55 mm

$$F = \sum (Pm)^2/P$$

where: Pm is the amount of the monthly precipitation and P is amount of annual precipitation mm and F is modified Fournier coefficient. The R values were computed according to (Renard and Freimund, 1994). where the study area has two meteorological Stations (El-Sallum and Sidi Barrani meteorological stations) with more than 45 years rainfall data.

K = The soil erodibility factor was calculated using the laboratory data of grain size analysis, structure, permeability, and organic matter content using the following equation according to (Wischmeier and Smith, 1978):

$$K = 2.1 * 10^6(I2 - OM)(M)^{1.14} + 0.0325 * (S - 2) + 0.025 (P - 3).$$

where OM is organic matter content %, M = (silt + very fine sand) (100- clay), S = structure factor and P = permeability factorLS = slope length and steepness, is calculated from Digital Elevation Model (DEM) derived from ASTER images using the equation proposed by Moore and Burch (1986). They derived an equation for estimating LS based on flow accumulation and slope steepness. The equation is:

$$LS = \left(\frac{\text{Flow Accumulation} * \text{Cell size}}{22.13}\right)^{0.4} * \left(\frac{\sin \text{slope}}{0.0896}\right)^{1.3}$$

where flow accumulation is a grid theme expressed as the number of grid cells (readily derived from watershed delineation processing steps) and Cell size is the length of a cell side

C – The vegetation cover of the study area is few and fractional so the cropping management factor was delineated through the field survey for each mapping unit as well as remote sensing data depending on the normalized difference vegetation index (NDVI), where NDVI was used directly as a measure of vegetation cover (Vrieling et al. 2006), while the C factor for the barren areas is considered as 1.

P-factor mechanical erosion control practices are nearly absent in the studied area. If present the erosion rate has to be estimated at a site, this factor is assumed as unity. Contour

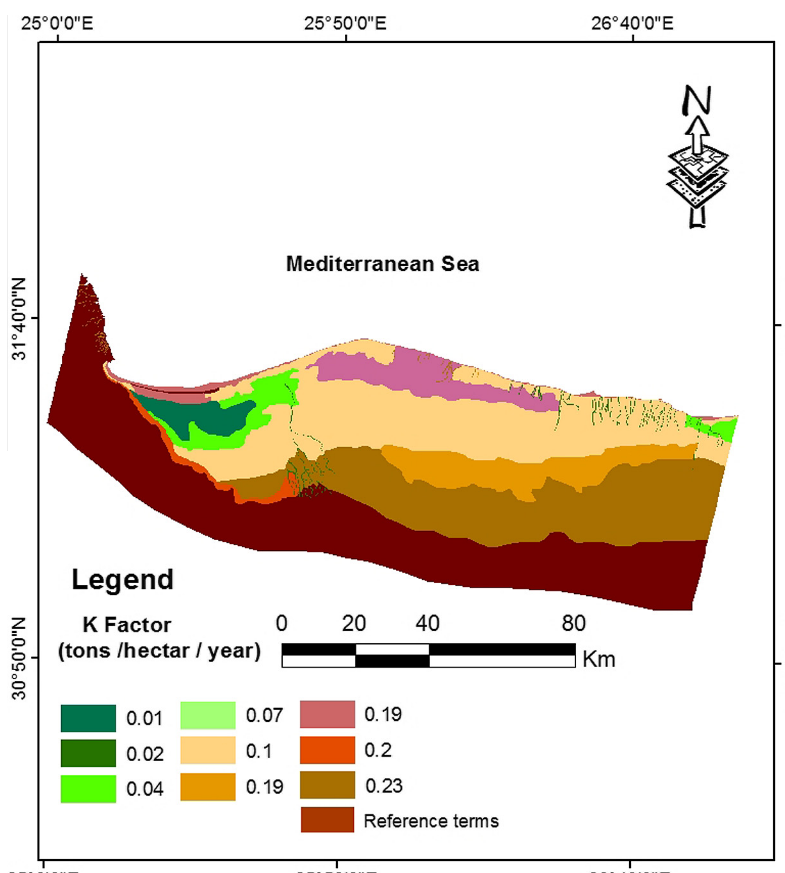

Figure 5 Soil erodibility map.

cultivation in the region is not practiced in a way that a proper *P*-factor can be assigned.

Maps production

The intermediate and final thematic maps were produce using ArcGIS 9.3 (ESRI, 2009) and digital image processing of Landsat 7.0 ETM+ satellite images dated to year 2007 was executed using ENVI 4.8© software (ITT, 2010).

Results and discussion

Landforms of the investigated Area:

The landform of the studied area was identified based on the Land sat ETM+ images, the digital elevation model (DEM) that has been derived from ASTER images Figure 3, topographic maps and the field check. The results obtained as shown in Figure 2, reveal that, the main land forms of the studied area are; sand plain, sand sheet, pediplain, decantation basin, overflow basin, foot slopes wadis, hummuks, sabkha and the sand beach.

Water erosion assessment of the study area

The Potential annual soil loss is estimated from the product factors (*R*, *K*, LS, *C* and *P*) which represent the geo-environmental of the study area in spatial analyst extension of Arc GIS 9.3. Software. Rainfall erosivity factor (*R*) estimated using the meteorological data meteorological Stations (El-Sallum and Sidi Barrani meteorological stations) with more than 45 years rainfall data. The value of the *R* factor in both El-Sallum and Sidi Barrani stations was estimated according to (Renard and Freimund, 1994).the result showed that $R = 32$ in Sidi Barrani and 25 in El-Sallum.

The soil erodability factor (*K*) of a soil is an expression of its inherent resistance to particle detachment (degradation) and movement by rainfall (erosion). It is determined by the cohesive force of the soil particles which may vary depending on the presence or absence of plant cover, the soil's water content and the development of its structure. In computing the *K* factor in the Universal Soil Loss Equation (USLE), Wischmeier and Smith, 1978 computed the *K* factor for a soil based on its texture; % of silt plus very fine sand, % of sand, % of

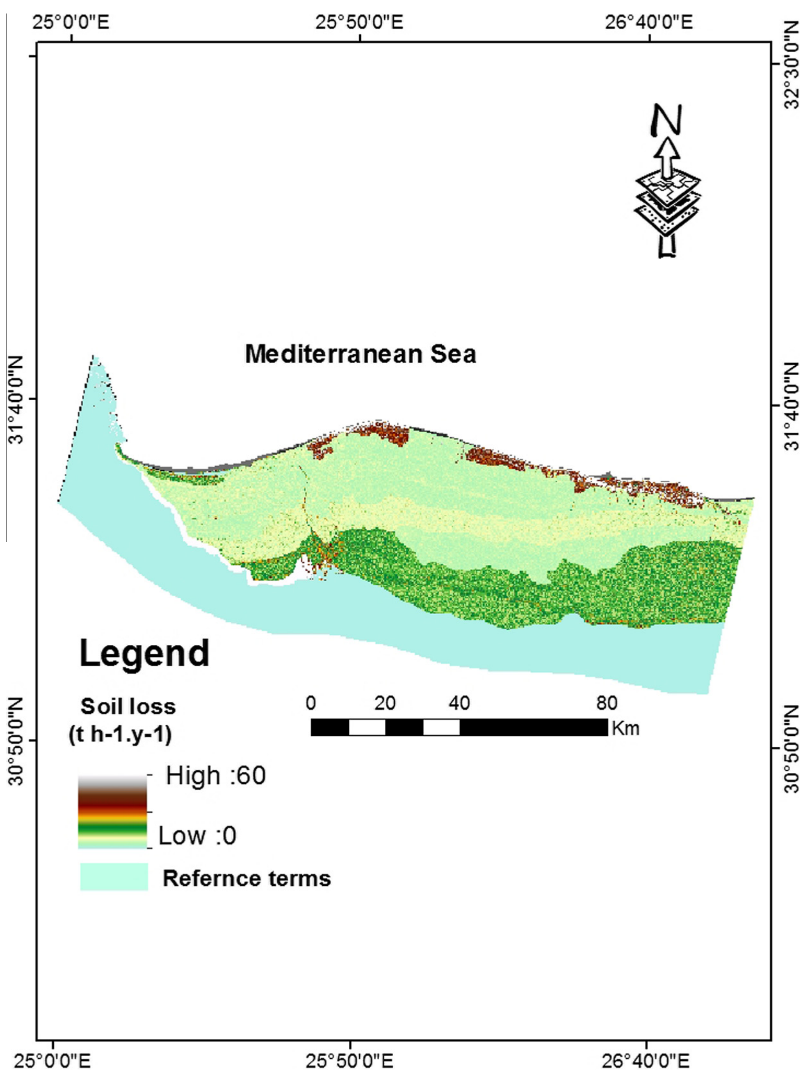

Figure 6 Soil loss map of the study area.

organic matter, soil structure, and permeability. The results indicated that 3.8% soils of the study area belong to negligible low erodibility. Moderately erodible soils account for 5% of the total area and are dispersed throughout the area while the soil is characterized as high to very high erodible where k factors value bigger than 0.1 $t\,h^{-1}\,y^{-1}$, accounts for about 57% of the total area. High erodible soils are with a surface layer that is rich in silt and very fine sand and poor in organic matter (Figure 5). Soil erosion by rainfall and runoff in the northern west coast zone of Egypt is active which is the result of natural land slopes, largely determined by water induced erosion and deposition. In this case, slope length normally decreases as slope steepness increases. The computation of LS requires factors such as flow accumulation and slope steepness. The flow accumulation and slope steepness were computed from the DEM using ArcGIS Spatial analyst extension. The LS-factor value in the study area varies from 0 to 6. The majority of the study area has LS value less than 1.5 and some specific areas only showing values higher than 5 (Figure 4). Soil loss was estimated by multiplying the respective USLE factors in Arc GIS software using Eq. (1). The USLE could be used to predict soil loss in the north of Egypt, taking into account the wide spatial diversity and limitations in the data. The average soil erosion rate of the studied area ranges from 0 to 60 $t\,h^{-1}\,y^{-1}$ (Figure 6). The maximum soil erosion rate was recorded in the foot slope unit where soil loss reached to 60 $t\,h^{-1}\,y^{-1}$, where LS values are very high, while soil erosion rate in overflow and decantation basin, high sand plain and hummuks have values of soil loss less than 4 $t\,h^{-1}\,y^{-1}$. Soil laboratory results were used for a variety of interpretations and the application of a soil loss model in all mapping units. These inquires through the USLE model have validated using plot sites data compared with soil erosion estimated using GIS techniques. The results show a high correlation between the estimated values and observed values which reached upto 94% in soils of the foot slope and wadis while the correlation in plains, sabkhas, sand sheets and basins reached upto 90%.

Environmental hazards in the study area

Three factors which were selected for monitoring and assessing the environmental hazards in the studied area could be categorized as salinity, sodicity and water erosion. Salinity is as common as sodicity and is largely a result of natural deep weathering and geological accumulation of salt from rainfall, therefore the current work focuses on the study of salinity and alkalinity as important environmental factors. The results show that an area about 1% of the total investigated area is suffering from very high salinity and a sodicity hazard where the salinity value reached upto 16 EC dS/m and the sodicity value reached upto 20%. Nearly 0.6–3.3% of the total area is identified as high hazard in both salinity and sodicity soils respectively as shown in Table 1 and Figs. 7 and 8. The areas demonstrated by high to very high hazards are located in the

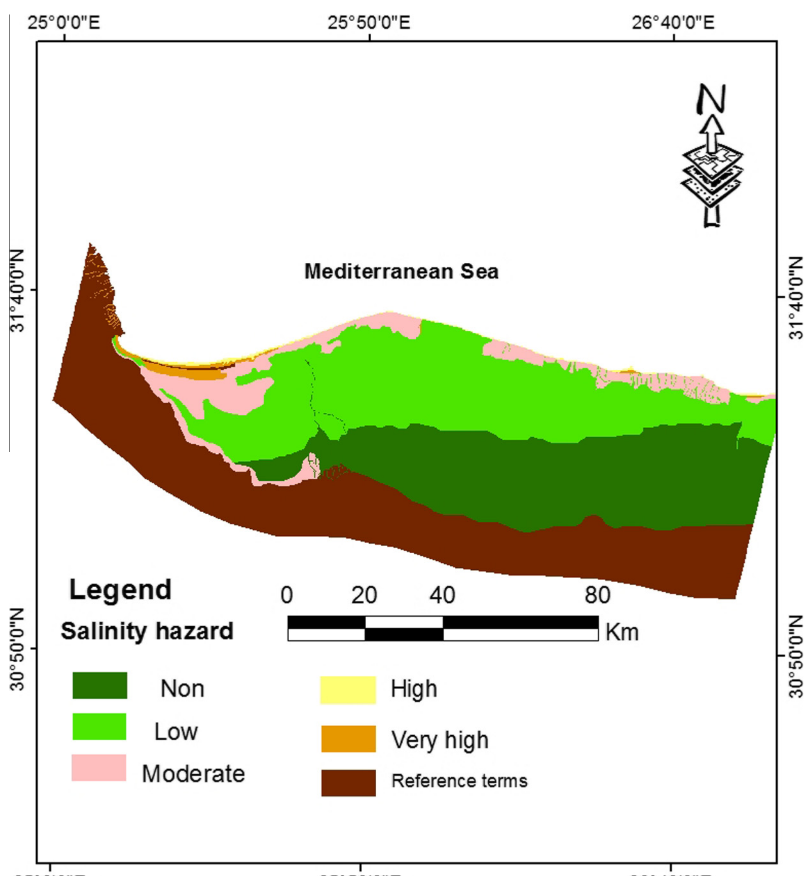

Figure 7 Soil salinity hazard of the study area.

Table 1 Salinity and sodicity hazard.

Salinity & sodicity hazard	EC (dS/m)	Area (%)	Area (hect.)	ESP (%)	Area (%)	Area (hect.)
Non	< 2	27.4	251,668	< 5	40.7	373,915
Low	2–4	29.4	270,047	5–10	19.3	177,139
Moderate	4–8	7.6	69,963	10–15	1.8	16,302
High	8–16	0.6	5096	15–20	3.3	30,976
Very high	> 16	1	9111	> 20	0.9	8096
Reference terms		34			34	

north where the water erosion brings salts from the southern to the northern parts, thus more severe problems such as dry land salting occurs, often rendering land unsuitable for agriculture. An area about 7.6% and 1.8% are classified respectively as moderate in both salinity and sodicity hazards, although about 56.8% and 60% of the total area are classified as none to low salinity and sodicity hazards respectively Table 1.

Water erosion hazard

The soil loss values obtained were classified in five groups, as shown in the erosion hazard map in (Figure 9). First of these five broad classes and ranging is non to light erosion hazard areas, where average annual soil loss rates are less than 4 t h^{-1} - y^{-1} and the last group is very high hazard areas where soil loss values are over 30 t h^{-1} y^{-1}. The presented results in Table 2 show that about 11.4% of the study area is classified as non to light potential erosion hazard where soil loss < 2 t h^{-1} y^{-1}, and about 27.8% of the total area is characterized by low erosion hazard. In terms of actual soil erosion hazard, it is observed that the rest of the area is under moderate to high erosion hazard where the soil loss values range between (10–20 t h^{-1} y^{-1} and it occupied an area about 22% of the total investigated area. Meanwhile 1.5% of the study area is classified as high to very high erosion hazard (soil loss > 20 t h^{-1} y^{-1}). The spatial pattern of classified soil erosion hazard zones indicates that the areas with high and very high hazards are located in the north and northwest regions of the study area, while the areas with low erosion hazard are in the eastern and central parts of the study area.

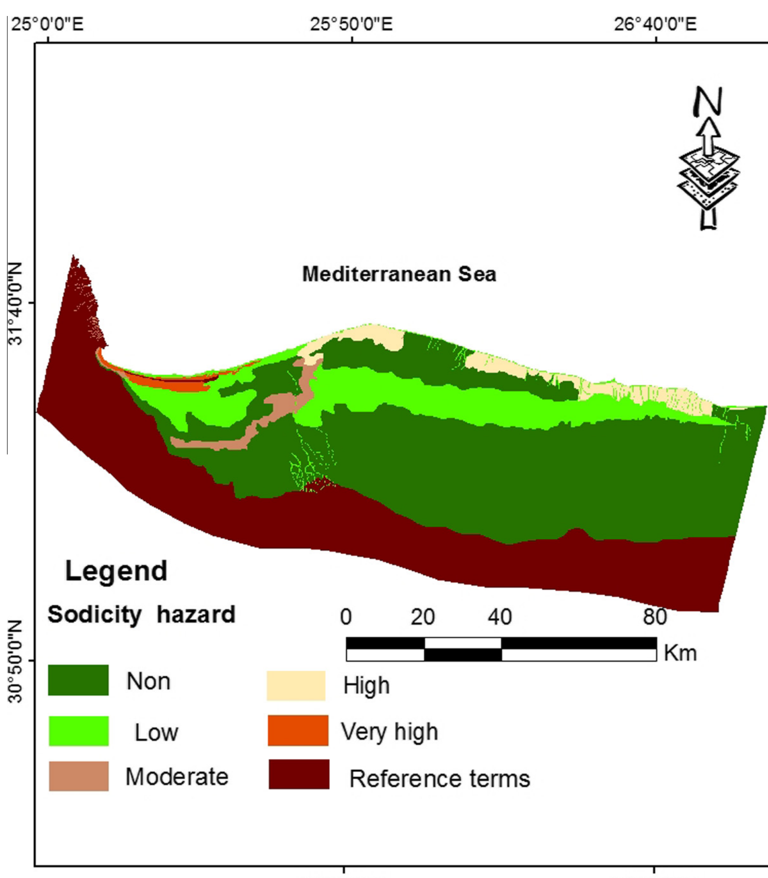

Figure 8 Soil sodicity hazard of the study area.

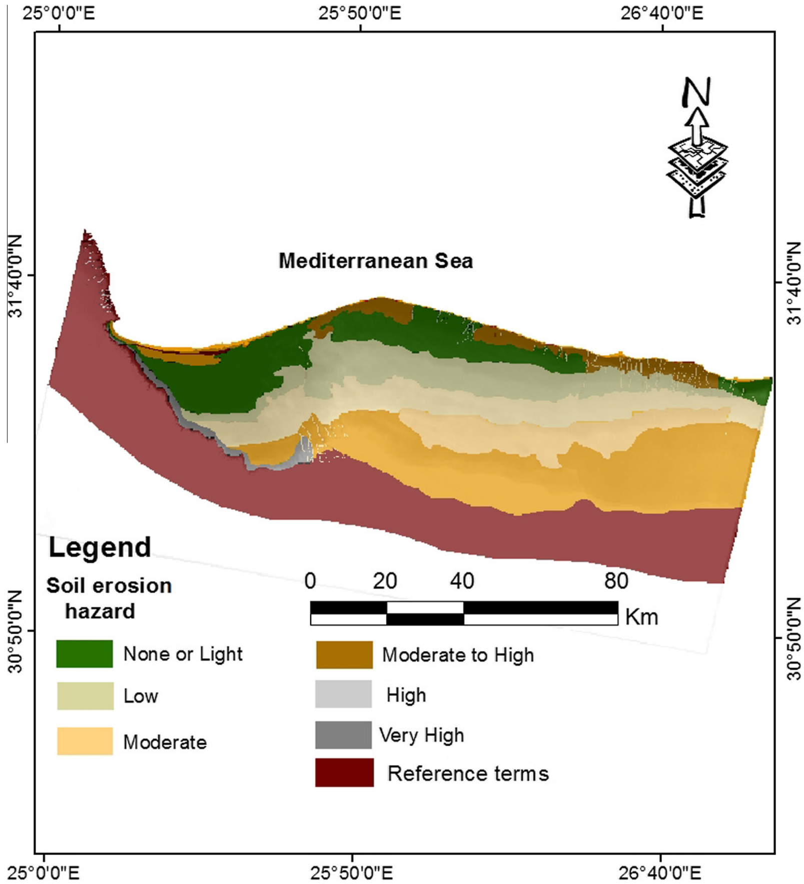

Figure 9 Soil erosion hazard of the study area.

Table 2 Soil erosion hazard of the study area.

Erosion hazard	Rate ($t/h^{-1}y^{-1}$)	Area (%)	Area (hect.)
Non	< 2	11.4	104,379
Low	4–10	27.8	255,555
Moderate	10–20	22	202,405
Moderate to high	10–20	3.3	30,388
High	20–30	0.2	1642
Very high	> 30	1.3	11,514
Reference terms		34	

Erosion hazard management

Soil erosion estimation and hazard assessment is essential for the proper planning and management of future soil erosion disasters. The areas with low erosion hazard are located in the eastern and central parts of the study area, while the areas located in the north and northwest regions of the study area are characterized by high to very high soil erosion hazards where the vegetation cover is low to very low, relief and aridity factors are very high which are core to economic development. Therefore, in these areas priority should be given to reduce or control the rate of soil erosion by means of conservation planning. Rahman et al. (2009) proposed a program for soil erosion management, where low erosion hazard should be protected strictly and lumbering and human activities would not be permitted. On the other hand the management of moderate erosion hazard should be to protect them from further erosion, vegetation degradation and removal and stabilization through plantations. Given the probability that the rate of erosion will increase in future in the investigated area of very high erosion hazard, therefore, proper land-use planning is needed such as suitable cropping pattern for agricultural land and also low development densities may be allowed under certain conditions. In these measures, preference should be given to the agronomic measures of soil conservation, such as conservation tillage, in conservation planning and lower cost erosion control techniques can also be implemented.

Salinity hazard management

Saline soils cannot be reclaimed by chemical amendments, conditioners or fertilizers. A field can only be reclaimed by removing salts from the plant root zone. The management of salinity hazard can be done by the following methods (1) selecting salt-tolerant crops, (2) leaching requirement method by moving the salt below the root zone by applying more water than the plant needs, (3) use of artificial drainage method which combines the leaching requirement method, and (4) managed accumulation by moving salts away from the root zone to locations in the soil, other than below the root zone, where they are not harmful.

Sodicity hazard management

There are three methods that can be used for sodicity hazard management, (1) change the plant species to a more tolerant species, (2) change the variety to a more tolerant variety, (3) replace the sodium with calcium and then leach the sodium out by two possible approaches for doing this: dissolve the limestone (calcium carbonate) or gypsum (calcium sulfate) already present in the soil or, add calcium to the soil. If free lime is present in the soil, it can be dissolved by applying sulfur or sulfuric acid. Sulfur products reduce the pH which dissolves the lime, thus freeing up the calcium. If free lime or gypsum is not present in adequate amounts as determined by a soil test, then calcium can be added.

Conclusion

A quantitative assessment of environmental hazard of the study area is the main aim of this work using remote sensing and geographic information systems techniques. Soil erosion, salinity and sodicity hazards are serious problems in north western coast of Egypt and leads to reduced soil quality and degradation of the soil resources. Soil salinity and soil sodicity are associated with soil erosion where the result showed increase of salinity and sodicity values at the north of the investigated area. This accumulation of salts is the result of water erosion which moves salts from southern to the northern parts. The results showed that EC values reached 16 dS/m and ESP reached upto 20% in small areas, but it will be very dangerous in the future when there is gradual accumulation of salts in the upper layer of soils. The maximum soil erosion rate is recorded in the foot slope unit where soil loss reached 60 $t\ h^{-1}\ y^{-1}$ where the LS factor value reached upto 6. The result illustrates that about 22% of the total area is classified as moderate hazard where soil loss ranges between 10 and 20 $t\ h^{-1}\ y^{-1}$. But about 1.5% of the study area is classified as high to very high erosion hazard (soil loss $>20\ t\ h^{-1}\ y^{-1}$). The spatial pattern of classified environmental hazard zones indicates that the areas with high and very high hazard are located in the north and northwest regions of the study area, while the areas with low hazard are in the eastern and central parts of the study area. The USLE can be used to predict soil loss in the north of Egypt, taking into account the wide spatial diversity and limitations in the data. Remote sensing data and GIS played an important role for monitoring and assessing the environmental hazard in north western coast of Egypt.

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