4th International Conference on Water Resources and Arid Environments (ICWRAE 4): 640-648
5-8 December 2010, Riyadh, Saudi Arabia

Assessment and Mapping Areas Affected by Soil Erosion and Desertification in the North Coastal Part of Egypt

Ahmed A. Afifi[1] and Abd Allah Gad[2]

[1]Department of Soils and Water Use National Research Centre, Dokki, Giza, Egypt
[2]National Authority for Remote Sensing and Space Sciences, Cairo, Egypt

Abstract: The study aim is to mapping and assessing qualitatively the areas sensitive to water and wind erosion in the north coast of Egypt using the data available and a provisional methodology for assessing desertification. The provisional methodology of the FAO/UNEP (1984) for assessing and mapping of desertification was adopted for investigating the active desertification processes in the study area. Detailed methodologies for assessment criteria and class limits have been established for desertification processes: water and wind erosion. For purposes of assessment and mapping it is necessary to study, describe, quantify and codify the various aspects of desertification (status, rate, inherent risk and hazard). To evaluate the hazard of desertification consideration has to be given to the status, rate and inherent risk of desertification by dominant determinative processes, including human and animal pressures on the environment. The water erosion hazard map reveals that most of the study area suffered from moderately to severe water erosion hazard except in some areas concentrated in the eastern part of the study area. The wind erosion hazard map illustrates that most of the study area suffering for moderate to severe wind erosion except in a small area distributed along the study area have slight wind erosion hazard.

Key word: Water erosion • Wind erosion • Desertification • Remote sensing • GIS

INTRODUCTION

Soil erosion is the consequence of a set of important processes, which are most active in the absence of vegetation, on both cropland and for uncultivated arid and semi-arid environments, where water is the main limiting factor in plant growth [1].

Various approaches and equations for risk assessment or predictive evaluation on soil erosion by water are available in literature. With integration and application of statistical approaches and GIS techniques, specific quantitative models to assess and predict soil erosion are also available [2-4].

Erosion models are generally developed for a specific region over small scales. Their application at regional scales and in regions for which they have not been tested and validated is therefore, rather restricted [5-8]. Alternatively, erosion risk mapping based on qualitative data integration provides a better option for regional erosion assessment [9, 10]. Thus, in many parts of the world, soil erosion risk mapping is used for identifying high erosion areas where resources of soil and water conservation programs can be effectively concentrated [11, 12].

It should be noted that soil erosion is a complex issue related with many influence factors and investigators face great challenges for quantifying relationships between soil erosion and its influence factors. In fact, quantification of soil erosion currently is a process with complex and unstructured decisions. As a result, an integrated and systematic approach should be implemented. However, most of the models are established based on either empirical approaches or statistical methods and significant uncertainty of predictive simulations could result.

The study aims to mapping and assessing qualitatively the areas sensitive to water and wind erosion using the data available and a provisional methodology for assessing desertification.

Corresponidng Author: Ahmed A. Afifi, Department of Soils and Water Use National Research Centre, Dokki, Giza, Egypt.
E-mail: a.afifinrc@gmail.com.

MATERIALS AND METHODS

Environmental Setting of the Study Area: The study area represents the northern coastal zone of Egypt in a buffer zone of 20 Kms from the coast line with the Mediterranean Sea, representing an area of 32242.43 km^2 (Figure 1). 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 are suffering mostly from high to moderate relative humidity. The maximum relative humidity occurs in 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 evapotranspiration.

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 was the main mapping tools (Figure, 2). Image analysis was made accordance with field observation. A number of 162 soil profiles representing the mapping units were studied (Figure, 2). The soil sample was collected, analysed and classified to the level of the sub-great group according to [13] not inserted. The main input data for calculating these indices include land surveying and laboratory analyses, Landsat ETM+ image (path 177 / row 39) band 2,4,7 for False Color Composite (FCC), Digital Elevation Model (DEM), climatic data and geological map of the studied areas [14]. 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. Arc-GIS, version 9.2 have been used as the main GIS software for producing geo-referenced maps. Measuring units and rating of wind and water erosion has chosen according to [15]. Natural vulnerability was calculated on a basis of

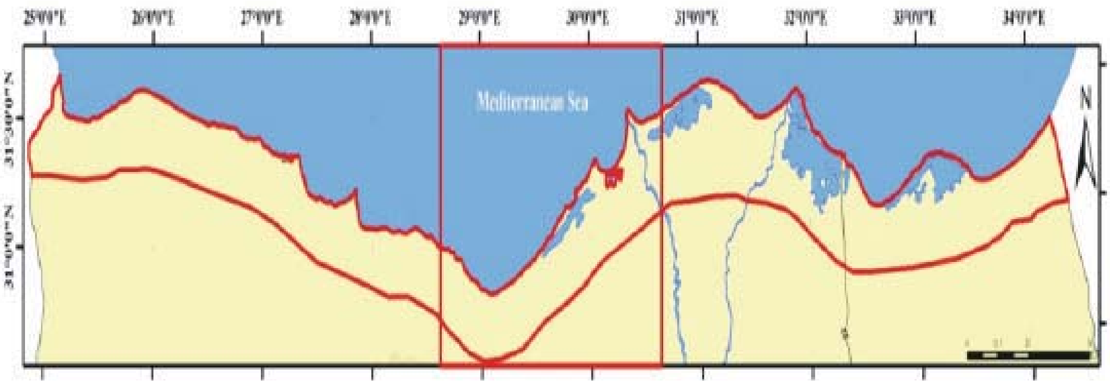

Fig. 1: The area of study

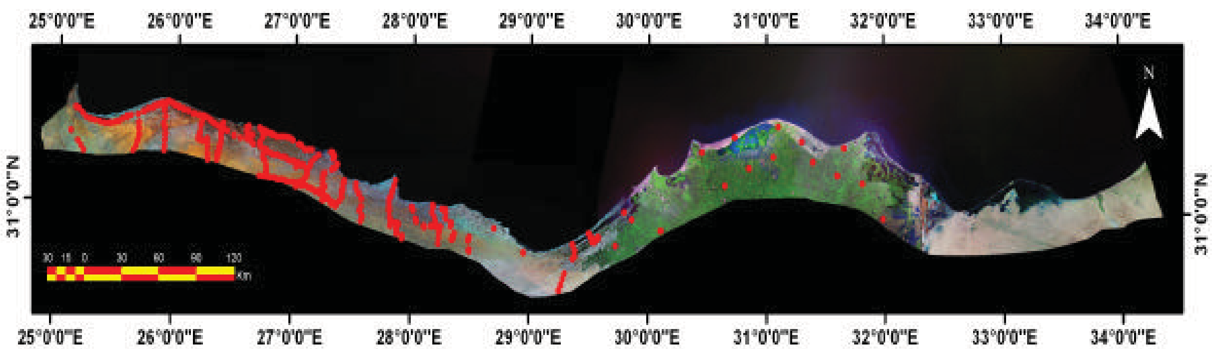

Fig. 2: FCC (band 2,4,7), 2003 of the whole area and location of soil samples

Table 1: Class Limits for the chosen criteria for assessing of a different aspects of water erosion

Desertification aspect	Assessment factors	Class limits Slight	Moderate	Severe	Very severe
	1 Surface. status (%of gravels)	<10	10-25	25-50	>50
	2 Soil thickness (cm)	>90	90-50	50-10	<10
Rate	1 Increase in erode area per year.	<1	1-2	2-5	>5
	2. Soil loss, t/ha/yr	<2	2-3.5	3.5-5	>5
Inherent risk	Rating of climate aggressively	0.03	0.03-0.06	0.07-0.1	>0.1
	Rating of potential soil loss in t/ha/yr	<5	5-15	15-25	>25

Table 2: Class limits for the chosen criteria for assessing of different aspect of wind erosion

Desertification aspect	Assessment factors	Class limits Slight	Moderate	Severe	Very severe
Status	1. Soil thickness (cm)	>90	90-50	50-10	<10
	2. Surface gravel %	<15	15-30	30-50	>50
Rate	1. Soil loss, t/ha/yr	<2	2-3.5	3.5-5	>5
	2. Increase in erode area per year	<1	1-2	2-5	>5
Inherent risk	1. Wind erodibility group (texture class)	SCL, SCSi	Rest of textural class	LS	S
	2. Mean annual wind speed, m/sec	<2	2-3.5	3.5-4.5	>4.5

Where: SCL=Sand Clay Loam; SCSi=Sandy Clay Silt; LS=Loamy Sand and S=Sand

Table 3: Classes of desertification

Class of desertification	% area in various desertification categories Slight	Moderate	Severe	Very severe
Slight	>30	<30	<40	
Moderate	<30	>30	<40	
Severe	<30	>40		<30
Very severe	<20		>40	>30

soil, topography and climatic factors adopted in the universal soil loss equation. Assessing of desertification is performed by assessing numerical ratings to land affected by each one of the processes within the specific classes of desertification. Four classes of desertification are used to show the intensity (slight, moderate, severe and very severe), (Table 1 and 2). The very severe class indicates the extreme conditions. Mapping the desertification aims to demonstrate its causes and dynamics. It is rather useful for planning preventive activities. To evaluate the desertification hazards reference has to be made to the natural susceptibility of land to desertification on assessment of status, rate and inherent risk and man made factors (Table 3).

RESULTS AND DISCUSSION

Remote Sensing Work: A number of 16 satellite images were subjected to image classification for preparing a base map (land use/land cover map) and assessment of field observation points. Several contrast-stretching processes were applied to the images. The histogram equalization stretching process was used and resulted in the maximum contrast between features. False color composite enhanced images were produced using the combination of bands 2, 4, 7 rendered in red, green and blue respectively. The created FCC's and their visual interpretations were used as guides for field work survey. Rectification of studied scenes, (ETM 2003) was performed using sufficient number of GCP's, which are distributed randomly all over the images. The root mean square (RMS) error was found to be 0.74.

Supervised classification technique was applied on all images for the purpose of obtaining the land use/ land cover maps. A hybrid classification method for automatic clustering of satellite-observed scenes was used. It employs a partial clustering algorithm augmented by a hierarchical split and merge step at each interaction and dynamically computes the image-specific split-and-merge thresholds.

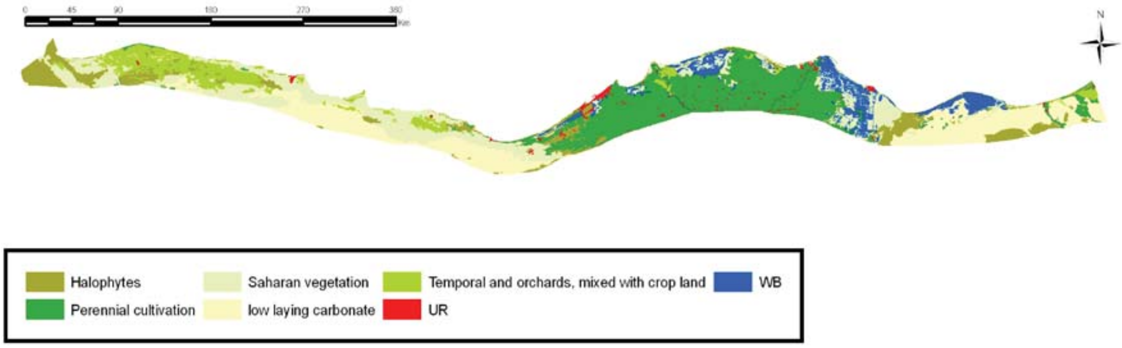

Fig. 3: Land use/ land cover map based on satellite image

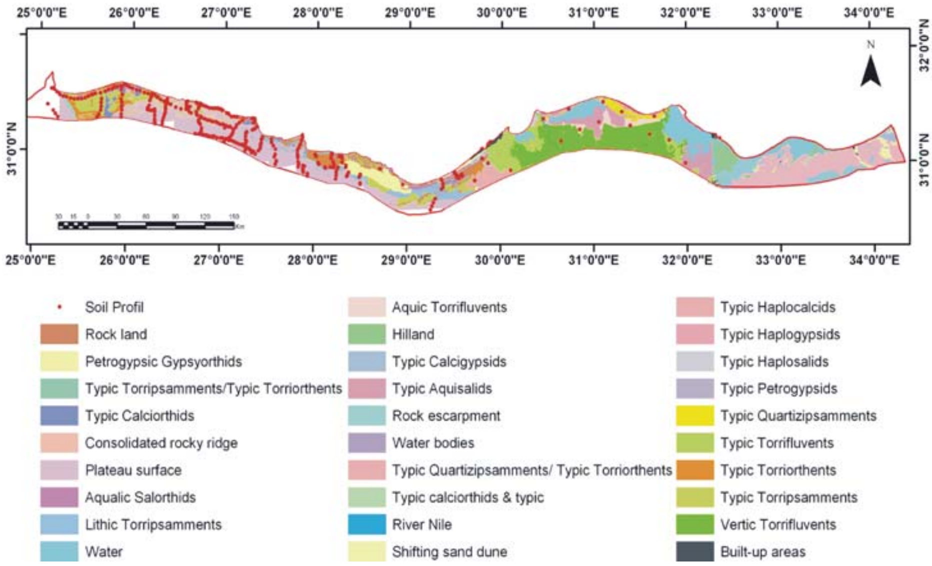

Fig. 4: Soil units and observation points of the study area

In the proposed enhancement, two steps are added into the hybrid classification after the split and the merge processes, respectively. The two added k-means steps ensure that every pixel will be assigned to the nearest cluster centre after each split or merge. Thus, the following step is provided with a more accurate intermediate result than in the original algorithm. The advantage is improved classification accuracy (Figure, 3).

A number of three field missions were performed to collect ground truth data concerning landscape characteristics, soil properties and vegetation status. These data were used in the supervised classification and land use mapping. Linear traverses schedule was followed [16] in such frequency and intensity that a large variety of terrain is covered as complete as possible.

The performed filed It was possible to investigate a number of 432 observation sites and collecting 346 soil samples from 162 soil profiles representing the different landscape features in the target area (Figure, 4). It was also aimed to collect some ground control points to be used in the geometric correction of satellite images. These points represented well defined locations (i.e. cross roads, building corners… etc.). They were also chosen spread all over the study area for attaining reliable results of geometric correction.

Water Erosion: Standard methods for assessing accelerated water erosion in the field have not yet been devised for large areas. The result is that many estimates of magnitude of water erosion are made assuming mathematical models such as the universal soil loss equation or in the opinion of the observers. (Figure, 5) illustrate the water erosion status class, which indicates that 47% (15295.02 km^2) of the total area has slight wind erosion status, cover Mostly the studied area. Whereas, the severe and very severe classes are located as some

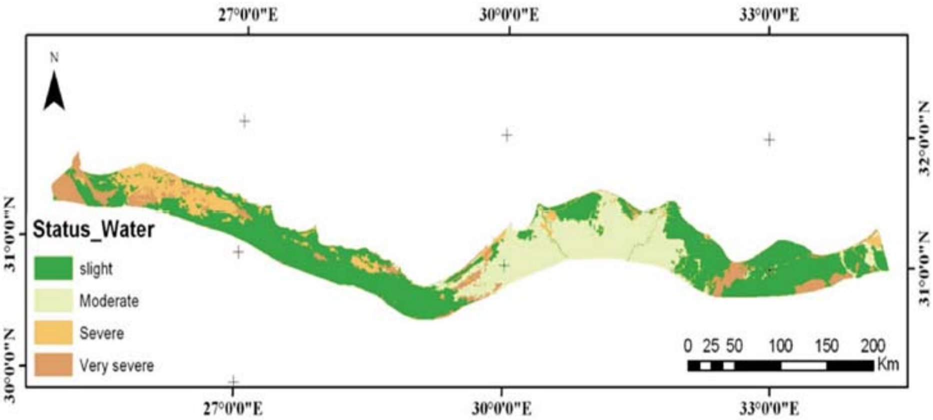

Fig. 5: Water erosion status

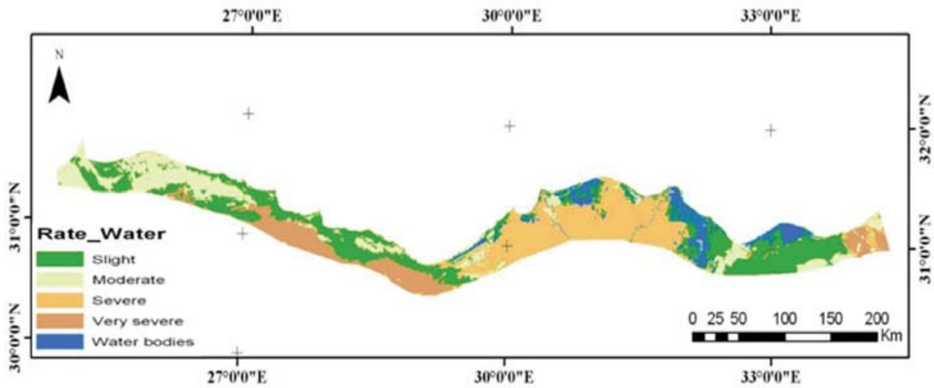

Fig. 6: Water erosion rate

patches distributed along the study area representing 11% concentrated mainly in the north western part of the study area. The severe class covered an area of about 3598.44 km^2 while, the very severe class cover 3852.66 km^2 . The rest of the study area 9496.22 km^2 (29.45%) represents a moderately class of the water erosion status which concentrated mainly in the middle part of the study area in the north delta.

The water erosion rate (refers to the change with time). As indicated in (Figure, 6) 34.35% (11075.65km^2) of the total area is in slight rate of water erosion and is clearly seen in the eastern and western part of the north cost while the middle section of the study area (north delta) has small patches.

The moderately rate class of water erosion represents 22.06% (i.e. 7111.32 km^2) of the total area, distributed as some patches concentrated mainly in some part of the north western part of the study area. Nevertheless, the severe class represents an area of 29.45% (i.e. 9496.22 km^2), concentrated mainly in the middle part of the study area in north delta. However, the severe class distributed as some patches in the eastern and western part of the study area. The very severe class cover an area of about 4559.24 km^2 (14.14%) of the total area. This class distributed mainly in the north western part and as small patches in the north eastern part close to Rafah.

The data in (Figure, 7) revealed that the wind erosion inherent risk, 15.19 % (4899.02 km^2) of the total area represents a slight class of inherent risk. This class is distributed mainly in the western part of the Nile delta in Al-Bahiera governorate. While, 29.45% (9496.22 km^2) of the study area, represented as moderately class is distributed in the middle part of the study area. However, 55% of the study area is suffering from severe to very severe inherent risk of wind erosion. Wherein, 33.3% (10735.87 km^2) of the total area is distributed mainly in the western and eastern part of the study area. Nevertheless, the reset of the study area exhibit a severe class for wind erosion inherent risk and is clearly seen in the western and in the eastern part of the study area as patches.

Wind Erosion: In the context of desertification by wind erosion, aeolian deposits present serious problems in many parts of the world. As indicated in (Figure, 8),

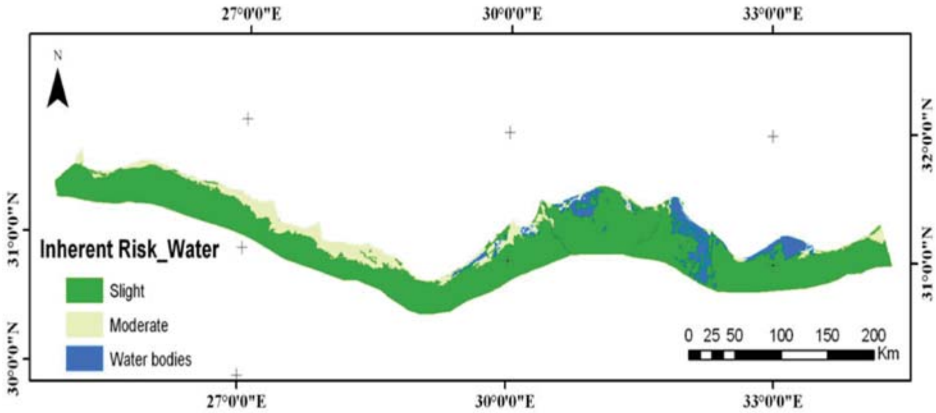

Fig. 7: Water erosion inherent risk

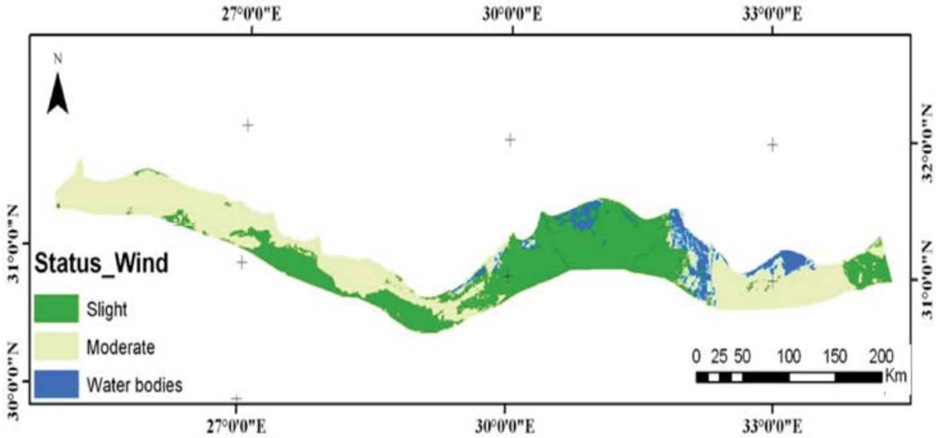

Fig. 8: Wind erosion status

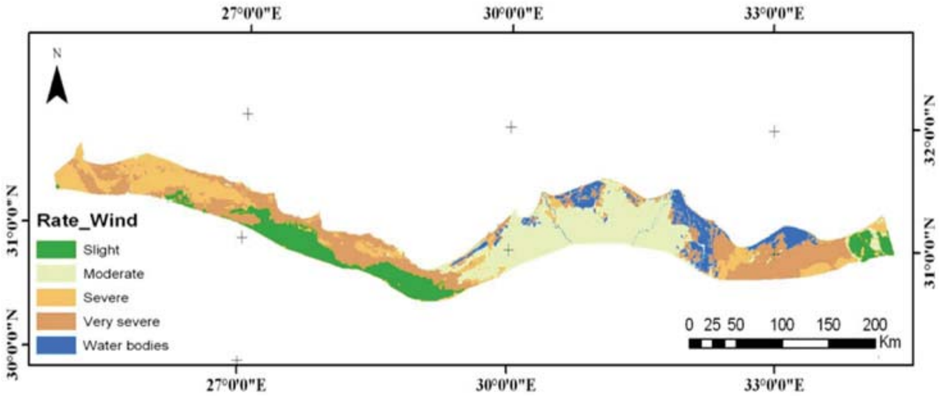

Fig. 9: Wind erosion rate

most of the studied area are located in the moderate wind erosion status class. Since, it is occupying an area of 17205.1 km^2 (53.36%). Nevertheless, the rest of the studied area exhibits an area of 15037.33 km^2 (46.64%) represents by slight wind erosion status class and is distributed mainly in the middle part at the north Nile delta.

According to the rate of wind erosion rate the data revealed in (Figure, 9) showed that almost 56% of the studied area exhibit severe to very severe wind erosion rate. Wherein, 34.26% (11046.84 km^2) exhibit a very severe wind erosion rate while 22.06% represent severe wind erosion rate class (i.e. 7111.32km^2). These classes are distributed mainly in the eastern and western parts of

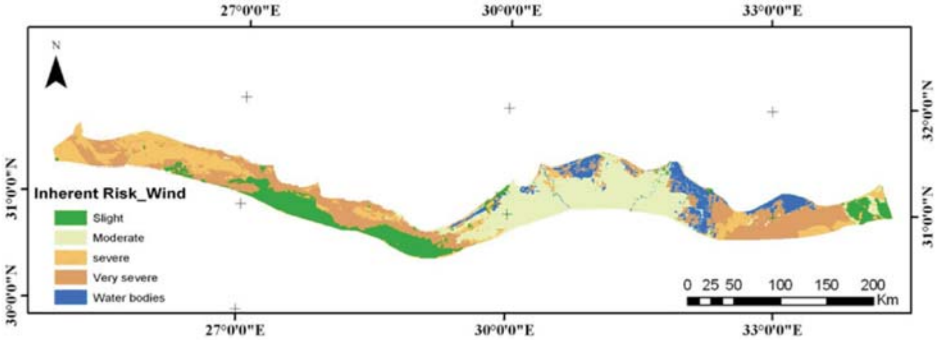

Fig. 10: Wind erosion inherent risk

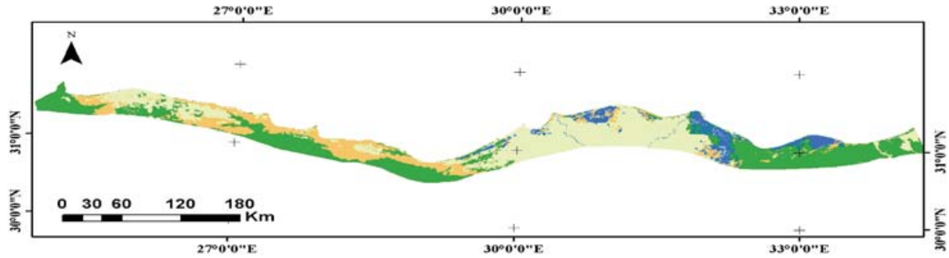

Fig. 11: Animal density

the studied area. The rest of the studied area is located between slight to moderately class. The slight class is located in western part of the delta close to Al-Bahera Governorate and is covered by an area of 4559.24 km^2 (14.14%). However, the moderate class (29.54%) is distributed mainly in the middle part of the study area at the northern part of the Nile delta.

The wind erosion inherent risk as illustrated in (Figure, 10), exhibited that 15.19 % (4899.02 km^2) of the total area represents a slight class of inherent risk. This class is distributed mainly in the western part of the Nile delta in Al-Bahiera governorate. While 29.45% (9496.22 km^2) of the study area, is distributed in the middle part of the study area. However, 55% of the study area is suffering from severe to very severe inherent risk of wind erosion. Wherein, 33.3% (10735.87 km^2) of the total area is distributed mainly in the western and eastern part of the study area. Nevertheless, the reset of the study area exhibit a severe class for wind erosion inherent risk and is clearly seen in the western and in the eastern part of the study area as patches.

Erosion Hazard: Desertification hazard is expressed as a combined effect of status, rate and inherent risk including animal and population pressure on the environment.

Regarding to the animal density, data in Figure (11) show that the 39.43% of the studied area (12712.69 km^2) represented by slight animal pressure which is distribution mainly in the eastern and western part of the study area. However, 40% (13067.61 km^2) of the total area located in the moderate animal density and is located in the middle part of the study area. While the rest of the study area is represented by severe class and is distributed as small patches in the western and eastern part of the study area.

The population density as revealed in (Figure, 12) 59.34% (19132.28 km^2) of the study area has a slight population pressure. This class is exhibited in the eastern and western part of the study area. However, 10.89% (3510.38 km^2) of the total area is located in the moderate class of population density. The moderate class is distributed as some patches in the western part of the study area. The rest of the total area is located in the severe class of population pressure which is distributed mainly in the northern Nile delta and in some patches of the western part of the study area.

Combining all the previous data (status, rate and inherent risk) together the erosion hazard is predicted as follows; Data in (Figure, 13) illustrate that the study area (83.71%) is located mostly in moderate water erosion hazard, distributed mainly in the western and middle part of the study area. However, it is also extended as patches in the eastern section of the study area, while, the rest of the study area is located in the slight water erosion hazard class.

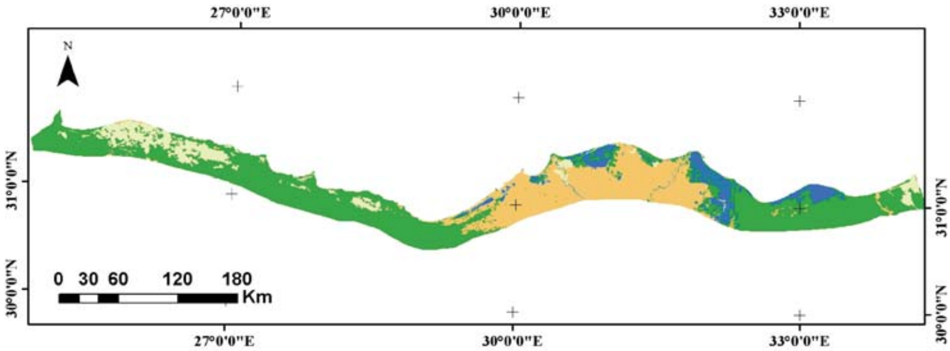

Fig. 12: Population density

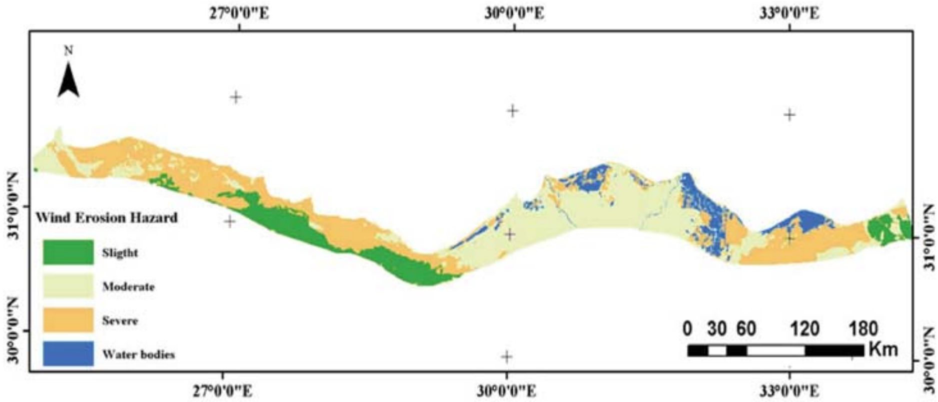

Fig. 13: Wind erosion hazard

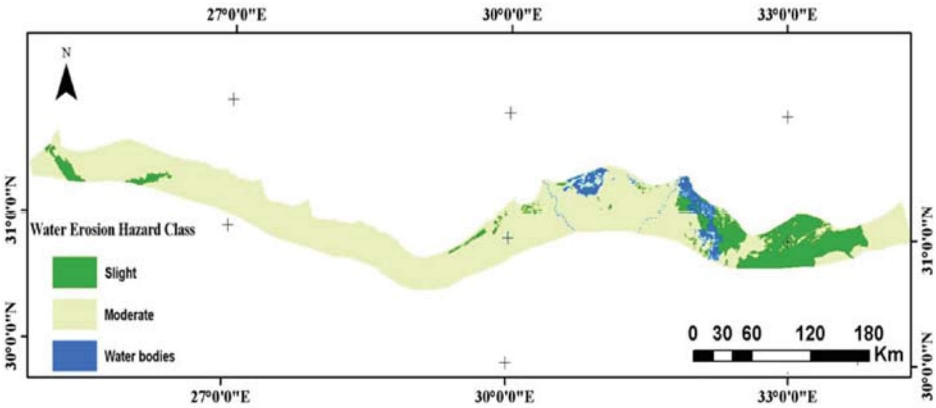

Fig. 14: Water erosion hazard

According to wind erosion hazard, the study area exhibits mostly moderate to severe wind erosion hazard except in small parts of the western part of the study area (Figure, 14). However, the severe class is located in the western and eastern part of the study area representing 43.82% (14127.94 km^2) of the study area. Nevertheless, the rest of the studied area (14.14%) is located in some parts of the western section.

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. It can be recommended that mathematical modelling should be developed for the operational monitoring of different elements contributing in desertification. Multi scale mapping of a model is 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 erosion hazard. However, the Nile Valley is moderately sensitive because of its vegetation cover.

REFERENCES

1. Grazhdani, S. and S. Shumka, 2007. An approach to mapping soil erosion by water with application to Albania. Desalination, 213: 263-272.
2. Gong, J., 2001. Geography Information System. Science Publishing Company, Beijing.Lewis, L.A.,
3. Lewis, D.T., P.M. Seevers and J.V. Drew, 2005. Use of ERTS-1 imagery to interpret the wind erosion in Nebraska's Sand Hills, Journal of Soil and Water Conservation, 30(4): 181-184.
4. Wu, Q. and D. Dong, 2001. GIS Based Theories and Methods for Investigations of Geological Hazard and Water Resources. Geology Publishing Company, Beij.
5. Jetten, V., G. Govers and R. Hessel, 2003. Erosion models: quality of spatial predictions. Hydrological Processes, 17: 887-900.
6. Jetten, V., A. De Roo and D. Favis-Mortlock, 1999. Evaluation of field-scale and catchmentscale soil erosion models. Catena, 37: 521-541.
7. Renschler, C.S. and J. Harbor, 2002. Soil erosion assessment tools from point to regional scales- the role of geomophologists in land management research and implementation. Geomorphol., 47: 189-209.
8. Merritt, W.S., R.A. Letcher and A.J. Jakeman, 2003. A review of erosion and sediment transport models. Environmental Modelling & Software, 18: 761-799.
9. Van Rompaey, A.J.J. and G. Govers, 2002. Data quality and model complexity for regional scale soil erosion prediction. International J. GIS, 16: 663-680.
10. Vrieling, A., SM. De Jong, G. Sterk and S.C. Rodrigues, 2008. Timing of erosion and satellite data: a multi-resolution approach to soil erosion risk mapping. International J. Applied Earth Observation and Geoinformation, 10: 267-281.
11. Fox, D., W. Berolo, P. Carrega and F. Darboux, 2006. Mapping erosion risk and selecting sites for simple erosion control measures after a forest fire in Mediterranean France. Earth Surface Processes and Landforms, 31: 606-621.
12. Verstraeten, G. and H. Zhu, 2005. RUSLE applied in a GIS framework: calculating the LS factor and deriving homogeneous patches for estimating soil loss. International J. Geographical Information Sci., 19(7): 809-829.
13. USDA Soil Staff, 2004. Key to soil taxonomy, A basic system of soil classification for making and interpreting soil survey, USDA, Handbook, Washington D.C., USA.
14. 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.
15. FAO/UNEP, 1984. Provisional methodology for assessment and mapping of desertification. Rome: Food and Agriculture Organization of the United Nations,United Nations Environmental Programme, pp: 84.