INTEGRATION OF REMOTE SENSING TECHNIQUE AND GIS FOR EROSION RISK MODELING IN SYRIAN COASTAL ZONE

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ABSTRACT

Syrian coastal zone natural resources were exposed to severe pressure during the last two centuries. Large forestry areas were cut for different purposes and most of the remaining ones are degraded with different levels. The results of this study can be considered as fundamental and basic information about the status of natural resources and soil erosion severity as well as it allowed the production of guidelines and recommendations for the whole coastal zone management.

The study aimed to: 1) Implement a methodological approach and capacity building program, for supporting plans to control and manage land degradation in Syrian coastal zone, 2) provide the country planners and decision makers with thematic map (erosion risk map) which help them to know the level of sensitivity to erosion over the coastal zone, 3) provide the country planners and decision makers with technical tools for acquiring knowledge on causes and effects of land degradation, and 4) produce guidelines and recommendations for supporting coastal land degradation control and management.

The applied methodology is based on an holistic approach which, the main components of the land; such as soil, vegetation, geomorphology, hydrology are not considered individually but as a whole, they are mapped simultaneously, taking also into account interactions between them and man's influence, so that the result is something more than just the sum of all of them.

The methodology is mainly depending on: 1) the usage of Landsat TM 7 satellite image to produce the current land use map, 2) Geographic Information System (GIS) to produce different thematic maps 3)

field survey in order to collect the information related to reconnaissance survey and erosion risk estimation, and 4) programming special software and GIS module to estimate the soil erosion risk and to produce soil erosion risk map. This GIS module included most factors which influence soil erosion.

The achieved results are mainly relevant to erosion risk estimation, where areas and locations of different erosion risk classes were assigned (soil erosion risk map).

Based on the results of this study, the project working team was able to provide some general recommendations to be used as input data for the detailed analysis programs.

General recommendations for the land degradation management of the whole study area were set into two main groups. The first one is related to the ***technical issues*** that deal directly with erosion phenomena it self. The other one is related to the ***policies and strategies*** that designed for sustain management of the land.

Keywords: *Remote sensing, GIS, soil erosion, erosion risk map.*

INTRODUCTION

The issue of land resource conservation is strongly talked about now days in Syria like in all Mediterranean countries. However, in the coastal zone, where there are many natural resources have to be protected and conserved. Protection of natural resources will enhance the environment on one hand and decrease the degradation process on another hand.

Degradation processes are accelerated not only by natural assets of the landscape (relief, geomorphology, geology, soil characteristics, rain intensity…..) but also strongly by people intensity and human practices and activities (intensive agriculture, industry, transportation….).

The study aims to:

- suggest a model for soil erosion in Syrian coastal zone.

- Produce thematic maps (erosion risk map) which help country planners and decision makers to know the level of sensitivity to erosion over the coastal zone and this help them to take the right decision how to control the erosion.
- Introduce a new technical tools for acquiring knowledge on causes and effects of land degradation in the coastal area as well as with management tools for supporting the implementation of sustainable development action in the area.
- Produce guidelines and recommendations for supporting coastal land degradation control and management.

GENERAL DESCRIPTION OF THE STUDY AREA

Syrian coastal zone is located in the northwestern part of country. Bordered in the west by the Mediterranean Sea with coastline of about 220 km. The region can be viewed as a major natural resource and "transitional" in character, linking the Mediterranean Sea with arid zones of the interior Syria and the Arab world.

The coastal zone of Syria covers about 4190 km^2 (2% of the national territory). The region is divided into two governorates; Latakia governorate in the north with 2300 km^2 total area and Tartous governorate in the south with 1900 km^2 area.

Geomorphologically: the coastal region can be divided into 5 main geomorphologic areas: shore –line, coastal plain, hilly areas, river valleys, and mountainous areas.

Pedologically: Syrian costal soils can be divided into main five groups: coastal plain soils, piedmont soils, summit soils, river bed soils, and forest soils (Darwish, 1986 -GORS, 1991). The natural land cover of the coastal area in Syria is similar to those natural covers in all Mediterranean countries (Nahal 1984).

Climatically: the entire coastal region belongs to the Mediterranean humid or subtropical types of climate, with the amount of rainfall and temperature gradually increasing from the west to the east and decreasing from the higher to the lower slopes of the coastal mountains and from north to south down the Bassit block (PAP/RAC, 1990). Thus, a general characteristic of the coastal zone is a combination of high temperature and medium amount of rainfall. The annual temperature averages for Latakia and Tartous are almost 20 ^{o}C, as compared to 12.5 ^{o}C for Slenfeh, in the mountainous hinterland (Eid, 2004).

MATERIALS AND METHODOLOGY

A- MATERIALS

Satellite image

LandSat 7 satellite image (2 views, 174/35 and 174/36) covering the whole study area was used. This satellite image is collected in year 2001, spring time. The following processes have been done to the two views: Layer stuck, rectification, mosaic, false colour band combination, enhancement. Then visual interpretation was applied to produce land cover / land use map.

Arial photos

1/20.000 scale B/W aerial photos of the coastal area. 2 stripes (from the southern part of the study area) were not available. These photos were used to understand the land form. They used in parallel with the Landsat image to draw the land form map.

Topographic maps

Topographic maps for the study area are available at the 1/100 000 and 1/50 000 scale.

They used to produce different GIS layers.

B- METHODOLOGY

The study was conducted at the reconnaissance survey scale. It is particularly suitable to the assessment of land resources over a large area. It is based on an holistic approach (from the Greek "*olos*" meaning "all complete"), according to which, the main components of the land, such as soil, vegetation, geomorphology, hydrology are not considered individually but as a whole, they are mapped simultaneously, taking also into account interactions between them and man's influence, so that the earth surface is the result of something more than just the sum of all of them. The result of the applied methodology is a Land Unit Map, where the basic cartographic unit is represented by a portion of land composed by a series of "land facets", each of them considered to be homogeneous, at the scale of the survey, with regard to its geomorphologic, pedologic and vegetation characteristics.

Satellite images are essential tools of the survey as they provide a reliable basis for the interpretation of the landscape and allow a "landscape guided" approach (Zonneveld, 1979) to the survey of natural resources, resulting in a better cost-effectiveness of the work.

The methodology consists from the following steps:

1. Preparation of land unit map:

Based on the available materials, the land unit map was prepared. Every land unit consist from three parts: land system, land form and land use / land cover. These units are suggested by UNEP/MAP Environment Remote Sensing Regional Activity Centre specialists / Italy and modified by the author to suite the situation in Syria.

The proposed land system types, land form types and land cover / land use types are as following:

Land System types: Lower coastal Plain, Coastal Plateau, Steep Hills and Upper Plateau.

Land form types: Flat topped Crest, Sharp Crest, Rounded Crest, Fluvial Scarps, Badlands, Undulating Planation Surface, Flat Planation Surface, Erosion Slopes, Accumulation Foot Slopes, Accumulation Plain, Alluvial Valley, Fluvial Valley, Beaches and Coastal alluvial plain

Land Cover / Land Use types: Closed forest, Closed maki, Open forest, Open forest & shrubs, Open forest and olives, Open forest and fruit trees, Open maki, Open maki and olives, Citrus plantations, Citrus plantations and olives, Citrus plantations and field crops, Greenhouses and field crops, Olives, Olives and open maki, Olives and citrus plantations, Olives and greenhouses, Olives and open forest, Olives and field crops, Olives and fruit trees, Field crops, Field crops and citrus plantations, Field crops and greenhouses, Fruit trees, Fruit trees and open forest, Fruit trees and field crops, Urban, Sandy soil, Rock outcrops and olives, Quarries and Reservoirs.

Simplified Land cover / land use types: Closed natural vegetation, Opened natural vegetation, Olive plantation (dominant), Opened natural vegetation with olives, Fruit trees (dominant), Field crops (dominant), Green houses (dominant), Barren land, Water bodies and Urban.

2. Reconnaissance survey

Field work was done and forms of reconnaissance survey and erosion risk estimation were filled. The field work was done according to stratification method for selecting the sites for the investigation.

3. Data processing and Preparation of Erosion risk map:

Data collected were processed on spatial computer program and the results were transferred to GIS layer and used to produce the erosion risk map.

The erosion risk map was created; based on the land unit map and analysis of the relating factors. Values were given to these factors and transferred into rating numbers automatically. Sum of the rating numbers for all these factors were also calculated automatically. The extracted values referred to the soil erosion risk. Six soil erosion risks were put. Rating of factors is explained in table 1.

Table (1): Factors contributing in soil erosion and their rating:

Factors	Rating	Factors	Rating
Land cover/Land use types	1 - 12	Vegetation density	1 - 12
Slope gradient	1 - 32	Conservation practices	-6 - 0
Slope length	1 - 8	Depth of rills and gullies	0 - 4
Slope form	1 - 3	Spacing of rills and gullies	1 - 6
Soil texture	1 - 8	Mass movement area	1 - 3
Soil depth	0 - 3	Mass movement rate	1 - 4
Surface sealing	0 - 4	Sheet erosion activity	0 - 4

Six risk classes were suggested according to the rating sum. The following table explains this process.

Table (2): Ranking of the erosion risk classes

Class Description	**Rating sum**	**Erosion Risk class**
Not relevant	-999	0
Not or insignificantly susceptible	> 0 - 17	1
Slightly susceptible	> 17 - 25	2
Moderately susceptible	> 25 - 33	3
Highly susceptible	> 33 – 49	4
Very highly susceptible	> 49 - 65	5
Extremely susceptible	> 65 - 100	6

Rating values, rating sum and erosion risk classes were suggested after long discussion among expertises in the field of soil erosion and the author.

RESULTS AND DISCUSSION

Based on the applied methodology areas and locations of different water erosion risk classes were achieved. See table (3) and figure (1).

Table (3): Areas of every erosion risk class

Risk Class	**Risk Class ID**	**Area KM^2**
Not relevant	0	108.1610
Insignificant susceptible	1	604.2125
Slightly susceptible	2	470.2043
Moderate susceptible	3	1336.5183
High susceptible	4	918.6685
Very high susceptible	5	158.1534
Extremely high susceptible	6	48.2834
TOTAL		**3643.7631**

Knowledge on causes of land degradation process is needed in order to select, for each management area, the most appropriate actions for natural resources conservation.

Obviously, the scale used for such a study does not allow a detailed analysis of causes of land degradation with relevant preventive or corrective measures, although it provides the opportunity to assess priority areas for more detailed studies and to get an overview of the main causes of land degradation processes in these areas.

The torrential rains which are responsible for severe water erosion processes act over an environment where certain morphological characteristics (mainly slope) and land use/land cover patterns - as described by the reconnaissance survey - represent the two key factors to assess land degradation and to be taken into account for devising land management programmes.

Among other factors which play an equally important role, some soil features - such as soil texture - can be mentioned as affecting in turn water infiltration rate and, as a consequence, the infiltration/runoff ratio.

THE ROLE OF MORPHOLOGY IN SOIL EROSION

The morphological asset plays a key role in characterizing erosion-prone areas and in defining management plans aimed at facing similar phenomena.

Table 4 presents areas of different risk classes with different land system types.

Table (4): Areas of erosion risk classes (KM^2) categorized according to land system types

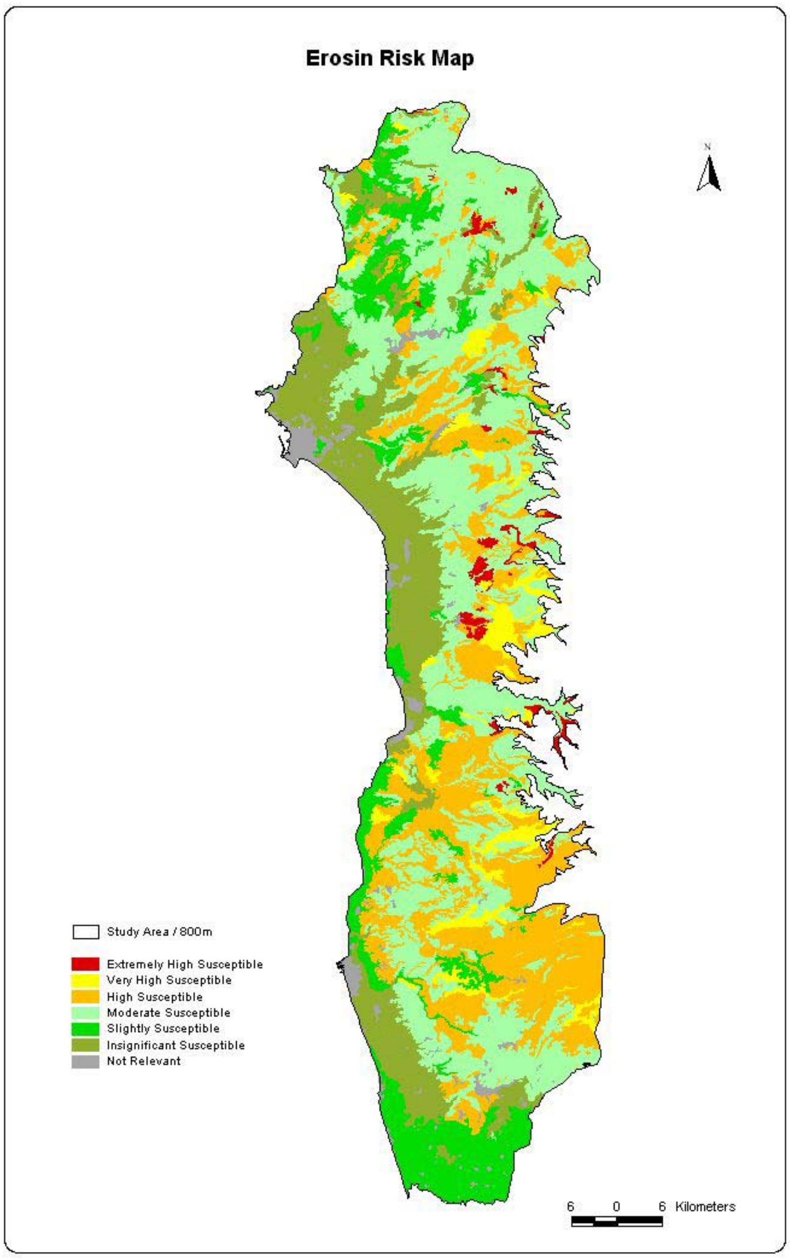
LAND SYSTEM TYPES	LS code	Not relevant	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5	Risk 6
Upper Plateau	A	1.29	0.00	23.11	22.90	0.00	0.00	0.00
Steep Hills	B	10.09	80.11	107.15	1032.39	738.91	124.00	30.74
Coastal Plateau	C	4.60	11.37	27.48	249.20	161.73	34.15	17.55
Lower Coastal Plain	D	92.19	512.73	311.87	32.02	18.03	0.00	0.00
Sum		**108.17**	**604.21**	**469.60**	**1336.51**	**918.66**	**158.15**	**48.28**
Form total		**2.97**	**16.58**	**12.89**	**36.68**	**25.21**	**4.34**	**1.33**

Slope gradient

Slope gradient is undoubtedly the most important factor in assessing erosion risk is the slope value. It weights half or more the total erosion risk value (up to 32 of rating sum). High slope gradient is mainly occurs in the steep hills. This land system class comprises 58.28% of the total study area with an area of 2123.39 km^2 (table 4). It is either covered by natural vegetation with different level of degradation or by some agricultural uses mainly olive plantations.

42% of the steep hills in the study area (893.65 km^2) classified as highly, very highly or extremely highly susceptible to erosion (Table 4).

Figure (1): Erosion risk Map



Slope length

Slope length becomes a critical factor in the land system of Lower Coastal Plain, where it plays a quite important role on more gentle slopes in which the presence of long slopes with quite uniform slope gradient contributes to the increase in runoff speed and in the erosive power of water.

Lower coastal plain in the study area comprises 26.54% of the total study area with an area of 966.83 km^2. Most of this land is arable land and used for agricultural purposes (crops, green houses, citrus…)

The highest three risk classes falling in the lower coastal plain comprises 1.86% (18.03 km^2) of this land system category; while the lowest three risk classes comprises 88.60% (856.61 km^2) of this land system category (Table 4).

THE ROLE OF LAND COVER / LAND USE IN SOIL EROSION

Syrian coastal zone shows, besides a quite high variety of morphological characteristics, some dominant patterns of land use types characterised by specific erosion risk classes.

Table 5 shows the data of erosion risk classes based on simplified land cover / land use types (data of the detailed land cover / land use types are not presented). Table 6 shows the simplified land cover / land use classified based on land system types.

Olive plantations

41.37% of the study-area (1507.16 km^2) is marked by olive plantations. It is characterised by a plant spacing which usually leaves more than a half of the soil surface unprotected from erosive action of raindrops. Table 6 shows that the most of those plantations are located on hilly areas, with morphologies varying from gently undulating to steep slopes and calcareous soils particularly rich in gravel and stones. About 40% of this land use type falls in the highest three erosion risk with an area of 596.46 km^2 (16.37% from the total study area).

Table (5): Areas of erosion risk classes (KM^2) categorized according to simplified land cover / land use types

Simplified LU / LC types	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5	Risk 6
Opened natural vegetation	0.00	48.68	42.02	78.77	41.77	23.87
Closed natural vegetation	66.21	22.17	316.08	0.01	0.00	0.00
Olive plantation (dominant)	24.62	106.62	779.45	537.12	59.34	0.00
Opened natural vegetation & olives	22.01	5.88	56.21	266.55	45.44	0.00
Fruit trees (dominant)	445.67	70.76	130.28	18.03	11.61	6.87
Field crops (dominant)	35.45	215.49	0.00	0.00	0.00	0.00
Green houses (dominant)	10.25	0.00	0.00	0.00	0.00	0.00
Barren land	0.00	0.00	12.47	18.20	0.00	17.55
Water bodies	0.00	0.00	0.00	0.00	0.00	0.00
Urban	0.00	0.00	0.00	0.00	0.00	0.00
Sum	**604.21**	**469.61**	**1336.52**	**918.67**	**158.15**	**48.28**
% Form total	**16.58**	**12.89**	**36.68**	**25.21**	**4.34**	**1.33**

Table (6): Areas of simplified land cover / land use (KM^2) falling in different land system types

LS / LC	**Upper Plateau**	**Steep Hills**	**Coastal Plateau**	**Lower Coastal Plain**	**Not Relevant**	
Land cover / Land use Types	**A**	**B**	**C**	**D**	**NR**	**SUM LC**
Open Natural Vegetation	0.852	205.553	24.760	3.941	0.000	**235.106**
Closed Natural Vegetation	3.411	391.995	2.360	6.702	0.000	**404.468**
Olives Plantations	41.749	1002.842	368.703	93.864	0.000	**1507.158**
Open Natural Vegetation / Olives	0.000	369.151	19.818	7.117	0.000	**396.086**
Fruit Trees (Dominant)	0.000	128.181	54.866	500.161	0.000	**683.208**
Field crops (Dominant)	0.000	0.000	0.000	250.940	0.000	**250.940**
Green Houses (Dominant)	0.000	0.000	0.000	10.253	0.000	**10.253**
Barren Land (Dominant)	0.000	15.588	30.965	7.444	2.083	**56.080**
Water Bodies	0.000	0.000	0.000	0.000	19.807	**19.807**
Urban	0.000	0.000	0.000	0.000	80.491	**80.491**
SUM LS	**46.012**	**2113.310**	**501.472**	**880.422**	**102.381**	**3643.590**

Arable land

At lower altitudes, on the coastal plain, land use is characterised by tree plantations (especially citrus), intensive farming and field crops. See table 6.

Arable land is also a critical area to be highlighted in the coastal plain, where high slope length - even if with a moderate slope gradient – combined with agricultural activities (in particular, citrus and other fruit trees plantations and field crops) may induce erosion phenomena.

The same trend is occurring with the other agricultural land use types (field crops and green houses.

Natural vegetation cover

61.42% from the opened natural vegetation is falling in the highest three risk classes with an area of 144.4 km^2 . The density of vegetation cover of this land use type has different percentage, ranging from 30% to 70% with different slope gradient and different level of degradation.

The closed natural vegetation has different trend to erosion risk. About 100% of this land cover type is falling in the in the lowest three erosion risk classes with an area of 404.46 km^2. The vegetation cover of this land cover type is very dense with coverage percentage more than 80%. This dense vegetation cover absorbs the rain drops strikes and minimizes the influence of the water on the soil even if this vegetation locates in very sloppy area. About 78% of this land cover type is falling in the risk class 3 with an area of about 316 km^2. This is because most of this cover type is falling in very sloppy areas.

Based on the field survey evidence, most of these lands still pure natural areas with very dense vegetation cover. Decreasing the vegetation density in this area can increase rapidly the erosion risk to higher classes. So, in such areas vegetation cover plays more important role than the slope gradient in generating water soil erosion.

Urban

90 % of the urban areas are falling in the coastal plain with an area of 80.48 km^2 (about 11% of the lower coastal plain) which is the fertile arable land. This land is used from hundreds years for agriculture. It is highly recommended to keep this land for agriculture and look for less fertile land for urban expansion.

RECOMMENDATIONS FOR THE WHOLE STUDY AREA MANAGEMENT

General recommendations can be set into two main groups. The first one is related with ***technical*** issues that deal directly with erosion phenomena it self. The other one is related with ***policies and strategies*** that design for sustain management of the land.

RECOMMENDATIONS AT THE TECHNICAL LEVEL

- Protect, conserve and improve the vegetation cover on steep and very steep slopes.
- Establishing natural protected areas.
- Replanting fruity forestry species in the cleared forested areas.
- Establishing contour stones terracing in sloppy areas and maintain these terraces annually and when needed.
- Establishing bench terracing and contour ploughing in less sloppy areas.
- Improve and support the modern irrigation systems.
- Increase the projects of water catchments (dams, reservoirs and tanks).
- Stop the practice of burning the agricultural residuals, especially on the boarders of the forest land in order to minimize forest fire risk.

- Restricting the urban expansion in the forest land and arable land.

RECOMMENDATIONS AT THE POLICIES LEVEL

Policies should be followed in order to protect the soil from erosion. The following are some political recommendations which can improve the land conservation:

- Creating a cohabitation relationship between the local people and the forest land.
- Strictly applying the environment and forest law.
- Establishing land degradation monitoring system (monitoring indicators).
- Improve the awareness system about land degradation and land conservation.
- Improve the capacity building for the related staff who are working in the field of land degradation and natural resources conservation.
- Conducting researches and projects at national level related to land degradation and sustainable development and involving the participation approach in such kind of projects.
- Involvement in international projects which are relevant to land degradation.
- Improve the governmental agricultural loan system in order to facilitate the construction of the terraces and applying modern irrigation system.
- Avoiding construction of new roads through forest lands unless, it was for actual and necessitous needs and if can't be helped, applying geometric basis for constructing.

CONCLUSION

Management and conservation of natural resources can be well done by the usage of modern technologies like Remote Sensing RS, and Geographic Information System GIS and Global Positioning System GPS. On the other hand modelling and producing thematic maps can give better understanding for the phenomena under investigation and give the country planners and decision makers easier way to decide better planning for the future.

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