Study of Erosion Processes Using Satellite Data

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Abstract

The Spanish Mediterranean coast was defined by the Risk of Desertification World Chart (FAO, 1977) as the only European zone with very high erosive risks. This fact, joined to the increasing worries regarding the erosive processes analysis, has led to the presentation of several studies from different points of view.

Remote sensing has been proved as a very useful tool to work with in this matter. In the study we have done the methodology to follow in order to achieve an erosion risk map from satellite data has been developed in the Adra river basin (Almeria, Spain).

Its validity at a river basin level as well as its extrapolability to other Mediterranean areas has been also taken in account.

Finally, the methodology that has been proposed in this job is compared to traditional methods used for risk mapping

INTRODUCTION

Remote sensing has been defined as the capability to obtain information about an object without keeping contact with it, being this term restricted to those methods that use reflected or objects' emitted electromagnetic energy, what excludes electric, magnetic and gravimetric research due to the fact that they measure strength fields (SABINS, 1978).

This technique is based on the fact that Earth's surface materials have their own spectral response by which we can identify them.

Researches and publications about remote sensing applied to erosion study are relatively new and their development has followed a parallel way to the one followed by multispectral scanners and informatics.

Until the present moment, Landsat MSS and TM images have been essentially used in the coverage factor evaluation for erosion risk studies and to detect and quantify eroded areas. Anyway, these kinds of data have been considered priceless in the development of erosion control plans due to the fact that they make up a reliable data source.

The use of conventional information added to satellite images increases the amount of data provided by these ones. This consideration raises the possibility of integrating all those data with the idea of achieving erosion risks cartography.

METHODOLOGY

In order to properly evaluate the different degrees of hydric erosion in the test area, it is needed to resort to the relevant sources of information by studying the factors that produce it (KEECH, 1978).

In our case, it has been observed that the main factors are the following:

- state and characteristics of vegetation coverage,
- slopes,
- ground erosionability.

Regarding climatic factors, -they also contribute with an important weight to erosive processes-, it can be considered that they are included in the vegetation state of development, drainage net identification or in the topographic features for that areas that otherwise are homogenous. This way we do not need to use these kinds of data (KEECH, 1978).

Quantification of resulting effects could let us settle the intensity of erosive processes by computing the yearly soil losses.

This quantification can be obtained using the *Universal Soil Loss Equation (USLE).*

This equation can be written as:

$$\mathbf{A=KxRxLxSxCxP}$$

where:

A: soil loss estimation (Tm/Ha/year)

K: soil erosionability

R: rain erosivity

L: slope lenght

S: slope angle

C: coverage factor

P: conservative practice

Nevertheless, according to HUDSON (1978) as this equation has been developed for the Eastern United States, the extrapolability to areas as Europe or Africa, where the soil types and characteristics as well as crops growing practices are different, is not justified. We have to add also that it is needed to test experimentally the empirical relationships the ecuation works with if we want to apply it out of the tangle where it was developed.

For these reasons, it has been considered that the parameters that make up the ecuation can be grouped together in a way that makes it possible to extract the information from satellite images. Thus, LxS will be represented by the topographic slope percentage, KxR can be evaluated considering the drainage net density and CxP by the vegetation state and characteristics. This assemblage agrees with the erosion causing factors that have been set for this area.

Data regarding each of the previous groups can be extracted from different data sources:

state and characteristic of vegetation coverage can be defined working with satellite images.

- A digital elevation model can be created in order to use it for the slopes percentages obtention.
- drainage net can be interpreted from aerial photographs or satellite images with enough spatial resolution.

It is necessary to integrate the information given by the thematic maps showing the variables in order to obtain an erosion risks cartography. The integration will be possible due to the data compatibility when we work with a geographic information system that is able to work with either raster or vector data.

Once this obstacle has been overcome, the maps are merged so that we will have, firstly, a substratum fragility map and, as a final product, an erosion risk map representative for the basin we have studied.

STUDY AREA CHARACTERISTICS

The Adra river basin is located in the border between Granada and Almería provinces, being included in the so called Alpujarras natural region (figure 1).

The basin has a relief axis in the North-South direction, making the area topography very complex because of the heterogeneous geologic structure and geomorphology. These characteristics influence on some features like:

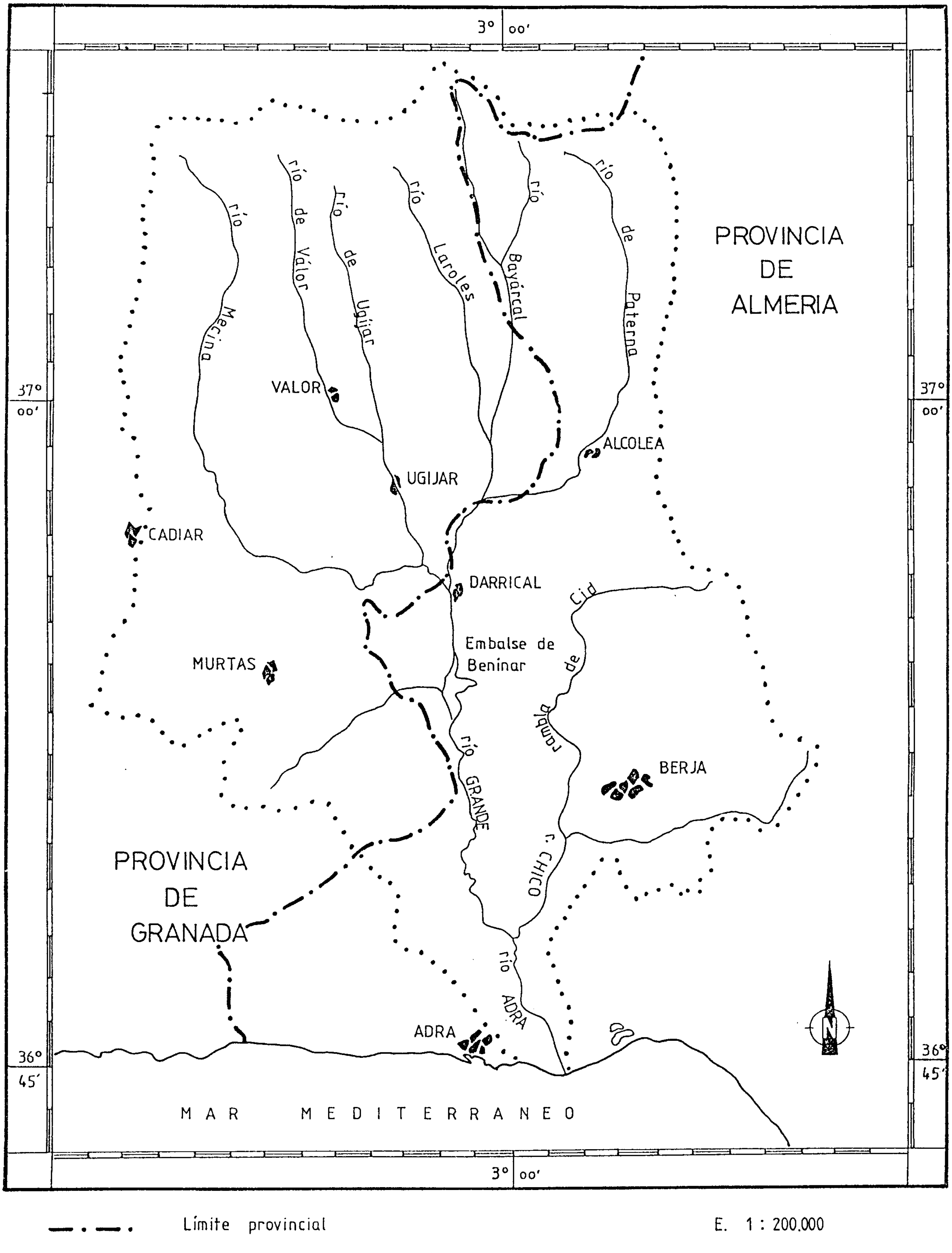
- Contrast marked height differences,-the slopes being much stepped-. This factor allows us to find crops growing in places where the slope or erosive barriers would act as a very big obstacle in different

  areas.
- Drainage net growing deeper.

Postorogenic intense activity (neotectonics) is the origin of the relief structures.

Regarding the climate, it can be considered as a typical Mediterranean one showing some slight differences as the orography of the area changes.

As for the hydrology, two sections are distinguishable: the Cuenca Atta zone that includes the Ugíjar and Alcolea sub-basins with a moderately nival behaviour and, the Cuenca Baja with a pluvial one. The drainage net belongs to the dendritic kind with very high densities and shallow run-off rates. On the whole, the equilibrium state profile has not been reached as the number of riverbeds with an upper order is not very important.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PROVINCIA DE ALMERIA
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río Mecina
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río de Ugíjar
río Laroles
río Bayárcal
río de Paterna
VALOR
UGIJAR
ALCOLEA
CADIAR
DARRICAL
Embalse de Beninar
MURTAS
rambla de Cid
BERJA
río GRANDE
r. CHICO
río ADRA
ADRA
N
MAR MEDITERRANEO
Límite provincial
Límite de la cuenca hidrográfica
E. 1 : 200.000

Finally, regarding vegetation, their main attributes are the following:

- Scarcity of climatic communities. There are only wide areas of Mediterranean evergreen oaks.
- Subserial brushwood occupies the Sierra Nevada and Sierra de Gádor medium heights.
- Serial brushwood is the widest spread unit.
- Units that have their origin in human-made factors such as crops or pines afforestation are more common than natural vegetation. They are placed from flat river valleys *(ramblas)* to step slopes, sometimes protected against erosion with terraces.

DATA SOURCES

The sources used for the development of the proposed methodology are:

- *Landsat-5 TM images*

  Adra river basin is included in the 200-034/ 4 scene (figure 2). The date chosen for the study was 7/16/86 after having considered the vegetation phenologic state at this time of the year.

- *Cartographic data*

  Topographic maps at a scale 1:100,000 corresponding Guadix (11-21) and Adra (11-22) among other ones. They were used in the digitizing process.

- *Aerial photographs*

  The ones we worked with belong to the 1984-1985 National Geographic Institute flight covering the Aldeire (1028) and Adra (1043) maps.

DATA PROCESSING AND PRODUCTION

The aim that has been pursued in this phase of the study is to produce thematic maps that could be proved as indicative of the factors that were previously considered as erosion causing.

1. **Landsat images:** A maximum likelihood supervised classification was done in order to produce a thematic map that shows different kinds of coverage. This process was carried out after the images had been properly corrected (radiometric and geometric corrections).

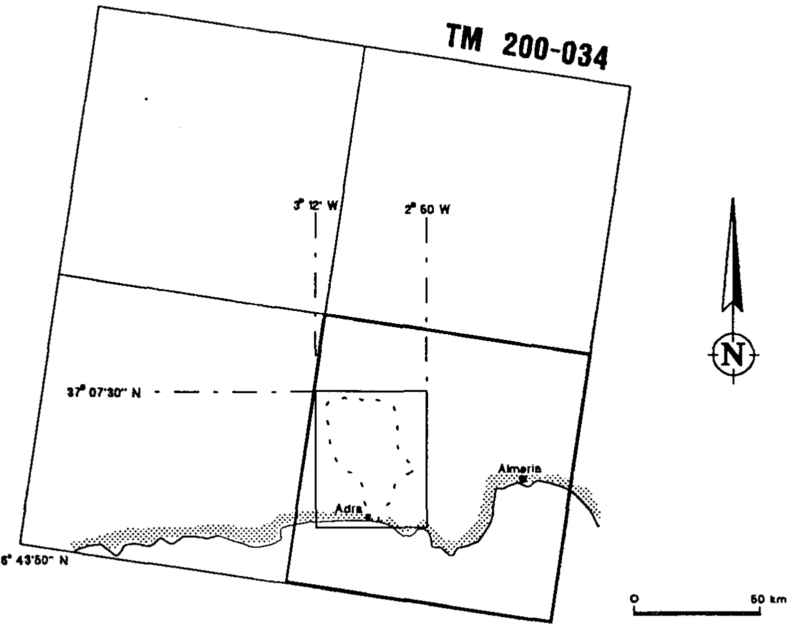

Figure 2. Study area situation in the Landsat system of reference.

The achievement of this aim follows a certain path that begins with the building of a false colour image after taking in account the contribution in terms of information that each of the TM bands gives us. The false colour image chosen is used in the training areas selection process needed to carry out the classification. Sampling over these areas was also necessary to be able to make a classes description.

Once the classified image had been obtained, vegetation density, substratum alteration and kind of coverage criteria were used to build an assemblage of the initial classes.

As a final product, after drawing the Adra basin perimeter, the thematic map was built. Eight classes of coverage were distinguished (TABLE 1).

Table 1. Area covered by the distinguished vegetation classes.

Vegetation class	Area (Has)	%
Irrigated lands	3.857,286	5,72
Brushwood Ss.	7.359,839	10,92
Sparse brushwood	20.897,140	31,10
Scrubs	17.245,680	25,59
Tree-covered areas	5.010,031	7,43
Mixed forest areas	4.858,878	7,21
Improductive	8.147,943	12,09

Gradient filters with North-South and East-West direction were firstly applied on the digital elevation model and two shady aspect images were obtained. The next step was the application of a mathematic formula considering both of them:

slope =100 x sqrt ((dfdx/30) x (dfdx/30)+ +(dfdy/30) x (dfdy/30))

where:

dfdx: image East-West filtered

dfdy: image North-South filtered

and 30 being the pixel value in metres.

This led us to produce a map where the slopes percentages from 1% to 100% could be seen as grey values. They where then grouped together considering the geomorphologic characteristics of the area and the final slopes map was this way obtained (TABLE 2).

Table 2. Surface covered by the slopes intervals.

Slopes Range		**Area (Has)**
1	0-12%	16.463,85
2	12-18%	11.156,63
3	18-24%	12.245,06
4	24-35%	18.713,36
5	>35%	13.211,16

2. Cartographic data

A digital elevation model was built by means of digitizing the curves in the scale 1:100,000 maps and interpolating linearly the values for each pixel. This model was used in the development of a map in which the slopes percentages were shown.

3. Aerial Photographs

Drainage net extraction was carried out by interpreting the aerial photographs. As this task was finished, it was digitized and a drainage net density map was built. A density slicing was carried out and then a low pass (smoothing) filter was run over it.

The drainage density map shows the net symmetry we have talked about previously.

RESULTS

The building of fragility degree and erosion sensitivity indices maps by processing the previous ones are the objectives pursued in this last phase.

The fragility degree becomes apparent when an analysis of the kinds of vegetation coverage and its distribution through the slopes range is made. To get to this map, the criteria that were taken in account were the substratum protection effect that each of the vegetation classes has and the changes it shows when the topographic slope increases. These criteria can be expressed in a bidimensional matrix (FIGURE 3).

Table 3. Bidimensional matrix for fragil.

ITY EVALUATION	**1**	**2**	**3**	**4**	**5**
Mixed forest	8	8	8	8	8
Tree-covered	8	8	8	8	8
Scrubs	8	6	6	5	5
Irrigated lands	7	6	6	5	3
Brushwood	6	5	5	4	4
Sparse brushwood	4	3	3	2	2
Improductive	1	1	o	0	o

Slopes percentages

where vegetation classes and slopes intervals are the entries and a group of values that increases as fragility decreases are the exits.

Again an assemblage of these values was made and a simplified fragility map with five classes was the result (TABLE 3).

From this map, an evaluation of the surface covered by each of the classes was carried out (TABLE 4).

Table 3. Fragility classes assemblage.

Table 4. Fragility intervals coverage areas.

Fragility degree	**Area(Has)**	**%**
Very High	8520, 511	12,63
High	23.633,570	35,05
Medium	21.891,880	32,46
Moderate	1712,506	2,50
Low	11.659,680	17,29
	67427,440	***99,98***

The erosion risk or ground potential erosion map achievement follows the same procedure than the previous one. This time, the maps that make up the data sources are the fragility one and the drainage density map.

The relationships that can be established between both of them is based in the fact that those areas where the drainage density rate is bigger are more liable to suffer edafic materials losses than the ones where it is smaller. Moreover, if a stepped slope and a scarce to bare coverage are added to that, the erosion risks in those areas will be the highest ones or vice versa.

On this basis, another bidimensional table was designed (TABLE 5) and, as for the previous cases the groups were built. A simplified map (figure 4) with nine classes (TABLE 6) results from this task. The surface covered by each of these classes is (TABLE 7).

Table 5. Bidimensional matrix to evaluate erosion risk.

Fragility

\	1	2	3	4	5
1	13	10	7	4	1
2	13	10	7	4	1
3	13	10	7	4	1
4	14	11	8	5	2
5	14	11	8	5	2
6	14	11	8	5	2
7	15	12	9	6	3
8	15	12	9	6	3

Table 6. Erosion risk intervals: assemblage.

HIGH	**MEDIUM**	**LOW**
Medium	Low	Minimum
7	4	1
High	Medium	Low
8	5	2
Maximum	High	Medium
9	6	3

FRAGILITY

Table7 Erosion intervals areas coverage.

Risk	Area (Has)	% Area
Minimum (1)	9549,226	13,43
Low (2)	3643,536	5,12
Low (4)	893,826	1,25
Medium (3)	12594,96	17,66
Medium (5)	8971,68	12,68
Medium (7)	1487,628	2,09
High (6)	17874,70	25,15
High (8)	13965,157	19,65
Maximum (9)	2077,105	2,92
Total	**71.057,78**	

A 2.92% of the basin surface belongs to the maximum erosion risk class. This one is mainly related to badlands and river margins where the slope percentage is very high. As a general rule, terrains with a higher risk degree used to cover approximately the 27% of the whole basin. So, as a conclusion, we can consider that erosive processes in the river Adra basin fall within a very important magnitude category.

CONCLUSIONS

Remote sensing data have been proved as a reliable and useful data base in erosion studies in the Adra river basin. Landsat-5 TM images provide us with high spatial and spectral resolution source that let us accurately identify the areas where these processes are taken place.

The final map that has been reached through the application of the proposed methodology is a document that properly shows the erosive risks for the study area. Thematic maps validity has been tested in a field study where it was also noticed that the amount of information provided by the digital classification of coverage is superior to the one from different sources like Crops and Uses Maps.

Concerning the methodology itself, we consider that, taking in account the results obtained, its validity has been also proved in the study area. Nevertheless, field data acquisition is also an interesting factor to consider as they could become a basis to check our results with in case it was translated to a numerical basis.

As for the documents we have produced, a qualitative assessment on erosive processes state has been carried out. Anyway, quantification would be also feasible by extrapolating properly to the Mediterranean area the values tabulated for the USLE equation parameters or measuring and sampling (soil losses estimation) in the field.

Taking in account the model we have developed and, being the Adra river basin considered as a typical Mediterranean one, the extrapolability of this methodology to other areas and, by these means the obtention of a regional cartography turns out to be possible.

Finally, comparing remote sensing data to the ones that conventional methods give us, the first ones show great advantages not only regarding the amount of information we can deal with but also because of the speed and accuracy their processing involves and, also the possibility of multitemporal assessment they provide to our studies.

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