ANALYSIS OF WATER EROSION USING GIS AND REMOTE SENSING FOR THE MANAGEMENT OF PROTECTED NATURAL ENVIRONMENTS IN THE SOUTH OF THE PROVINCE OF SALAMANCA (SPAIN)

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1. Introduction

The soil is a natural resource that must be conserved in protected natural areas since it is one of the determinant physical supports in territorial planning because it governs its different uses. Accordingly, specific studies must be carried out aimed at estimating soil losses at individual project level and at the general level of Natural Environments in order to establish methodologies for the control and ordering of activities, above all in protected environments whose focus is on sustainable activities. The basic objective should delimit different erosive forms where best it reflects the risk of water erosion (gullies, rills) and the degree (weak, light, important, and burden) and the processes induced (slides, scarp, remontant erosion...) in addition the evolution with time.

2. Methodology

The study zone is the Protected Natural Space of "Batuecas-*Sierra de Francia"* and the Community interest site (LIC) of Quilamas: both sectors are included in the National Topographic Map (MTP) at 1/50,000 scale corresponding to Serradilla del Arroyo (526), Tamames (527) NE Martiago (551), Miranda de Castañar (552) and N of Hervás (575).

In the first phase, Geographic Information Systems (GIS- ArcGis 9) were used to determine the potential risk of erosion and generate models and cartographies of erosive risk by means of the analysis of a relational database, which allows classifications, map algebras etc., to be elaborated. Integrated in this database are the basic thematic parameters: the R, K and LS factors -of the Universal Soil Loss Equation (USLE)- following the methodology used by Wischmeier & Smith (1978) in Morgan & Kirby. (1984). These specific cartographies were superimposed to establish the synthetic cartography of potential erosive risk (Graña et al., 2003).

In a second phase, we obtained a cartography of the plant cover, or C factor, from the current synthesized map of vegetation, and performed a field campaign to characterise each patch of vegetation selected and determine more precisely the parameters affecting the C factor (height of tree canopy, percentage of organic matter, percent area of tree cover, shrub cover, etc) owing to its importance since it significantly reduces the risk of soil erosion. The use of remote sensing techniques (PCI v8.1) allowed us to delimit the highly eroded sectors, with gullies and rills, by use of multitemporal scenes from Landsat-5 satellite images, Thematic Mapper ™ sensor. "Fig. 1".

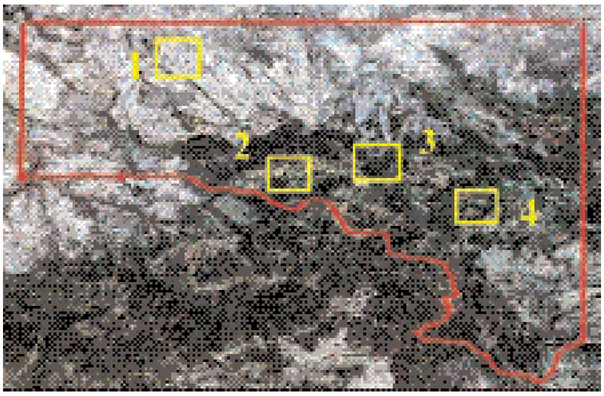

Fig. 1. Satellite image showing some degraded sectors with erosion in the form of gullies and rills.

The values of the plant cover are a function of the emitivity of each surface cover in different zones of the electromagnetic spectrum, using a series of indices, such as the vegetation index (VI) or the normalized vegetation index (NVI) (Van Der Knijff et al., 2000).

The classification and later grouping of the different digital levels of the image allowed new values of the plant cover to be added to the database of the GIS, together with observation of the erosive forms present throughout the natural environment (gullies, rills…). Unsupervised classification categorizes the pixels of the image according to spontaneous classes, grouping them as a function of similar spectral values. This classification helps to understand the potential classes of the image and affords a preliminary interpretation of the sectors with erosive processes and forms (gullies) and plant covers (Toutin, 2004).

The conservation practices factor (Factor P) is taken as null (owing to its scant importance) so that, depending on the estimation of soil losses, the optimum conservation measures for each degraded sector can be determined.

Finally, in a third phase we performed a cross of the potential erosion map and the plant cover map, obtaining a map of current erosion "Fig. 2".

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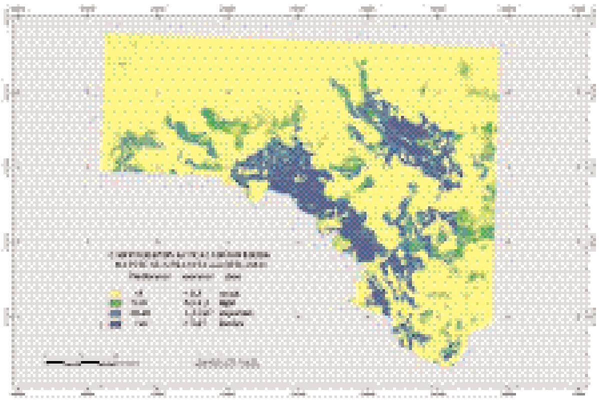

Fig. 2. Cartography of actual erosive risk.

We also carried out a detailed analysis of the zones where the erosive risk was high, delimited in the previous phase with remote sensing based on the spectral contrast of reflectivity values on the eroded and gullied surfaces "Fig. 3".

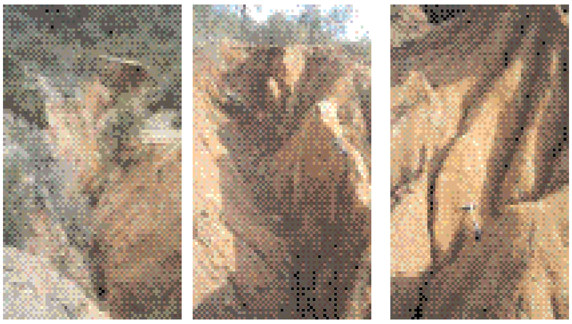

Fig. 3. Gullies with a depth of about 3 m in the Monsagro (left) and Aldehuela de Yeltes (middle and right) sectors.

These areas affected by accelerated erosion (badlands, rills, ravines…) were located in aerial photographs from different years (1956, 1978, 1990 and 1999) and were interpreted and plotted on the orthophoto and map at 1/10,000 scale of the studied area. Digitization of these areas allowed us to assess the retraction of the different scarps and predict, with GIS, the temporal morphological changes and the current and future evolution by estimation of the relative erosion rates and the effect on the extent and magnitude of the degraded zones and their effect on landscape quality.

In these tasks, erosion spikes were emplaced and pins in the zones of gully retraction with a view to quantifying erosion rates at individual sites or by sectors in the future.

3. Results and conclusions

Calculation of potential and current erosion in the Protected Natural Environments of "Batuecas-Sierra de Francia" and Quilamas has allowed us to estimate the degree of soil loss; this qualitative evaluation, based on parametric models, was then related to individual quantitative assessments (erosion spikes and pins….).

Joint use of GIS techniques and remote sensing helped to establish the potential zones of water erosion, delimiting the most problematic areas and using them as training areas to determine and characterise erosive forms (layer erosion, gullies, rills….) developed in each sector, bearing in mind the influence of the parametric factors (lithology, slopes, rainfall and vegetation).El riesgo de erosion actual, es altoen las zones elevadas de las sierras,

Multitemporal analysis of images (orthophotos, aerial photos and Landsat images) helps in the assessment of the rate of erosive processes and in estimating the degree of degradation that may be present in each zone analysed, distinguishing the zone with the greatest natural environmental impact as regards such processes, and hence making it easier for the management of the natural environment to establish the most appropriate conservation practices for each sector (P factor).

The field analysis in the training areas has allowed us to know the effect of the erosive processes as a function of the different lithologies with mean depth data for the different substrates: detritic Tertiary (3-4 m), granite (1-2 m) and slates (< 1 m).

This GIS and remote sensing analysis favours the elaboration of cartographies of the present and future risks of soil loss, which may facilitate the tasks of prevention and detection in the location of different activities and influence in the cartography of landscape naturalness and quality.

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