



Assessment of soil erosion at national level: a comparative analysis for Spain using several existing maps

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Abstract

Soil erosion has been recognised as a critical environmental issue leading to soil degradation and desertification in Mediterranean areas. Due to the seriousness of the environmental and socio-economic impacts associated to the process at different scales, many studies have faced the process at global, national, regional and local levels.

At national level, the quantification and assessment of soil erosion is a basic step to elaborate and promote environmental policies that help decision-makers undertake appropriate action in combating soil erosion and its consequences. Adequate application of such policies on the basis of a spatial knowledge of the process is crucial to maintain and even improve the quality of soil resources.

However, the analysis of some existing cartographic documents reveals some discrepancies. A comparison of several studies (ICONA, CORINE and GLASOD) assessing soil erosion at national level in Spain has been carried out. The analysis using the maps of soil erosion presented by these studies shows differences in the spatial representation of the process. This may be due to the different methodologies, input data and scales used.

1 Introduction

Soil erosion remains a serious problem in many areas of the European countries, increasing the risk of desertification in the most vulnerable areas, particularly in the Mediterranean region. As an estimation about 115 millions ha are suffering from water erosion [1].



The main causes of soil erosion are inappropriate agricultural practices, deforestation, overgrazing and construction activities [2] [3] [4] [5].

On-site effects of soil erosion usually consist of a decrease in soil depth, a selective removal of fine soil material and of plant nutrients, and in more severe cases the uprooting of plants and/or trees and dissection of the terrain by rills and gullies. Off-site effects may consist of land and crops down the slope being covered with a layer of sediment, deposition of eroded material in riverbeds, lakes, reservoirs and irrigation channels, and pollution of streams by sediment and chemical substances [6].

In order to implement environmental policies and strategies for combating these effects there is a need for spatial data about soil loss by accelerated erosion. At the European level, the GLASOD [7] is the only study giving an overview of the extent of soil degradation by water erosion for all the European countries at a scale of 1:10 000 000. It has been actually used by the European Environment Agency (EEA) for assessing the state of the environment in Europe [8]. This Agency supports the European Commission in developing and promoting policies for environmental conservation. Considering the implications that such policies could have in Mediterranean countries where soil erosion is a critical issue the emerging question is how reliable is the GLASOD map in representing soil erosion for European Mediterranean countries. Information contained in the GLASOD map was compared with available information on soil erosion existing in such countries. This paper presents the results achieved for Spain. For other Mediterranean European countries (e.g. Portugal and Italy) can be found elsewhere [9].

Two maps were used to perform the comparative analysis. On the one hand, the erosion map at the scale of 1:5 000 000 from the CORINE project [10]. On the other hand, the erosion map at the scale of 1:2 000 000 carried out by ICONA [11]. The latter synthesises information from studies dealing with soil erosion of watersheds at the scale of 1:400 000.

2 Approach for comparisons

For making possible the comparative analysis, the equivalencies between the types of erosion defined in each map were previously established (Table 1).

Table 1. Equivalencies between the GLASOD, MOPT and CORINE map legends. Source: Sánchez *et al.* [9].

| GLASOD | MOPT | CORINE |
|----------|--|----------|
| Extreme | Extreme (>200 t/ha/year) Very High (100-200 t/ha/ year) | Extreme |
| Strong | High (50-100 t/ha/ year) | |
| Moderate | Moderate (12-50 t/ha/ year) | Moderate |
| Low | Low (6-12 t/ha/ year) Very Low (0-6 t/ha/ year) | Low |

The differences that come out when comparing the different studies are described in terms of underestimate (-) and overestimate (+) of the GLASOD map values in relation to the other two maps, with the following gradation (Tables 2 and 3):

Table 2. Qualification of differences of water erosion degrees between the GLASOD and the MOPT maps. Source: Sánchez *et al.* [9].

| | Soil erosion map (MOPT, 1991) | | | | |
|--------|-------------------------------|------------------|----------|------|-----------------------|
| | DEGREES | Very low/ Low | Moderate | High | Very high/ Extreme |
| GLASOD | Light | | - | -2 | -3 |
| | Moderate | + | | - | -2 |
| | Strong | +2 | + | | - |
| | Extreme | +3 | +2 | + | |

Table 3. Qualification of differences of water erosion degrees between the GLASOD and the CORINE maps. Source: Sánchez *et al.* [9].

| | CORINE | | | |
|--------|--------------------|-----|----------|------|
| | DEGREES | Low | Moderate | High |
| GLASOD | Light | | - | -2 |
| | Moderate | + | | - |
| | Strong/ Extreme | +2 | + | |

It should be pointed out that these maps have been produced using different methodologies. An expert-based approach was used for the GLASOD map whereas a modification of the USLE approach for CORINE and ICONA maps. The comparative analysis is focussed on the spatial representation of soil erosion and the discussion of the methodologies used is out of the scope of this paper.

3 Results and Discussion

The analysis carried out reveals that in general terms the GLASOD map does not match correctly the process of soil erosion in Spain. Differences identified through the comparison of the GLASOD map with the ICONA map are shown in Table 4. As examples:

- The Cantábrica Chain, the Vascos Hills and a wide area of the provinces of Pontevedra and Orense are underestimated.
- The Ebro valley is also underestimated specially the area close to the Costero-Catalana Chain.

Table 4. Summary of differences between the GLASOD and MOPT maps. Source: Sánchez *et al.* [9].

| CATCHMENTS | -3 | -2 | - | + | +2 |
|-----------------------------|-------------------------------|--|---|---|---|
| NORTE | Nervión Oría-Urumea | La Limia area | Cantábrica Chain Vascos Hills Provinces of Pontevedra- Orense | | |
| DUERO | | | | El Abadengo Ibérico Chain Central Chain | |
| TAJO | | | | Province of Cáceres (southern) Gredos and Guadarrama Mountains Ranges Corridor between Alberche and Jarama rivers Alcarria | Mountains of Albarracín |
| GUADIANA | | | Hills of Toledo Mountains of Almadén | La Mancha Badajoz-Mérida Plain of Huelva | |
| EBRO | Costero- Catalana Chain | | Logroño-Pamplona-Ejea de los Caballeros | Ibérica Chain | |
| PIRINEO ORIENTAL | | | | | Empordà |
| JÚCAR | | Palancia area | Los Serranos Alto Mijares Alcalatén Els Ports L'Alcoià | Coastal plain of Valencia-Castellón Baix Vinalopó region Ayora region Casas Ibáñez-Tarazona de la Mancha-Motilla del Palancar | Almansa area Altos de Chinchilla Llanos de Albacete La Plana de Requena-Utiel Mountains of Cuenca |
| SEGURA | | | Mountains of Subbéticas Chain between Jumilla-Pinoso | Hellín | Campo de Cartagena Low Segura |
| SUR | | Penibéticas Chain | | Vera-Mazarrón | Campo Antequera Hills of Baza Nevada Hills |
| GUADALQUIVIR | | Los Pedroches Countryside of Córdoba | | Úbeda-Linares-Jaén | Lowland of Granada Hoya Guadix-Baza Mountains of Segura Mountains of Cazorla |

- The Ibérica Chain, as a whole, is overestimated, specially the Mountains of Albarracín and the area through which the Jiloca river runs.
- In the centre of the Iberian Peninsula, the plains of La Mancha are overestimated, whereas the Hills of Toledo and the Mountains of Almadén remain underestimated.
- In the Mediterranean area, the Penibética Chain, the inland area of the province of Castellón (Els Ports) and the Costero-Catalana Chain are underestimated. On the other hand, the plains of Granada (*hoyas* of Guadix and Baza, lowland area of Granada), the coastal plain of the provinces of Valencia and Castellón and the area of L'Empordà in the coastal area of Cataluña are all overestimated.

It should be also highlighted that the map units set by GLASOD to assess the status of human-induced soil degradation are not homogeneous when related to the water erosion process in Spain. The most noteworthy case is a large unit in the mid-southern part of the Iberian Peninsula, which stretches across such different physiographic units as Morena Hills, Hills of Toledo, plains of La Mancha, *penillanura extremeña* and part of the Guadalquivir basin. Therefore, it would be a good idea to review the specifications of map units so that these units will be tailored to the physiography of Spain.

Comparison between the GLASOD and CORINE maps reveals the following differences:

Underestimated areas:

- (-2) Cantábrica Chain
- (-) Galicia, central area of the Northern plateau, Ebro valley, Hills of Gredos, Hills of Toledo, provinces of Badajoz and Huelva, Morena Hills, Penibética Chain, L'Alcoiá (province of Alicante) and Els Ports (province of Castellón).

Overestimated areas:

- (+2) The coastal plain of Valencia-Castellón.
- (+) Ibérico Chain, La Mancha, coastal area of Cataluña, northern of the Murcia Region and *hoyas* of Guadix and Baza (province of Granada).

After these results, a preliminary assessment of the reliability of the GLASOD map was extended to other European countries. This assessment as based on expert opinion. A questionnaire including key questions was prepared and distributed to the national experts. Specifically, the questions referred to the degree of match of the GLASOD map, the natural regions having high erosion risk, the areas with severe soil erosion (hot spots) and the availability of more detailed information. For most of the European countries the degree of match of the GLASOD map with other national and/or regional existing studies on soil erosion is moderate-low or even low (Table 5).

Table 5. Analysis of the GLASOD map by countries following the answers given by national experts to the questionnaire prepared.

Source: Sánchez *et al.* [12] ^(*) No answer to the questionnaire; ^(#) The expert did not make comments on the GLASOD map on water erosion. Therefore, it is supposed that the map is correct; ⁽¹⁾ Hot spots corresponding to these countries can be represented from the map made by De Ploey [13]. Also France, England and Greece are included in such map; ⁽²⁾ Studies on water erosion by catchments are published at the scale of 1:400.000. A synthesis at national level has been also made and published [11]; ⁽³⁾ A map showing the actual soil erosion risk in Germany is being compiled by BGR (Bundesanstalt für Geowissenschaften und Rohstoffe); ⁽⁴⁾ A map containing many years' average water caused soil losses in tons by ha and years and by districts is available [14]; ⁽⁵⁾ There is a project taking place now in which it is planned to identify erosion risk areas; ⁽⁶⁾ Water erosion maps have been produced as a joint effort of several research institutes in five Nordic countries. Such maps have not been provided; ⁽⁷⁾ Countries included in the map on water erosion risk made by the CORINE project; ⁽⁸⁾ A cartographic study on soil erosion at national level has been made by INRA-IFEN [15].

| COUNTRY | DEGREE OF MATCH (GLASOD MAP) | NATURAL REGIONS OF HIGH EROSION RISK | WATER EROSION "HOT SPOTS" | DATA ON SOIL LOSS AT NATIONAL OR REGIONAL LEVEL | STUDIES ON WATER EROSION AT NATIONAL OR REGIONAL LEVEL |
|------------------------|------------------------------|--------------------------------------|---|---|--|
| SPAIN | Low | Depicted by catchments | Represented at the scale given ⁽¹⁾ | By catchments and by administrative regions | Yes ⁽²⁾⁽⁷⁾ |
| PORTUGAL | Low | Non-depicted | Non-represented ⁽¹⁾ | Non-provided | Yes ⁽⁷⁾ |
| ITALY | Low | Non-depicted | Non-represented ⁽¹⁾ | Non-provided | Yes ⁽⁷⁾ |
| GREECE ^(*) | | | | | Yes ⁽⁷⁾ |
| IRELAND | High | Non-depicted | Non-represented ⁽¹⁾ | Non-provided | Unknown |
| ENGLAND ^(*) | | | | | |
| FRANCE ^(*) | | | | | Yes ⁽⁷⁾⁽⁸⁾ |
| THE NETHERLANDS | High ^(#) | Non-depicted | Non-represented ⁽¹⁾ | Non-provided | Unknown |
| BELGIUM | High | Non-depicted | Non-represented ⁽¹⁾ | Non-provided | Unknown |
| GERMANY | Moderate-Low | Non-depicted | Non-represented ⁽¹⁾ | Non-provided | Yes ⁽³⁾ |
| AUSTRIA | Low | Non-depicted at the scale given | Represented (unknown scale) | By districts | Yes ⁽⁴⁾ |
| DENMARK | Moderate-Low | Non-depicted | Non-represented ⁽¹⁾ | Non-provided | Yes ⁽⁵⁾ |
| SWEDEN ^(*) | | | | | |
| NORWAY ^(*) | | | | | |
| FINLAND | Low | Non-depicted | Non-represented | Non-provided | Yes ⁽⁶⁾ |

On the other hand, it seems reasonable that the spatial representation of the soil erosion process varies on the scale. This can be a shortcoming for making comparisons like those ones included in this paper. For this reason, the results achieved in this comparative analysis should be understood as an orientation rather than as determinant conclusion. However, even at the same scale differences may arise because of the methodology applied in each case for evaluating the process. This issue is illustrated in Figure 1.

According to the information provided by the ICONA map [11], the areas having extreme or very high soil erosion (hot spots) would be the following (Fig. 1A): Subbética Chain (provinces of Alicante and Murcia), Navarrés region (province of Valencia), El Maestrazgo (provinces of Teruel and Castellón), Alto Palancia and Alcalatén regions (province of Castellón), Puertos de Beceite (province of Tarragona), Costero-Catalana Chain (provinces of Tarragona and Lérida), Penibética Chain (provinces of Málaga and Granada: Contraviesa, Alhama, Tejada and Almjara Hills, Axarquía, Hills of Ronda), Morena Hills (Madrona Hills-province of Ciudad Real-, Los Pedroches-province of Córdoba-), La Limia (province of Orense), Hills of Toledo, Mountains of Almadén (province of Ciudad Real), lower catchment of Nervión (province of Vizcaya), Oria and Urumea (province of Guipúzcoa).

However, this spatial pattern of hot spots clearly differs to those shown in Figures 1B and 1C. In these last cases, information provided by the map of the CORINE project -high erosion risk areas- [10] and by the De Ploey's water erosion map [13] have been respectively considered.



Figure 1. Spatial pattern of soil erosion hot spots according to different studies: (A) MOPT [11]; (B) CEC, [10]; (C) De Ploey, [13].



4 Conclusions

Although the GLASOD map [7] on soil erosion gives a general overview of the water erosion process at global scale, it does not seem adequate for undertaking such issue at more detailed scales (e.g. at European level) as pointed out by several scientists (e.g. Thomas & Middleton [16]). This is because some inappropriate interpretations may arise by translating information from global to national or regional situations.

The results achieved in this study are summarised in Table 5, and the following remarks come up:

- The GLASOD map only seems to be largely correct and acceptable at the scale represented for a few countries such as Ireland, The Netherlands and Belgium. For other countries the mentioned map matches very lowly (e.g. Austria) or moderately lowly (e.g. Finland) the water erosion process.
- There are some countries (e.g. Germany) where the validation of the GLASOD map is difficult because of information from more detailed studies is not yet available. In other cases (e.g. Norway, Sweden) no validation has been made at this stage.
- The comparison analysis between the GLASOD map and the present erosion risk map of the CORINE project reveals differences in spatially assessing water erosion in Spain. Such differences are accentuated when comparing the GLASOD map with information synthesised from maps prepared at a more detailed scale. In this country, it has been concluded that the GLASOD map does not correctly assess water erosion in much of its territory.

From the above, it seems that in general the GLASOD map does not evaluate properly the water erosion process at European level. According to Van Lynden [6] the major issues are:

- The scale, which is too small for evaluating the erosion process at the detail required for Europe.
- The kind of information made, which comes from the quantification of qualitative assessments based on subjective and qualitative data. Therefore, there is a need for objective and quantitative data reflecting adequately the factors and causes responsible of the erosion process in each country.

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