HOW CAN SOIL DEGRADATION BE APPROACHED FOR SUSTAINABLE LAND USE? A HOLISTIC PERSPECTIVE FOR THE MEDITERRANEAN REGION BASED ON SOIL QUALITY, CHARACTERISTICS AND PROCESSES

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Abstract
Both aggregated indices of soil characteristics and spatial analysis of soil degradation processes have been applied in the Mediterranean region for assessing soil degradation. However, these approaches do not consider soil as a complex body that holds a particular status according to its forming processes and the environmental conditions of an area. In relation to this, the recent concept of soil quality opens new dimensions to assess soil degradation according to the inherent characteristics of soil and/or referred to a specific land use. This paper discusses the possibilities offered by the concept of soil quality to assess through soil functions, criteria and indicators the extension of soil degradation in the Mediterranean Region, where some soils characterised as degraded soils are actually soils that are in equilibrium with environmental conditions according to their forming processes. The adequate assessment of soil degradation is crucial to propose and implement management practices that guarantee a sustainable use of soil resources.

Additional Keywords: soil, protection, sustainable land use planning,

Introduction

Soil degradation has became a relevant environmental issue in the Mediterranean region due to changes in the land use pattern (e.g. agricultural intensification, urban-industrial expansion) occurred in the last decades. Approaches for assessing soil degradation mainly deal with: (1) application of indices by the aggregation of soil characteristics (e.g. FAO-PNUMA-UNESCO 1998), and (2) spatial analysis of soil degradation processes (e.g. soil erosion) by applying models (e.g. USLE model; Wischmeier and Smith 1965) within a GIS (Geographical Information System) environment. Both approaches have been applied in the Mediterranean region. Using a modification of the FAO indices (Sánchez *et al*. 1999), it has been calculated that about 17% of the Valencian Region (east of Spain) has high or very high soil physical degradation, about 22% has high or very high soil biological degradation and about 6% has soil chemical degradation. On the other hand, applying a modification of the USLE model (Antolín *et al*. 1998), it has been estimated that about 30% of the Valencian Region is suffering high or very high soil erosion.

However, both approaches do not consider soil as a complex body that holds a particular status according to its forming processes and the environmental conditions of an area. In fact, some soils characterised as degraded soils in the Mediterranean Region are actually soils that are in equilibrium with environmental conditions according to their forming processes.

The recent concept of soil quality (e.g. Doran and Parkin 1994; 1996; Karlen *et al*. 1997) opens new dimensions to assess soil degradation. Approaches for assessing soil degradation based on the concept of soil quality are being developed and applied elsewhere (e.g. Rodriguez *et al*. 2002). In the Mediterranean Region, Recatalá and Sánchez (1993) developed an approach for soil environmental impact assessment based on soil quality.

This paper discusses the possibilities offered by the concept of soil quality to assess through soil functions, criteria and indicators of the extent of soil degradation in the Mediterranean Region, as a basis to propose and implement adequate management practices for a sustainable use of soil resources.

Approach for Assessing Soil Degradation

The approach is sensitive to an environmental perspective for assessing soil quality, recently emphasized by soil scientists (e.g.Doran and Parkin 1994; Karlen *et al*. 1997; Sims *et al*. 1997) and institutions (e.g. National Research Council of America 1993). The value of this perspective is that it expands the concept of soil quality beyond one of soil productivity, which is the criterion usually used to asses soil quality (e.g. Westman 1985). This environmental perspective takes into account the soil functions referred to protection of natural resources and to maintain ecosystem and human health as well as the productivity function. Within this environmental perspective, soil quality can be viewed in two ways (Karlen *et al*. 1997): either as an inherent soil characteristic governed by soil-

forming processes or as the condition or "health" of the soil relative to a specific land use. In this paper, soil environmental quality implies the first approach, which is more appropriate for assessments at regional level.
The approach consists of three steps: (1) spatial analysis of soil degradation processes, (2) assessment of soil resources quality, (3) identification of sensitive areas to soil degradation. The combination of the results achieved in the first and second step allows us to identify the areas where there is a spatial coincidence between the most intense soil degradation processes and the better soil resources quality (Figure 1). Efforts must be concentrated in such areas. In these areas, adequate management practices should minimize the effects of soil degradation processes while maintaining or even improving the quality of soils.

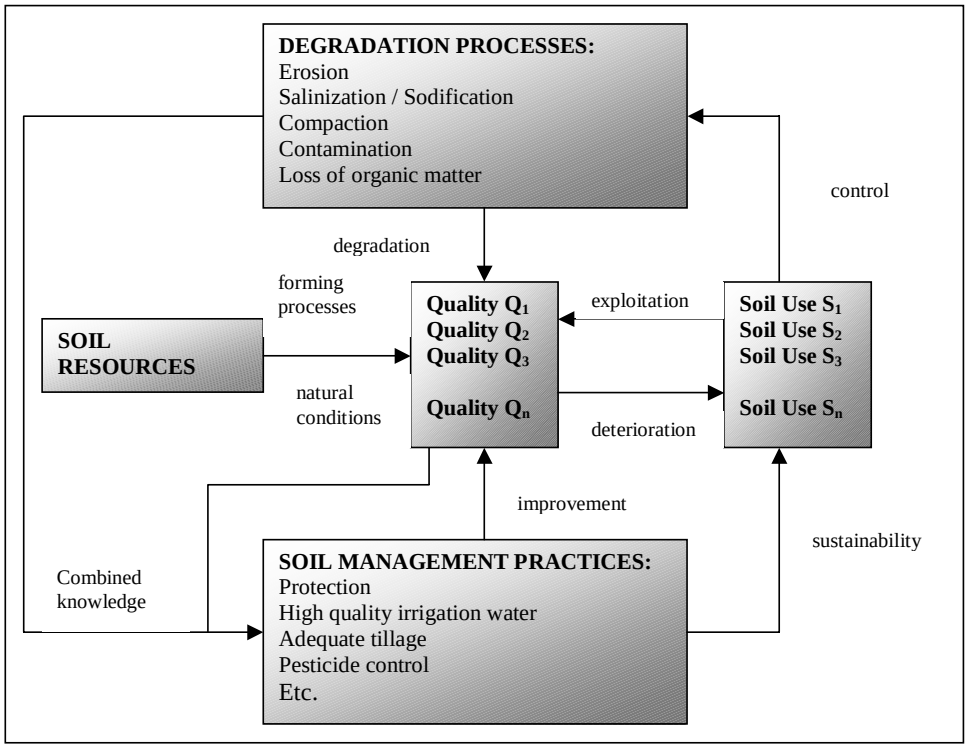


Figure 1. Analysis of degradation processes and soil quality resources for a sustainable land use.

Spatial analysis of soil degradation processes
This analysis can be carried out by using any model that fits in the region. In the Mediterranean region, the USLE model has been the most extensively applied to assess soil erosion (e.g. Antolín *et al.* 1998). Other models based on a weighting-rating procedure have been also applied to assess soil erosion, especially in the context of land use planning (e.g. Recatalá and Sánchez 1997).

Assessment of soil resources quality
Soil quality is assessed here taking into account the relevant soil function referred to maintain ecosystems. This is an important soil function recently recognised by the environmental perspective cited above. This function depends on the soil forming processes and on the environmental conditions of an area, which are responsible for the soil quality. In this context, soil quality can be classified taking into account the soil trends towards equilibrium with natural environmental conditions occurring in the region. Recatalá and Sánchez (1993) and Recatalá (1995) studied all the possible trends in the region. The relative proximity to equilibrium, identified on the basis of some diagnostic horizons (e.g. mollic horizon, FAO 1988) or soil properties (e.g. salic properties, FAO 1988), can be used to define the classes for soil quality. For instance, in the Mediterranean region, soils having a mollic horizon are supporting mature ecosystems. Therefore, the presence of a mollic horizon is a soil quality indicator as it indicates that soil is in equilibrium with the natural environmental conditions. Five classes ranging from very low to very high soil quality are established reflecting different degrees of proximity of soils to equilibrium with natural environmental conditions (Table 1).

Table 1. Classification of soil resources quality according to their proximity to equilibrium with natural environmental conditions (after Recatalá and Sánchez 1993; Recatalá 1995)

Classes of soil quality	Types of soil resources
Very high	(1) Soils having a mollic A horizon; lacking salic and fluvic properties (e.g. Phaeozems, Chernozems, Kastanozems, Rendzic Leptosols, FAO 1988) (2) Soils developed on sandstone; having an argic B horizon (e.g. Acrisols) (3) Soils which are coarser than sandy loam to a depth of at least 100 cm of the surface; lacking fluvic and/or salic properties (e.g. Arenosols) (4) Soils showing gleyic properties within 50 cm of the surface under natural conditions; lacking fluvic properties (e.g. Gleysols, Histosols) (5) Soils having salic properties under natural conditions; lacking fluvic properties (e.g. Solonchacks)
High	(6) Soils developed on limestone, having an argic B horizon; lacking a mollic A horizon (e.g. Chromic Luvisols) (7) Soils developed on sandstone; having a cambic B horizon (e.g. Orthic Acrisols)
Moderate	(8) Soils developed on limestone or unconsolidated materials; having a cambic B horizon; lacking a mollic A horizon; lacking a B argic horizon; lacking gleyic, salic and fluvic properties (e.g. Cambisols) (9) Soils developed on limestone or unconsolidated materials; having a calcic horizon, a petrocalcic horizon or soft powdery lime within 125 cm of the surface; lacking a mollic A horizon, lacking salic, gleyic and fluvic properties (e.g. Calcisols)
Low	(10) Soils developed on limestone or unconsolidated materials; lacking a mollic A horizon, a cambic B horizon, an argic B horizon; lacking salic, gleyic and fluvic properties (e.g. Regosols) (11) Soils showing fluvic properties (e.g. Fluvisols)
Very Low	(12) Soils which are limited in depth by continuos hard rock or a continuos cemented layer within 30 cm of the surface, lacking a mollic A horizon (Lithic Leptosols) (13) Soils in which human activities have resulted in profound modifications of the original soil characteristics (e.g. human-induced saline soils) (e.g. Anthrosols)

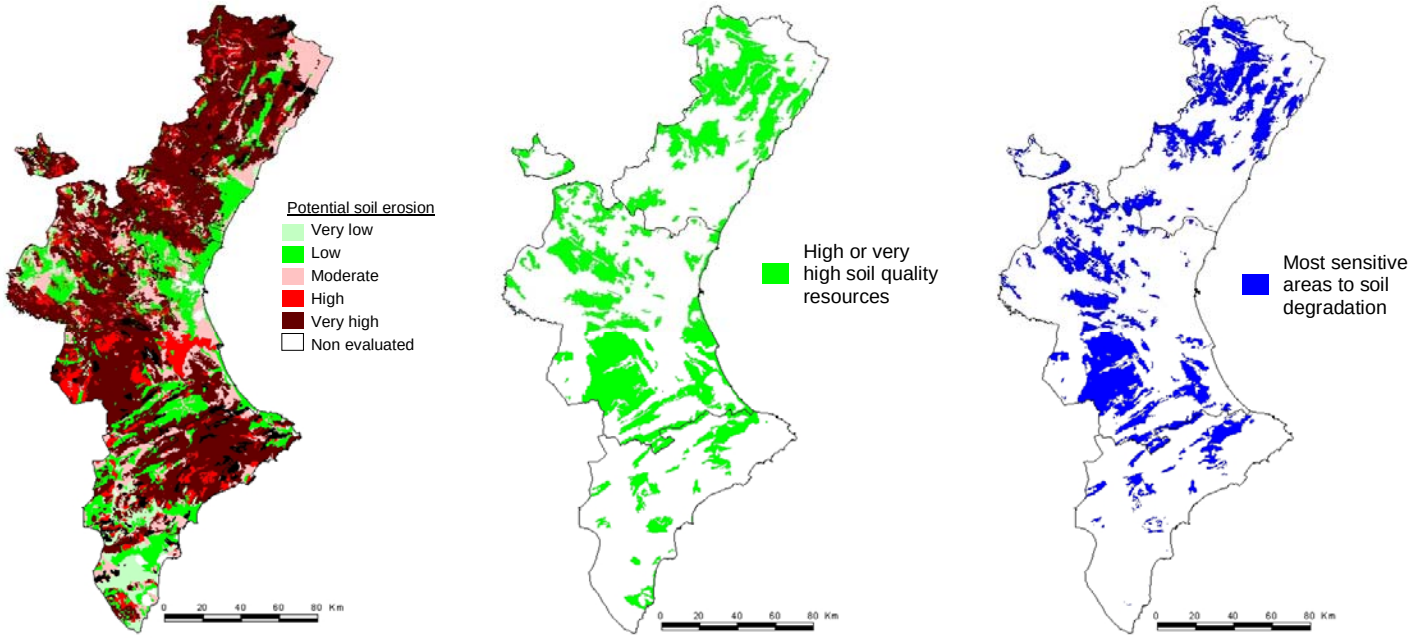
Identification of sensitive areas

Combination of maps of soil degradation processes with soil quality maps allow the classification of areas according to the degree of sensitivity to soil degradation. This can be easily done using the facilities of a GIS. The most sensitive areas will be those where degradation processes are very intensive and have the better soil quality resources.

Results and Discussion

As an example of application of the approach proposed here, the potential soil erosion map (Figure 2a) of the Valencian Region (a part of the Mediterranean region located at the southern of Spain) has been combined within a GIS environment with the map of high soil quality resources (Figure 2b). Other combinations are also possible (e.g. map of salinisation with map of soil quality). Figure 2c shows the areas where there is a spatial coincidence between high or very high potential soil erosion and high or very high soil quality resources. These are the most sensitive areas to soil degradation. Efforts must be directed to such areas in order to avoid any disturbance that accelerates soil erosion and consequently the soil degradation. For instance, to maintain the vegetation in these areas is critical for achieving a sustainable ecosystem. Otherwise, high or very high soil quality resources can be progressively degraded and lost.

Over recent decades, the land-use pattern of the Valencian Mediterranean Region has seen an intensification of agrarian activity and an expansion of industrial-urban uses (including tourism), which is consistent with most of the European Mediterranean Region (UNEP 1986). As a consequence, soil degradation and other environmental issues (e.g. water pollution) have emerged rapidly. These human induced soil degradation processes are increasing the risk of desertification in extensive areas of the region (Sánchez 1991). As a consequence, soils far from the equilibrium with natural environmental conditions are found elsewhere (e.g. Lithic Leptosols, FAO 1988). The approach proposed here is sensitive to this issue. Its application would prevent, for example, the destruction of soils having a relevant function in maintaining mature ecosystems. Given that the soil issues identified in the Valencian Mediterranean Region are similar to those identified in the broader European Mediterranean Region (UNEP, 1986), it follows that the approach can be extended to this larger region.



(a) **(b)** **(c)**

Figure 2. (a) Potential Soil Erosion in the Mediterranean Valencian Region, (b) High or very high soil quality resources (c) Most sensitive areas to soil degradation.

Conclusions

An holistic approach that combines spatial analysis of soil degradation processes and assessment of soil quality resources has been proposed to identify the most sensitive areas to soil degradation in the Mediterranean region. Application of this approach allows the concentration of efforts of sustainable soil management in the areas where there is a spatial coincidence between the most intense degradation processes and the better soil quality resources.

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