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Soil management guidelines in Spain and Portugal related to EU Soil Protection Strategy based on analysis of soil databases

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ABSTRACT

The prevailing soil group in the Iberian Peninsula is Cambisols, followed by Regosols and Leptosols. In addition, Luvisols, Fluvisols and Calcisols also cover part of this territory. The processes that degrade soil quality need to be continuously addressed, so that policies for protecting the sustainability of land use practices (e.g., agriculture) and reuse of contaminated sites can be improved.

To establish appropriate soil management principles, this paper reviews two important soil information databases in Spain and Portugal, which have been chosen based on the amount and quality of the information they contain. These databases include characterizations of selected soil parameters and information on the current state of the soil resources. Our study confirmed that areas with lower organic carbon content also have higher crusting and erodibility. Soil connectivity is a key concept for developing integrated approaches to planning and management of soil as a natural resource. A set of indices of connectivity is identified to establish guidelines for soil management decision-support protocols. The key factors for regulatory decisions in the EU Soil Protection Strategy context are soil properties (organic carbon, among others), soil degradation (erosion), soil contamination state, topography and land use.

Considering the interaction of the identified key factors, "Sector Soil Units" are proposed as a dimensionless measuring concept to develop integrated and coordinated soil protection policies for relatively small and homogeneous areas on the Iberian Peninsula, regardless of national and regional borders.

1. Introduction

The importance of soils to humans from socio-economic and environmental perspectives cannot be underestimated (Boardman, 2003; Nortcliff, 2009). The Kyoto protocol has highlighted that soil, as a major carbon reservoir, must be protected and enhanced by monitoring and verification of soil carbon changes. Additionally, soil protection policies that maintain soil biodiversity and proper land management practices that facilitate carbon sequestration in agricultural soils could help mitigate the effects of climate changes and raise awareness of global soil protection issues (De Graaff et al., 2013; Kibblewhite et al., 2012). The prevention of soil degradation must always be a priority because soil is a fundamental resource for the development of life. For these reasons, among others, the European Commission has promoted a series of initiatives to develop a Thematic Strategy for Soil Protection. As an issue of paramount importance in Europe, the soil degradation problem requires timely interventions.

Recent developments in hydrology and geomorphology include the connectivity principle, which describes how different elements in a landscape are connected and how water and matter move between these components (Baartman et al., 2013; Masselink et al., 2013; Puttock et al., 2013, 2014). In the soil connectivity concept, there are three key factors: organic carbon (OC), erosion and soil contamination state.

Soil carbon evaluation, in the carbon sequestration context, and soil protection have attracted the interest of the scientific community over the last decade (Alvaro-Fuentes et al., 2011; Batjes, 2008; Carr et al., 2009; Chuai et al., 2013; Follett and Reed, 2010; Jandl et al., 2007; Schmidt et al., 2011; Schulp et al., 2008; Wang et al., 2009; Wellock et al., 2011). Soil organic matter is very important to maintain soil productivity, and agricultural management practices can significantly influence the chemical properties of the soil organic matter (Ding et al., 2002; Muñoz-Rojas et al., 2012; Olson et al., 2011; Powlson et al., 2011; Prosperi et al., 2011; Rodríguez-Murillo, 2001; Saha et al., 2010). Furthermore, soil organic matter quality is essential to soil carbon storage and the rate of mineralisation of nutrients and can be an important determinant of the nutrient supply capacity of soil.

Today, soil organic matter is also studied in relation to the carbon cycle and its influence on global climate change. Carbon cycle models require accurate estimates of the amount of carbon in the different reserves, which are difficult to obtain because of the poor knowledge of

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specific properties of different soil types (Batjes, 1996; Canadell et al., 2007), the high spatial variability of carbon in the soil, even within a soil map unit (Cerri et al., 2000), and the different factors that govern the soil OC cycle (Novara et al., 2012; Parton et al., 1987; Pastor and Post, 1986; Vaccari et al., 2012).

Soil integrity is continually threatened by destructive processes such as the decline in organic matter, erosion, pollution and loss of biodiversity. Erosion is a natural process, crucial for soil formation, which takes place over geological time. However, anthropogenic activities have significantly increased the rate of erosion and consequently reduced soil productivity by removal of the fertile topsoil (Geissen et al., 2013). In cases where soils are superficial, high erosion rates may lead to irreversible damage to farmland, and even in soils with greater depth, loss of the topsoil may not be visible or sizable at first but can be potentially very damaging and irreversible in the long run. Erosion rate is very sensitive to both climate and land use, as well as to specific conservation practices at the cultivation level (Jordán et al., 2010). The areas subjected to water erosion are increasing; soils show ever-lower organic matter content and the potential for contamination of soils is still growing. These degradation processes can affect the soils in the Iberian Peninsula. Therefore, it is essential to evaluate the emergence of such processes and to take measures to reduce degradation; inhibit losses in fertility, carbon and biodiversity; and slow the diminishment of the soil's capacity to retain water.

Many surveys and studies on the environmental quality of soils have proved that the degradation of soils caused by pollutants can pose a threat to human health and the environment. Therefore it is essential to guard soil quality against these threats because accumulated pollutants can remain in soils for several years, even after the sources are removed (Chrastný et al., 2012; Rodrigues et al., 2009 a,b). Soil contamination occurs when chemical elements reach a certain critical level causing a deterioration or loss of one or more soil functions. Potential toxic elements are general indicators of industrial activities, and consequently an appropriate indicator of anthropogenic activity. Furthermore, modern agriculture, designed to produce as much food as possible, has led to a large increase in the use of pesticides and fertilisers. The Thematic Strategy for Soil Protection (European Commission, 2006) has identified soil contamination as one of the major risks to soil sustainability in Europe. Thus, over the last 20 to 30 years, soil protection policies have been developed gradually, both at a national level and at the EU level. These policies include prevention of contamination and remediation of contaminated locations.

Soil scientists now are focusing on sustainable management systems and their translation into environmental policies (Bouma and Droogers, 2007; Killham, 2011; Louwagie et al., 2011; Posthumus et al., 2011). The concept "quality of the soil" has recently become a focus of public attention because maintaining and/or improving soil quality are critical for agricultural productivity and sustainability (Obade and Lal, 2013).

To address the problem of soil management and conservation in the Iberian Peninsula, it is also important to consider the use and management of the water resources in the area. It is worth mentioning the growing interest, evidenced by coordinated programs and recent publications, in the integrated management of the cross-border waters between Portugal and Spain. Recently the European Union, mainly after the Amsterdam Treaty (European Union, 1997), has developed cross-sectorial policies with the aim of managing water resources in a more sustainable manner. Today the management of the water resources does not focus on structures as once was the case and tends to be more rational in terms of resource use. Perhaps a similar approach should be followed with the soil resource.

The aims of this work are i) to review two important soil databases that are available to study the Iberian Peninsula, a transnational region consisting of Spain and Portugal — these two sources are the Harmonized World Soil Database (HWSD) elaborated by the Food and Agriculture Organization (FAO) and the soil database provided by the Land Management and Natural Hazards Unit (embedded in the Research Centres of the European Commission); ii) to identify, from information gathered from the soil databases, the main key factors that should be taken into account in regulatory decisions; and iii) to introduce a new measuring concept to develop integrated and coordinated policies on the Iberian Peninsula regardless of national and regional borders because the resource soil cannot be managed on the basis of artificial boundaries.

To our knowledge, the two databases (FAO and European Commission) considered in this work have not been jointly analysed for the Iberian Peninsula. Additionally, there are few works in the literature that address soil research over regions comprising several countries, in particular, Spain and Portugal. Therefore, this work is the first attempt to establish a framework on soil policies for the Iberian Peninsula.

2. Materials and methods

Two soil databases have been used (FAO and European Commission). In March 2009, the FAO published a new database with more precise information about world soils, which allows the evaluation of land productivity and soil carbon levels and also allows future scenarios to be set up (www.fao.org; FAO/IIASA/ISRIC/ISS-CAS/JRC, 2009). The FAO database, named the Harmonized World Soil Database (HWSD, www.iiasa.ac.at/Research/LUC/External-World-soil-database/ accessed in September 2013), can be used to significantly improve knowledge of current and future land productivity, carbon storage and the carbon sequestration potential of the soils.

The quality of this database is reflected in the data it contains and the information it can provide. Four source databases were used to compile version 1.0 of the HWSD: the European Soil Database (ESDB), the 1:1 million soil map of China, various regional SOTER databases (SOTWIS Database) and the Soil Map of the World. The derived soil properties presented in the HWSD have been deduced from analysed profile data obtained from a large number of countries and sources. Over 16,000 different soil mapping units are included in the Harmonized World Soil Database (HWSD), which are linked to harmonized attribute data. Data can be related to GIS information thanks to the standardized database structure. It is possible to display or query composition in terms of soil units and selected soil parameters (OC, pH, water storage capacity, soil depth, cation exchange capacity of the soil and the clay fraction, total exchangeable nutrients, lime and gypsum contents, sodium exchange percentage, salinity, textural class and granulometry).

According to the FAO, land and water limitations can be identified and the risk of land degradation, particularly soil erosion, can be evaluated from the HWSD. Derived chemical and physical soil properties are provided for topsoil (0–30 cm) and subsoil (30–100 cm) separately in the database. In the framework of the HWSD, FAO has published a global Carbon Gap Map that identifies large soil carbon reservoirs.

The other data source used in this work comes from the European Commission. The Land Management and Natural Hazards Unit of the Institute for the Environment and Sustainability (Joint Research Centre of the European Commission; JRC-EC, http://eusoils.jrc.ec.europa.eu accessed in September 2013) has published maps with information about different soil properties.

This information is part of the European Soil Data Centre, which is one of the environmental data centres in Europe and is the main institution for soil data at the European level. It presents data and information regarding soils at the European level, and detailed information about soil threats (e.g., soil erosion, OC decline, compaction, salinisation, landslides and toxic elements) can be found.

The data are available in the native Esri grid format or as ASCII raster files. For example, the Soil Portal (JRC-EC) has published a map with information about the topsoil OC content. The Soil Portal also offers researchers information from its website about concentrations of eight critical toxic elements (arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc) in topsoils using 1588 georeferenced topsoil samples from the Foregs Geochemical database. A geostatistical analysis of