Spatial distribution of the vulnerability for ^{137}Cs and ^{90}Sr in Spanish soils considering the food chain pathway

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Abstract. The main aim of this work is to determine the geographical distribution of the potential soil capacity to transfer ^{137}Cs and ^{90}Sr in Spanish soils. The behaviour of these radiological contaminants in the soil is of key importance to determine the vulnerability, which in this case is related with the availability and transferability of the contaminants. Therefore, the transfer of the contaminants through the food chain pathway (soil-plant) is considered to be within a maximum depth of 60 cm in the soil. A categorisation of the contaminant behaviour is carried out considering soil processes, which are influenced by pedological and hydrological factors. Separate indexes are determined, namely water availability, physicochemical retention and a K or Ca content for the respective contaminants. Combining these individual indexes, a final index is obtained representing the results divided into five classes ranging from a minimum to a maximum vulnerability. The results are obtained using data from 1655 Spanish soil profiles, which are introduced into a Geographic Information System data base. A cartographic reference map, based on the soil map of the European Communities, is used to determine a regional distribution of the most representative soils found within Spain. The distribution for the potential transferability of ^{137}Cs and ^{90}Sr is represented by determining the most frequent value for the different soil types from results obtained for the individual soil profiles.

1. INTRODUCTION

The main aim of this research work is to determine the spatial distribution of the radiological vulnerability of Spanish soils taking into account their intrinsic properties which are involved in the fixation and mobility processes of ^{137}Cs and ^{90}Sr. After these radionuclides are deposited on the soil surface, a transfer through the food chain pathway is estimated according to the vulnerability approach developed in CIEMAT [1]. The food chain pathway considers the pedosphere to a critical depth of 60 cm where the maximum root activity and development occurs. Partial vulnerability indexes are obtained considering individual physical and chemical soil processes such as infiltration, migration, sorption and desorption and root absorption, respectively [1]. A final combination of these indexes determines the global vulnerability indexes for each individual radionuclide. In this case, the partial and global indexes are defined by five categories that range from a minimum (1) to a maximum (5) vulnerability.

The spatial distribution of a contaminant is a useful tool for assessing the human impact and to develop the optima strategies to manage an affected area. A Geographical Information System (GIS) [2] is implemented in order to create a georeferenced data base containing abiotic and biotic data and to determine the corresponding spatial distribution of the results. The final vulnerability maps present the radiological impact derived from a potential radiocaesium and radiostrontium contamination.

2. METHODOLOGY

A methodology is developed to combine detailed soil data from individual soil profiles and data obtained from maps in order to determine the spatial distribution of the soil vulnerability (Figure 1). This methodology can be divided into the following three phases:

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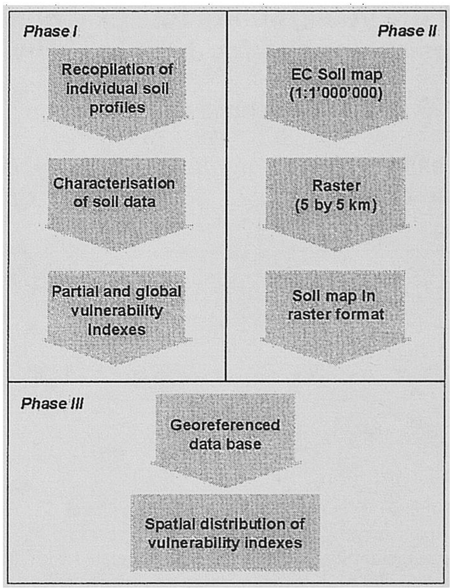


Figure 1: Methodological procedure.

Phase I: An initial database is generated containing detailed information of Spanish soils [3]. Data for a total of 1655 soil profiles are collected from bibliographical sources. A main condition is that the soil profiles include general data for each profile and physical and chemical data for the individual horizons (Figure 2). A pre-processing and characterisation is essential in order to harmonise the classification systems applied by the authors to the original soil data and to filter out any irregularities. Partial vulnerability indexes for ^{137}Cs and ^{90}Sr are estimated (Figure 2) according to the vulnerability approach for the individual soil horizons to the critical depth of 60 cm. The global vulnerability indexes for the corresponding contaminants are obtained by assigning the sum of the partial indexes to five categories.

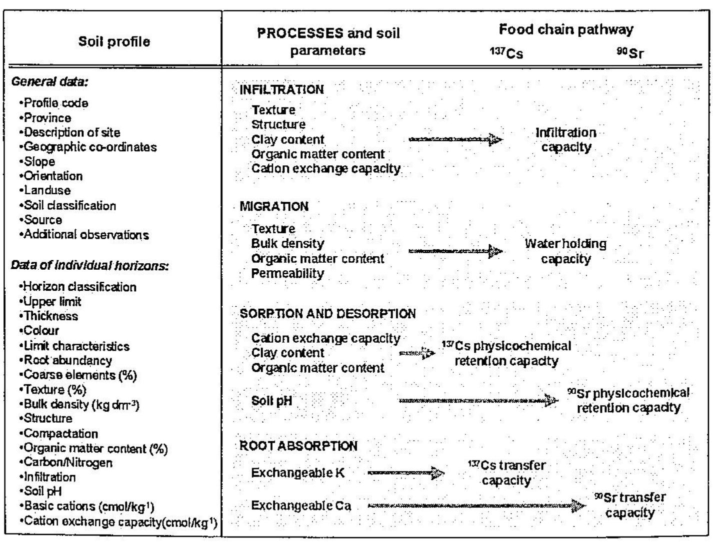


Figure 2: Soil profile data and parameters considered for the food chain pathway.

Phase II: The soil map of the European Communities [4] at a scale of 1:1,000,000 is selected. It is the most accurate and complete soil map which covers the entire Spanish territory and is based on the FAO/UNESCO legend. In order to facilitate the management of the cartographic data and represent the spatial distribution of the results, a raster of 5 by 5 km is created [5]. The data obtained from the soil map is characterised and prepared and the individual raster cell is represented by a data obtained from the map.

Phase III: A georeferenced database is generated combining the data and results for the individual soil profiles and the cartographic soil information corresponding to phase I and II, respectively. Grouping the individual soil profiles according to their soil types, the most frequent values represent the partial and global vulnerability indexes. These indexes are then assigned to the main soil type associated to the soil map of the European Communities to present the spatial distribution.

3. RESULTS AND DISCUSSION

The results for the infiltration capacity (Figure 3a) show that soils with a coarse texture, good structure or with hydromorphic properties are vulnerable. This affects an area of 60% of the Spanish territory presents a high vulnerability allowing the radionuclides to be transported to the root zone. The vulnerable areas are represented by soils with a coarse texture, good structure or with hydromorphic properties. Spanish soils (Figure 3b) show in general low or very low vulnerability for water holding capacity of 64% and 29%, respectively. Very high vulnerability is found in soils with a high clay content throughout the profile in the South and in organic soils in the Northwest.

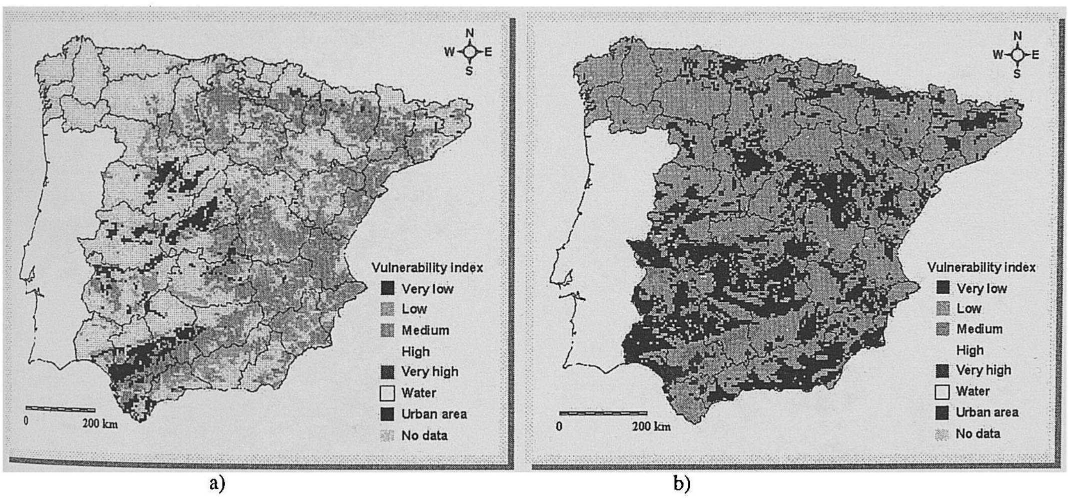
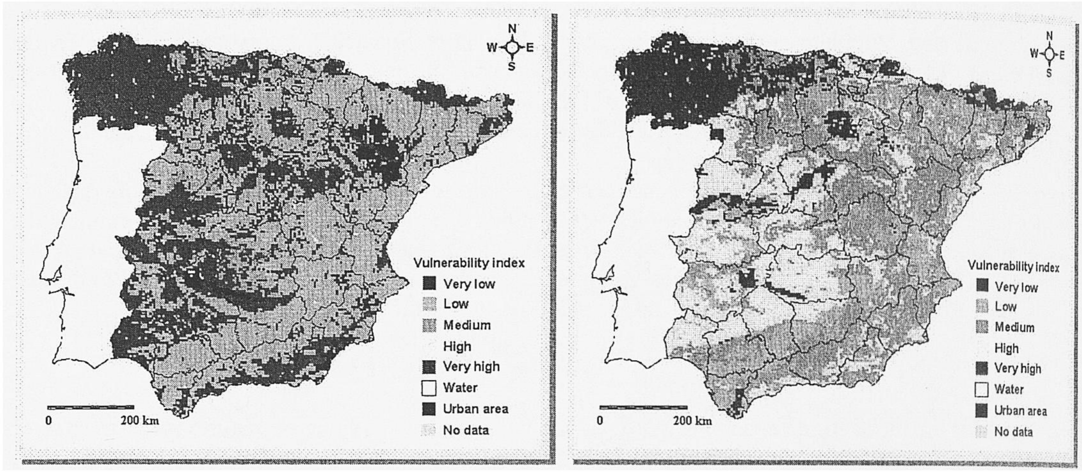


Figure 3: Partial vulnerability indexes of the a) infiltration capacity and b) water retention capacity.

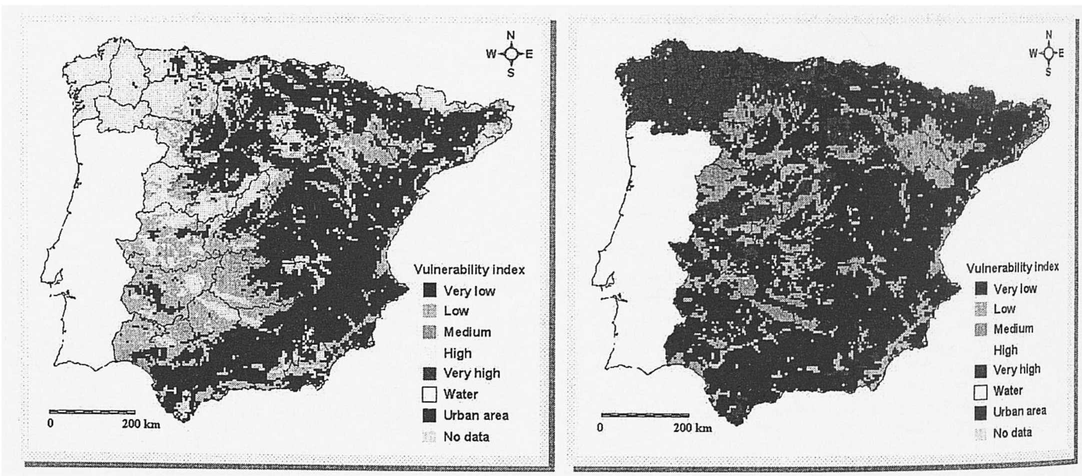
The physicochemical retention capacity of ^{137}Cs is determined by the clay content and type. Results (Figure 4a) show a low vulnerability for 54% of the area where soils have a clay texture in limestone areas. These soils have illite as a dominant clay which permits the ^{137}Cs to be strongly fixed and not bioavailable. In contrast, 40% of the area is represented by the highest vulnerability and is associated to soils with kaolinite dominant clays, low clay content, sandy or organic soils. In this case, ^{137}Cs is in the soil solution or in an exchangeable form. The ^{137}Cs transfer capacity is closely related to the former partial index and the clay minerals act as a reservoir for the K element in the soils. The K cation competes with ^{137}Cs in the root uptake by the vegetation and is often anthropologically influenced by agricultural practices. A low presence of K (Figure 4b) favours the availability of ^{137}Cs and corresponds to 15% of very high vulnerability areas with little or no clay in the soils.



a) b)

Figure 4: Partial vulnerability indexes of the a) ^{137}Cs physicochemical retention capacity and b) ^{137}Cs transfer capacity.

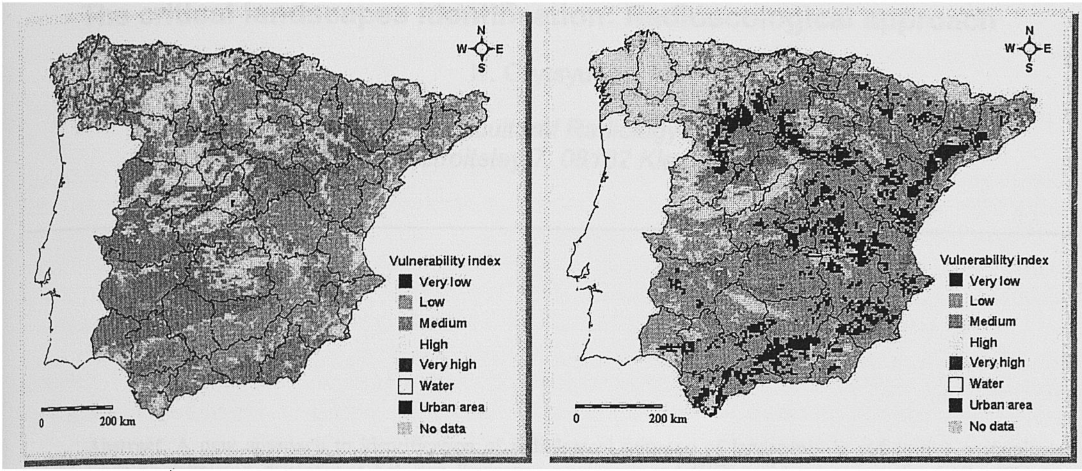
The physicochemical retention of ^{90}Sr is closely related to the lithology and distinguishes between acid and calcareous soils. High vulnerability values (Figure 5a) occupy an area of 27% where the acid status and nutrient content of the soil is low and therefore a greater radionuclide fraction is available for root uptake. The ^{90}Sr transfer capacity is closely related to the retention of ^{90}Sr and areas with a low Ca content (acid lithology) will favour the ^{90}Sr availability for plants. The high vulnerability values (Figure 5b) occupy 16% of the territory and low values are obtained from limestone lithology.



a) b)

Figure 5: Partial vulnerability indexes of the a) ^{90}Sr physicochemical retention capacity and b) ^{90}Sr transfer capacity.

The results of the global vulnerability index for ^{137}Cs (Figure 6a) show no extreme values. High values occupy 28% of the area and relate to soils with low pH, coarse textures and low K content. The global vulnerability index of ^{90}Sr is mainly influenced by the lithology (Figure 6b) where 26% corresponds to high and 52% to low values. Therefore soils on acid parent material have a capability to transfer the radionuclide and on limestone the contrary is true.



a) b)

Figure 6: Global vulnerability indexes for a) ^{137}Cs and for b) ^{90}Sr considering the food chain pathway

4. CONCLUSIONS

This is a first step on a national scale to obtain the spatial distribution of the radiological vulnerability for ^{137}Cs and ^{90}Sr in Spanish soils for the food chain pathway.

The methodology combines detailed soil and cartographic data in order to be able to identify areas where there is a potential availability and transferability of ^{137}Cs and ^{90}Sr in soils.

The spatial distribution of ^{137}Cs is closely related to the evolution of the soil and shows vulnerable areas throughout the Spanish territory where the soils are coarse textured and do not contain clays with a competitive analogue cation.

The vulnerable areas to ^{90}Sr are located mainly in the North-west and West including central parts of Spain and are associated to acid soils influenced by the lithology.

Although the spatial distribution is on a national scale, areas vulnerable to ^{137}Cs and ^{90}Sr are identified and will form the basis for a more detailed study of an affected area.

Acknowledgments

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