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Soil vulnerability to erosion assessed with remote sensing, digital elevation models and a fuzzy logic Multi-Criteria Evaluation

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Soil vulnerability is the capacity of one or more of the ecological functions of the soil system to be harmed. Soil vulnerability is related with the sensitivity of the soil system to degradation processes like erosion, desertification or salinization. Vegetation plays a crucial role in soil vulnerability because is a source of organic matter and a protection against rain, wind and other erosive agents. A soil covered by a dense and vigorous vegetation is more resistant against erosion. Another important factor that determines soil vulnerability is the topography. Slope and aspect have a great influence on vegetation distribution and losses of soil due to erosive processes. A key problem with traditional erosion models (USLE; RUSLE, etc.) is that input parameters are obtained locally or with large intervals of time. This technical problem greatly limits the update of soil erosion maps and their modification according to landscape changes (land use change, forest fires, etc.). To solve this technical difficulties, remote sensing and GIS techniques has been employed to compute input parameters of erosion models or develop new methodological approaches for soil vulnerability and erosion assessment.

This work presents a methodological approach to assess soil vulnerability using remote sensing and GIS techniques to estimate input variables and to develop calculations in a spatial basis. Input variables include information about vegetation status and topography. The main advantage of this approach is that input variables can be updated fast to reflect landscape changes and the phenological status of vegetation that substantially could affect soil vulnerability.

Soil vulnerability is assessed with a fuzzy logic model. Fuzzy logic emanates from Fuzzy Sets theory developed by Zadeh (1965) as a way to express and operate with membership degrees of the elements in a set. Fuzzy logic works well with continuous variables and with data uncertainties, and thus is very suitable to combine remote sensing and topographic parameters. A Multi-Criteria Evaluation is performed by defining a membership function for each input variable, and combining them in a proper way (definition of weights). This simplified fuzzy logic model of soil vulnerability was tested in two study areas of SE Spain. The first area (Granadella) had a wet Mediterranean climate, very rough topography and the landscape is dominated by pine forests and shrubs. A severe forest fire affected the study area and the model was applied just after the forest fire and three years later. The second study area (Escalona) has a semiarid Mediterranean climate, a rough topography and the landscape is a mixture of permanent crops, shrubs and pine forest patches. In this case, the model was applied in the late spring and late summer for 2000 and 2003. Soil vulnerability estimations were related with RUSLE erosion maps.

The simplified soil vulnerability model is highly and positively correlated with "traditional" erosion maps. It is sensitive to intra-annual and inter-annual vegetation changes, and thus the model reflects changes in soil vulnerability due to vegetation regeneration or degradation. The model performs well in the detection of soil vulnerability increments as estimated by the changes from actual to potential erosion. The model is a promising approach that, at this stage, reflects with great accuracy changes in soil vulnerability and that benefits from the definition of membership functions for input parameters in the fuzzy logic multi-criteria evaluation system.

References

Zadeh, L.A. (1965). Fuzzy Sets. Information and Control, 8:338-353.