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Modelling the Thresholds of Soil-Landscape Units using Fuzzy Logic

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Accurate regionalisation of point data reflecting real changes in soil types or properties is pivotal to the understanding of environmental problems which are controlled by soil and its spatial variation (e.g. soil erosion, landslides, floods, droughts, pollutant transfer, waste disposal). Technological advances have allowed the application of Fuzzy Logic to deal with imprecision and uncertainty, which are an inherent part of natural systems. The soil system is one such system where processes involved in soil development do not usually operate on a discrete level, but produce a continuum of change. Thus, Fuzzy Logic can help formalise our knowledge of the spatial variation of soil to produce better soil maps. However, so far, the full potential of this technique has not been exploited in soil-landscape modelling, and more specifically, in the classification of landform areas that are thought to have the same soil-formative environment. Whilst different membership functions have been applied to accommodate the continuous nature of soil, there remain significant challenges in the fuzzification of primitives, i.e. the definition of the parameters of the membership functions which replace crisp with continuous boundaries between landform classes.

A fuzzy landform model is parameterised for the study area of Marina Baixa (SE Spain) using trapezoidal membership functions of terrain attributes. These functions allow 1) the integration of non-linearities between landforms and soil properties in the transition zones between landform classes, and 2) the assignment of full membership across a range of values of terrain attributes. The resulting maps of landform classes (one for each class) are then defuzzified into one single landform-classification map, which is compared to a landform map produced using Boolean logic, i.e. with discrete boundaries.

Analysis of the defuzzified map of landform classes unveiled the existence of an extra landform class, which means that even hardened classes are based on richer information of continuous memberships and therefore, retain the potential of a fuzzy model. Results also show that one fifth of the pixels in the classification of the study area using Fuzzy Logic ended up in different landform classes from those using Boolean logic. Despite the high degree of overlap between the two landform classifications, some landform classes underwent major changes. The classification based on the application of Fuzzy Logic was able both to separate better some of the landform classes and to pick some finer variability than the discrete classification. Thus, Fuzzy Logic is able to improve the quality and accuracy of traditional soil-survey maps (or maps based on Boolean logic) by allowing a more detailed parameterization of the landform models which are their basis.