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Modelling an index for soil quality evaluation based on natural forest soils under Mediterranean conditions

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For millenniums, land use in the Mediterranean region has modified the forest landscape. Some practices have conducted to situations in which soil has been degraded showing such high risks of erosion and impoverishment that it is unable to carry out its natural functions. Soils from natural forest ecosystems have specific physical, chemical and biological properties based on the conditions in which they have been developed. Hence, modelling the equilibrium established among different key soil properties from stable forest ecosystems could be used as soil quality index, because disturbing practices lead to changes in that natural balance.

Here we report on the establishment of a soil quality index under Mediterranean semiarid-dry conditions for forest soils based on the use of multiple linear regression (MLR) integrating different physical, chemical and biochemical properties. Five forest sites in the province of Alicante (South-East Spain) were chosen for this study: Sierra de Orihuela (O), Sierra de Crevillent (C), Solana del Maigmó (MS), Umbría del Maigmó (MN) and Puig Campana (Pu). The annual rainfall range is 250-450 mm. All sites have in common the presence of a tree stratum occupied by *Pinus halepensis* (with *Quercus rotundifolia* in MN and Pu). Soils from O and MS are Entisols, while those from C, MN and Pu are Mollisols. All forests are developed over limestone.

A single sampling was carried out in August 2004.Thirty soil samples from the A horizon were randomly collected in each site (n=150). We selected the following soil properties as minimum data set: soil organic carbon (SOC), Kjeldahl nitrogen (Nk), aggregate stability (AS), water holding capacity (WHC), pH, electrical conductivity (EC), available P (P), cation exchange capacity (CEC), microbial biomass carbon (MBC), basal soil respiration (BSR), and the enzyme activities β-glucosidase, urease and acid phospatase. The predicted variable selected for the model was Nk, as a component of soil organic matter, which plays an important role in almost every soil function.

Principal components analysis (PCA) was carried out, and two components were obtained. PC1 was related to organic mater content in soil. PC2 represented the amount of nutrients and soil biochemical activity. When PC1 factor scores were plotted against PC2 scores, we observed that Entisols appeared separated from Mollisols by PC1. Hence, soil type, and thus, soil organic matter content determine the relationship between different soil properties. To confirm if the relationships between soil properties are controlled by environmental conditions, we carried out canonical correlations among the factor scores from soil properties PCA and environmental factors (precipitation, temperature, vegetation cover and vegetal biodiversity). We observed a high relationship degree (0.87) between both groups of variables in the first canonical correlation, which indicates a high influence of the structure of soil properties relationships by environmental factors. To select which environmental variable explained the highest variability of data, we developed PCA with environmental factors. We observed that the first component, that explained 49.1% of variability, was practically exclusively determined by precipitation (component score coefficient 0.99), reflecting that precipitation is the factor that best explains variability of all environmental factors.

Therefore, we included mean annual precipitation as categorical variable to correct deviations observed in the relations among properties in the different places. Then, we used this environmental variable divided into two categories, 250-350 mm and 350-450 mm, just the levels of precipitation which determine the presence of Entisols or Mollisols in the sites studied. MLR was carried out, and indicators were selected based on p-value. The expression showed how N can be predicted with the combination of the categorical variable precipitation, SOC, MBC, urease, EC, P, CEC and the interactions of SOC and CEC with precipitation. This model explains 93% of the variance in N, with residuals within normality.

This model shows the balance established among different soil indicators under specific climatic conditions at regional scale. The ratio Nc (calculated by the equation) divided by Nk (measured in laboratory) (Nc/Nk) can be used as soil quality index, because any disturbance or stress on soil will modify the relation in which the predicted variable is calculated, and a deviation in this ratio is going to be found. With the soils used to create this model, the ratio Nc/Nk is 1, and high quality soils within the range of precipitation implied in this model should provide the same relationship. Degraded soils should have ratios >1 or <1.