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Controlling factors explaining soil carbon in relation to soil depth for French soils

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Understanding the factors controlling soil organic carbon over vast areas is a major challenge, especially in relation to soil depth. In this work, we aimed at improving our understanding in which chemical and physical soil and environmental properties control soil organic carbon in relation to soil depth. Also, we postulated that variability in soil carbon may be better explained by modelling the soil carbon content within so called different land systems, which were defined by climate, land use, parent material and soil type. The latter was evaluated by comparing regression models for i) the original soil carbon data and ii) soil carbon data clustered by land system. Hence, the regressions models relied on continuous data related to topography, soil and bedrock properties and meteorological information.

With respect to data availability, we had the unique opportunity to use a wide range of data; the French Soil Monitoring Network and the Soil Inventory programmes have put major efforts in collecting, analysing and harmonizing soil data covering the French territory over the past years. Today, this has resulted in a comprehensive database, consisting of soil profile and site descriptions, and their chemical and physical soil properties. Additionally, spatially exhaustive datasets were available, expressing the ecological, climatological, topographical and geological processes.

Soil carbon was explained for three soil depth intervals; 0-30 cm, 30-50 cm and >50 cm, respectively. Analysis of the soil profile data and the chemical and physical data indicated that soil carbon mainly correlated to the CEC, pH, clay content and the cations associated with clay complexes. Next, only soil profiles described by a complete set of variables originating from the field inventory, laboratory analysis and spatially exhaustive data were selected. Insight in the relation of the variables with each other and with soil carbon was obtained by applying Principle Component Analysis (PCA) on the continuous data and Multiple Correspondence Analysis (MCA) on the categorical data. Results indicated that different variables were related to soil carbon contents at various depths. Parent material, bed rock properties, soil type, and specific variability in temperature and precipitation controlled the amount of carbon at greater depths. This may imply that these factors controlled the more recalcitrant soil carbon. On the contrary, in the top layer, the type of climate and land use and management were more important factors controlling the amount of soil carbon. Furthermore, the MCA analysis showed a significant relation between soil carbon and the explanatory variables and potentials for clustering based on the set of explanatory variables. More precisely, results indicated that clusters may represent different land systems defined by climate, land use, parent material and soil type. Therefore, hierarchical clustering on the principle components of the categorical data was performed which resulted in 4 different land systems. Finally, within each system, soil carbon was explained by a regression model relying on the continuous exhaustive dataset. The regression models indicated that the controlling factors differed for each depth interval and more variability of soil carbon could be explained when considering the land systems.