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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 (SOC) 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 SOC in relation to soil depth. Also, we postulated that large-scale variability in SOC may be better explained by modelling SOC within so called land systems, which were defined by climate, land use, parent material and soil type. Hereby, we overcome the difficulty of complex biological, chemical and physical processes that influence large-scale SOC models. That is, within the typical land systems the major biotic and environmental factors controlling the (de)stabilization mechanisms of SOC were assumed to be relatively homogenous. Within the derived systems, multiple linear regression (MLR) models were calibrated for SOC, using high-resolution environmental variables, thereby modeling the local processes. The approach was evaluated by comparing the MLR models per system with a boosted regression tree (BRT) calibrated on the full dataset of SOC, laboratory and environmental data.

The study was performed in Metropolitan France and covers approximately 542.0*10E3 km^2. This area offered a high diversity in geological, climatological and ecological characteristics. 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 variability in ecological, climatological, topographical and geological processes.

SOC was explained for three soil depth intervals; 0-30 cm, 30-50 cm and >50 cm, respectively. 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 SOC 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 related to SOC 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. On the contrary, in the top layer, the type of climate and land use and management were more important factors controlling SOC. Next, the land systems were derived using model-based clustering and regression models were calibrated. The overall performance of the MLR models was not substantially better than the BRT models. Yet, results indicated that (1) within specific systems the MLR models better explained SOC variability, especially at greater depths and (2) the controlling factors deviated for each system and soil depth. These findings are especially helpful for understanding soil functioning in relation to SOC for large-scale assessments and are a step forward in understanding the dynamics for top and subsoil SOC variability in heterogeneous environments.