Geophysical Research Abstracts
Vol. 21, EGU2019-6749, 2019
EGU General Assembly 2019

Dynamic modelling of soil structure and its links with soil processes: status and challenges

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Sustainable agricultural production requires the maintenance and improvement of soil quality, which can be defined as the capacity of soil to deliver a range of key ecosystem services. Soil quality and sustainable agricultural production are strongly determined by soil structure, as it regulates most important soil processes and functions such as water and air movement, biological activity, carbon and nutrient cycling, greenhouse gas emissions, risks of pollutant leaching, root growth and water and nutrient uptake by plants. Some soil-crop models have been developed that account for the effects of structure on transport and turnover processes in soil, but the structure in these models is static. In reality, soil structure is dynamic at time scales ranging from seconds (e.g. compaction, tillage) to minutes (e.g. soil sealing), seasons (e.g. root growth, activity of macro-fauna) and even decades (e.g. changes in organic matter content). The lack of a model framework that dynamically links structure with function, particularly at decadal to century time scales, has hampered understanding of how changes in land use, soil management and climate have resulted in insidious losses of soil quality and land degradation. Here, we present a conceptual framework for soil-crop models incorporating dynamic links between soil structure and function and discuss some of the critical challenges involved in developing such a tool. We also present a simple prototype model and the results of comparisons of simulations using this model with measurements of the recovery of soil structure and hydraulic functions following soil compaction.