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Towards coupled modelling of soil structure dynamics, soil processes and crop production

Abstract:
Soil-crop models can be useful tools to support analyses of the effects of crop and soil management practices on crop production and impacts on the environment (e.g. carbon sequestration, greenhouse gas emissions and the leaching of agro-chemicals). However, it is not clear that current generation soil-crop models can simulate accurately long-term trends in production due to climate or land use change. This is because soil-crop models do not consider many critical interactions and feedbacks in the soil-plant system. For example, the physical and hydraulic properties of the soil change with time under the influence of plants due to root growth and the carbon supply to the soil, while in turn, these dynamic soil properties influence water and nutrient uptake by plant roots and crop growth. Thus, in principle, soil physical and hydraulic functions are dynamic at time scales ranging from seconds (e.g. compaction) to seasons (e.g. root growth, activity of macro-fauna) and even decades to centuries (e.g. changes in organic matter content) even though they are treated as static properties in most models. Some soil-crop models account for seasonal variations in soil properties (e.g. bulk density) due to tillage loosening and post-tillage consolidation or soil sealing, but none can account for insidious long-term deterioration in physical quality at decadal to century time scales resulting, for example, from the over-exploitation of soil resources (e.g. nutrient mining) or climate change. A lack of quantitative approaches to model the full interplay of dynamic interactions between soil physical properties, processes and crop growth has hampered understanding of how changes in land use, soil management and climate result in soil degradation and a loss of crop productivity, as well as estimation of the likely time-scales for recovery of degraded soils.

In this presentation, a simple approach to incorporate dynamic treatments of soil physical and hydraulic properties in soil-crop models is discussed. The general concept is illustrated by two case studies in which we model: i.) interactions between soil structure and organic matter storage and turnover based on data taken from the Ultuna long-term “frame trial” (Kirchmann and Gerzabek, 1999; Kätterer et al., 2011), and ii.) the recovery of soil structural porosity by biological processes (e.g. root growth and earthworm activity) following traffic compaction, using data from the Agroscope soil structure observatory (Keller et al., 2017).

References

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