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The interaction between land use change, sediment fluxes and carbon dynamics: evaluating an integrated soil-landscape model at the millennial time-scale.

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Soil-landscape modelling has received growing attention as it allows us to evaluate the interaction between earth surface and soil bio-physical processes. At the landscape scale, human-induced land use change has altered the balance between soil erosion and production, and largely modified sediment fluxes. Intensification in soil redistribution rates affects the interaction between soil chemical, physical and biological processes at the landscape scale.

Here, we evaluate the SPEROS-LT model, a spatially explicit 3D model combining a dynamic representation of land use, soil erosion and deposition and the soil carbon cycle. We assess the impact of millennial-scale human-induced land use change on sediment fluxes and carbon dynamics in the Dijle catchement (central Belgium). The watershed has undergone a 3000 years continuous human-induced alteration of the vegetation covers for agricultural characterized by
Our study is based on land use reconstructions for the last 3000 years, including massive deforestation for agriculture in Roman Times and the Middle Ages followed by urbanization in the last 150 years. Land use reconstructions rely on simple land use allocation rules based on slope gradients. SPEROS-LT is parametrized for erosion rates against available figures in the literature by changing the transport capacity and the transfer coefficient which defines the amount of flux transferred between different land uses. Carbon content profiles at steady state (i.e. without influence of erosion or deposition) are calibrated for each land use and for the first upper meter of soil by comparing modeled profiles to an averaged observed profiles in stable areas of the pedologic region. We present a model sensitivity analysis and a full validation of the predicted soil carbon storage (horizontally, i.e. in space, and vertically, i.e. with depth) using a large database of observational data.

The results indicate (i) a good agreement of the erosion rates. Speros LT modeled erosion and export rates, both modern and averaged over the last millennium, fall into the published range. Mean erosion rate over the last 1000 years equals 4.6 t/ha over the entire catchment while the export rate is 1.2 t/ha. (ii) Carbon content in the erosion areas is well predicted for lower soil layers (from 20 to 80 cm) where no significant differences were found between observational and modeled C content. There is though a significant difference for the top soil where modeled mean is 0.92% compared to the 0.8% in observations. (iii) erosion and deposition's spatial patterns are relatively well represented: correspondence between erosion areas as extracted from the digital soil map and modeled erosion maps higher for slightly truncated areas than in high truncation areas (55% of the modeled erosions pixels correspond to a non-depositional area compared to 37%). Correspondence between the model and the soil map increases with the total deposition ranging from 19% to 30% Yet, the model overestimated the carbon content in depositional areas, where statistical differences between observed and modeled carbon amount were found for each soil layers. This indicates that other factors, not accounted for by the model, influence carbon turnover for these sites. They may have a different dynamic than eroding places, cycling carbon faster or transferring it quicker to higher depth.

Overall, the results indicates that the model performs relatively well in predicting sediment fluxes and carbon amount on long time scale during transient simulation. They underline the importance of developing an integrated approach to understand the dynamic and interactions at the landscape scale.