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Predicting the cropland soil organic carbon (SOC) distribution on a regional scale using airborne spectroscopy and topographic features

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The effects of soil redistribution on the carbon cycle have recently been receiving growing attention. In eroding agricultural landscapes, carbon gets transported from erosional to depositional landscape features forming a heterogeneous pattern in quantity and quality of the distributed carbon. At present, methods and research to characterize this horizontal (across the earth surface) and vertical (with depth) variability are focused on local slope scales. Approaches linking detailed local assessments to larger scales are limited. This significantly hampers our ability to understand the impact of soil redistribution processes on the global C cycle that occur at larger spatial and temporal scales.

Here, we present a method to predict the SOC distribution on a regional scale for high-input cropping systems using a combination of airborne spectroscopy, GIS-based analysis of a digital elevation model (DEM) and calibration with empirical data. For a North/South transect in Luxembourg, spatial modeling is used to integrate soil surface SOC data from airborne image spectroscopy (2m resolution), vertical SOC gradients from high resolution (0.10m) soil sampling and derivates of a high-res elevation model (5m resolution). This allows the prediction of the 3D distribution of cropland soil C to be interpolated over an area of c. 150 km^2 in Luxemburg which is characterized by intensive agricultural land use, a high variability in soils and a complex topography.

The model is able to predict patterns of C stock distribution for cropland on a regional scale using simple hydrologic and geomorphologic parameters and provides new insights into the spatial heterogeneity of soil carbon storage covering a large area. Eroding positions have a sharper decline of carbon content with depth than stable and especially depositional sites, which in contrast store high amounts of carbon in greater depths. Relative root mean square errors range between 23-49 % and the model is in good agreement with the empirical data. We estimate a mean C stock (to 100cm soil depth) of 13.2±4.8 kg C/m2 resulting in a total of 1.95±0.7 Tg C stored in the region's cropland soil. Our analysis shows that the link between topography and carbon content is consistent throughout a large variety of soil types. The model provides further evidence that geomorphic gradients play a key role in soil carbon profile development in agricultural landscapes and must be considered for SOC modeling. We postulate that the inclusion of the temporal dynamic of vertical and lateral soil fluxes will greatly improve our understanding of carbon dynamics on the landscape scale.