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Detecting small-scale spatial differences and temporal dynamics of soil organic carbon (SOC) stocks: a comparison between automatic chamber-derived C budgets and repeated soil inventories

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Carbon (C) sequestration in soils plays a key role in the global C cycle. It is therefore crucial to adequately monitor dynamics in soil organic carbon (ΔSOC) stocks when aiming to reveal underlying processes and potential drivers. However, small-scale spatial and temporal changes in SOC stocks, particularly pronounced on arable lands, are hard to assess. The main reasons for this are limitations of the well-established methods. On the one hand, repeated soil inventories, often used in long-term field trials, reveal spatial patterns and trends in ΔSOC but require a longer observation period and a sufficient number of repetitions. On the other hand, eddy covariance measurements of C fluxes towards a complete C budget of the soil-plant-atmosphere system may help to obtain temporal ΔSOC patterns but lack small-scale spatial resolution. To overcome these limitations, this study presents a reliable method to detect both short-term temporal as well as small-scale spatial dynamics of ΔSOC. Therefore, a combination of automatic chamber (AC) measurements of CO_2 exchange and empirically modeled aboveground biomass development (NPPshoot) was used. To verify our method, results were compared with ΔSOC observed by soil resampling. AC measurements were performed from 2010 to 2014 under a silage maize/winter fodder rye/sorghum-Sudan grass hybrid/alfalfa crop rotation at a colluvial depression located in the hummocky ground moraine landscape of NE Germany. Widespread in large areas of the formerly glaciated Northern Hemisphere, this depression type is characterized by a variable groundwater level (GWL) and pronounced small-scale spatial heterogeneity in soil properties, such as SOC and nitrogen (Nt). After monitoring the initial stage during 2010, soil erosion was experimentally simulated by incorporating topsoil material from an eroded midslope soil into the plough layer of the colluvial depression. SOC stocks were quantified before and after soil manipulation and at the end of the study period.
AC-based ΔSOC values corresponded well with the tendencies and magnitude of the results observed in the repeated soil inventory. The period of maximum plant growth was identified as being most important for the development of spatial differences in annual ΔSOC. Hence, we were able to confirm that AC-based C budgets are able to reveal small-scale spatial and short-term temporal dynamics of ΔSOC.