



Co-evolution of landscape and carbon profile through depth: understanding the interplay between transport and biochemical dynamics

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The soil is the largest reservoir of carbon in the terrestrial system but is going through rapid erosion due to anthropogenic influences. Understanding the interplay between biogeochemical transformation and erosion-induced redistribution on the soil organic carbon (SOC) dynamics is critical to our food security and adaptation to climate change. The vital role of SOC redistribution on SOC dynamics has drawn increasing attention in the past two decades, but quantifying such dynamics is still challenging. Here, we develop a process-based quasi 3-D model that couples surface water runoff, soil moisture dynamics, biogeochemical transformation, SOC transport, and landscape evolution at a high spatial and temporal resolution at a watershed scale. Specifically, this model simulates the evolution of SOC profiles across a whole watershed. We apply this model to two different human-impacted landscapes — a low-relief sub-watershed in the Clear Creek Watershed (CCW) in Iowa in U.S. and a high-relief watershed under the Gully Land Consolidation (GLC) project in the China Loess Plateau. In CCW, we simulate SOC profiles over 100 years and validate the results with observations. The SOC profiles tend to have ‘noses’ below the surface at depositional sites. We also compare the lateral SOC transport flux and the vertical soil-atmosphere carbon exchange rate at different locations. Generally, erosional sites are local net atmospheric carbon sinks and depositional sites are sources. We further apply our model to the GLC domain. Our simulation aims to address if the GLC project could provide a sustainable ecosystem in the intensively reconstructed topography. Model results show that upland has litter impact on consolidated gully area regarding soil and SOC flux. We also provide possible outcomes with different scenarios of land management inside the gully. This study not only helps us understand the dynamics of SOC stocks and profiles at a watershed scale but can also serve as an instrument to develop practical means for protecting carbon loss due to human activities.