Publishable Summary D3DC project (FP7 – MC IEF)

Studying the 3D dynamic evolution of soil organic carbon driven by erosion and land use changes at the landscape scale

Soil organic carbon (SOC) is widely recognized as a key factor controlling soil quality and as a crucial and active component of the global C-cycle. Hence, there exists a growing interest in monitoring and modeling the spatial and temporal behavior of this pool in order to help policymakers in developing an appropriate soil and climate change management strategy. So far, a large attempt has been made to map SOC at national scales based on land use, soil type, climate and agro-management. Nevertheless, detailed spatial-temporal SOC predictions are still lacking. Hence, this project aims:

1) to refine spatial predictions by studying the variability of SOC stock and stability at smaller scales in complex terrain driven by lateral soil transport processes (i.e. water and tillage erosion)
2) to make predictions of future spatial evolution of SOC driven by climate and land use change at the national scale up to the year 2100.

Intensified agro-management since the green revolution (from halfway the 20^{th} century) significantly increased soil erosion and its associated lateral fluxes of soil properties within agricultural catchments. During this relatively short period of time large amounts of fertile topsoil have been removed from erosional sites and have accumulated in depositional zones. As a consequence, the associated three dimensional spatial distribution of SOC has been modified significantly, especially within croplands under conventional tillage. As on the one hand erosion affects the stability of soil organic matter (i.e. breakdown of soil aggregates during transport process) and on the other hand organic carbon in depositional zones is assumed to be stored in stable environments, the increased within-field differences in SOC probably cause a major change in regional SOC dynamics. Nevertheless, the variability of SOC at smaller scales in complex terrain driven by soil erosion, such as stable subsoil carbon buried in depositional areas, is still rather understudied and is not (well) represented in current regional C estimates.

In the present project we unraveled the variation in quantity and quality of SOC depth distributions along typical hillslope transects under croplands (UK, Devon) and related these to soil redistribution rates and variations in C input, i.e. below and above ground biomass productivity. SOC stability has been studied in a depth specific context by running long-term incubation experiments. Moreover, the effect of potential increased C input has been tested by applying different rates of glucose additions on some of the incubated soil samples. The results show contrasting vertical patterns in SOC stock and stability depending on the rate and type of erosion. For example, sites characterized by deposition due to water erosion (i.e. footslope) have much higher SOC values near the surface, but show a fast decline with depth, while sites characterized by deposition due to tillage erosion (i.e. most concave position) have moderated SOC surface values that stay constant until a depth of 50 cm. The observed trends in biomass are reflecting within field C input differences, which on their turn are consistent with observed SOC patterns, i.e. low above ground C input values at steepest slope position and high below- and aboveground C input values at most concave and depositional areas, respectively. Respiration experiment results show that the topsoil C release rates are highest at the footslope and lowest at the plateau. For deeper layer the C release rates of all topo-position are comparable, except at the most convex position, where almost no C release was measured. Considering the glucose addition experiment, this picture is remarkably different as the most convex topo positions shows to be the most stable environments for the freshly added C (lowest C release). Considering deeper soil layers samples from the most concave topo-position released the most carbon over time. The present study improved our understanding of the influence of lateral transport processes (erosion) on the within field vertical heterogeneity in SOC stock and stability. Hence the scientific output of this project allows us to improve long-term soil fertility and C storage management in eroding landscapes and can be considered as a first step to refine 3D spatial and temporal models of SOC dynamics at regional scales or landscheme models such as JULES.

In addition, in this study we predicted future spatial evolution of SOC driven by climate and land use change for France up to the year 2100. Therefore, we combined 1) an existing model, predicting SOC as a function of soil type, climate, land use and management (Meersmans et al 2012), with 2) eight different IPCC spatial explicit climate change predictions (conducted by CERFACS) and 3) Land use change scenario predictions. We created business-as-usual land use change scenarios by extrapolating observed trends and calibrating logistic regression models, incorporating a large set of physical and socio-economic factors, at the regional level in combination with a multi-objective land allocation (MOLA) procedure. The resultant detailed projections of future SOC evolution across all regions of France, allow us to identify regions that are most likely to be characterized by a significant gain or loss of SOC and the degree to which land use decisions/outcomes control the scale of loss and gain. Therefore, this methodology and resulting maps can be considered as powerful tools to aid decision making concerning appropriate soil management, in order to enlarge SOC storage possibilities and reduce soil related CO_2 fluxes.