Control of Vertical Soil Variation on Temporal Variation of Soil CO_2 Production and Emissions

Steven De Gryze[1], Johan Six[1*]

Objectives

- Development of a depth-explicit soil organic matter (SOM) model based on the CENTURY model.
- Testing whether the rate constants of CENTURY can be reconciled with vertical soil transport
- Testing whether rates of vertical transport decrease with depth
- Sensitivity analysis of the decrease in SOM decomposition rates with depth

Approach and Procedures

A SOM model was written in MATLAB. The model includes a depth-dependent decrease in root C input and decomposition rate, and vertical soil movement due to pedoturbation and leaching. The calibration of this model was done based on experimental data of carbon isotopes (^{12}C, ^{13}C, and ^{14}C) from profiles in Iowa and mineral radionuclides (^{137}Cs and excess ^{210}Pb) from the U.K.

Results

The model was able to represent well these profiles of the carbon isotopes and mineral radionuclides (*figs. 1 and 2*). Nevertheless, several generally assumed concepts needed to be rejected to have a functional depth-explicit model. First, adding vertical soil transport (calibrated by the mineral isotope profiles) to the existing CENTURY caused a complete disappearance of the passive C pool. The latter could only be resolved by assuming a decrease in transport rates with depth and a 10-times smaller rate constant for microbial decomposition than the rate constant assumed in CENTURY.

[1]UC Davis Department of Plant Sciences
[*]Principal Investigator

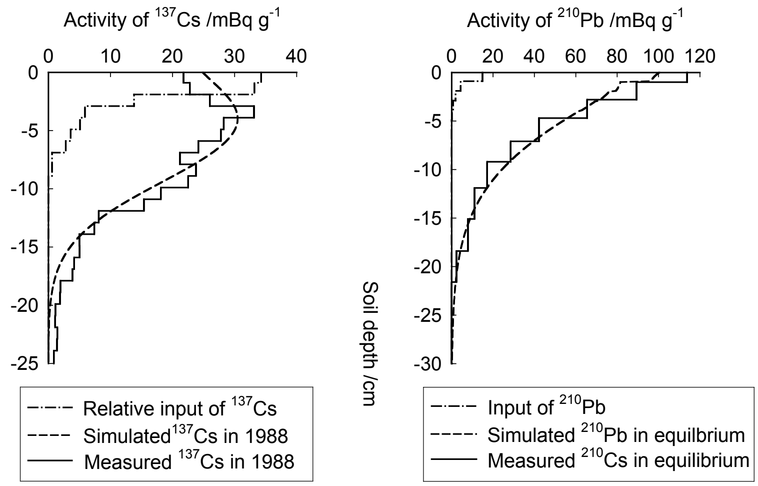

Figure 1. Input, measured, and modelled depth profiles of ^{137}Cs, and excess ^{210}Pb. Input and measured profiles are averages from data of Walling and Quine (1990, 1992) for ^{137}Cs, and He and Walling (1997) for ^{210}Pb-ex.

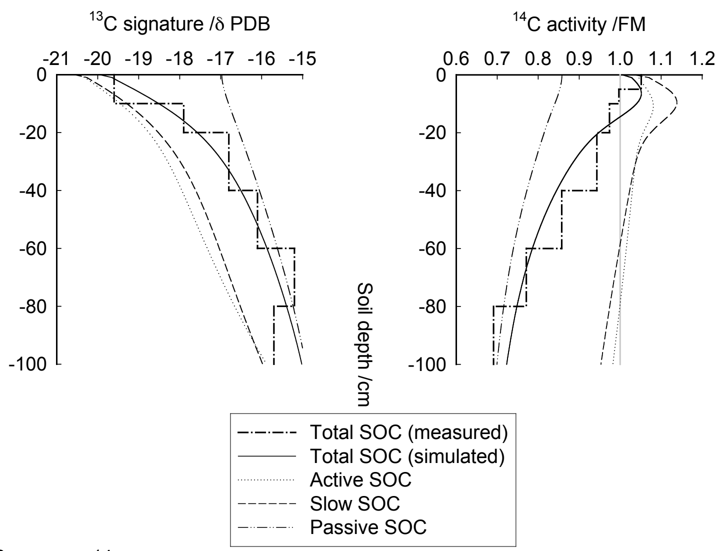

Figure 2 Simulated ^{13}C and ^{14}C signatures of three SOC pools and measured and simulated ^{13}C and ^{14}C signatures of total SOC with depth.

Discussion

The CENTURY model does not include any vertical transport of slow or passive SOC. Only the active C can move downward through leaching. Our results suggest that the omission of vertical soil transport in CENTURY leads to an overestimated mean residence time of passive SOM. Second, the first-order decomposition rate for passive C in CENTURY could not be reconciled with the vertical transport rates of SOC. A reduction in microbial decomposition rate of passive C of about 10 times was necessary to keep passive C at equilibrium levels. Third, no satisfactory model agreement could be found if the decomposition rate at 100 cm decreased more than 10 times that at the soil surface. As a result of the interplay between root inputs, reduced decomposition with depth and vertical transport, the relative importance of in situ SOC assimilation through root input versus carbon import from upper profile locations changes with depth. Our model simulation indicates that over the first meter of the soil profile, the importance of root input decreases with depth; while the importance of vertical C transport gradually increases. At 1 m, root input is responsible for only 25% of the C input. Hence, it is clear that vertical transport dominates soil C input at depth, and that it should be included when studying and/or modelling deep SOC dynamics. However, little experimental data exists on vertical transport rates at depth, which is necessary for further advances in understanding of deep-soil C dynamics.

The addition of vertical transport within a depth-explicit carbon model indicates that the conceptually defined turnover times of soil C and their response to changes in environmental factors might have been overestimated. All of the above results exemplify the important role that vertical soil transport plays in determining the turnover of SOC pools and ultimately the shape of the SOC profile.

References

He, Q. and D.E. Walling. 1997. The distribution of fallout Cs-137 and Pb-210 in undisturbed and cultivated soils. *Applied Radiation and Isotopes*, 48, 677-690.

Walling, D.E. and T.A. Quine. 1990. Use of caesium-137 to investigate patterns and rates of soil erosion on arable fields. In: *Soil erosion on agricultural land,* Boardman, J., Foster, I.D.L. and Dearing, J.A. (eds), pp. 33–53. Chichester, UK: Wiley.

Walling, D.E. and T.A. Quine. 1992. The use of caesium-137 measurements in soil erosion surveys. In: *Erosion and sediment transport monitoring programmes in river basins*. International Association of Hydrological Sciences (IAHS) Publication No. 210., pp. 143-152. Wallingford, UK: IAHS Press.

This research was funded by the Kearney Foundation of Soil Science: Understanding and Managing Soil-Ecosystem Functions Across Spatial and Temporal Scales, 2006-2011 Mission (http://kearney.ucdavis.edu). The Kearney Foundation is an endowed research program created to encourage and support research in the fields of soil, plant nutrition, and water science within the Division of Agriculture and Natural Resources of the University of California.