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Theoretical and numerical analysis of a soil organic matter decomposition model along vertical soil profiles and coupling the dynamics of carbon and nutrients dynamics.

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Abstract More than 250 models dedicated to the decomposition of the soil organic matter (SOM) were developed over the last thirty years. Among them, E. Bosatta & G. Ågren have proposed several equations based on the theory of organic matter quality noted q to describe heterogeneous SOM dynamics. These models are ruling the fate of carbon and nutrients concentrations in the soil organic matter.

One of these models considers the decomposition of SOM along a vertical soil profile [1]. Carbon and nutrients distribution functions are noted $\rho_c(q,z,t)$ and $\rho_\chi(q,z,t)$ $(g\,cm^2\,q^{-1})$ respectively where χ is a specific nutrient. The mass balance provides the following equations:

$$\frac{\partial \rho_c(q,z,t)}{\partial t} = -f_c \frac{u(q,z)}{e(q)} \rho_c(q,z,t) + f_c \int_0^{+\infty} D(q,q') u(q',z) \rho_c(q',z,t) dq' - \frac{\partial \left[\nu(q,z) \rho_c(q,z,t)\right]}{\partial z}, \quad (1)$$

$$\frac{\partial \rho_\chi(q,z,t)}{\partial t} = -f_c \frac{u(q,z)}{e(q)} \rho_\chi(q,z,t) + f_\chi \int_0^{+\infty} D(q,q') u(q',z) \rho_c(q',z,t) dq' - \frac{\partial \left[\nu(q,z) \rho_\chi(q,z,t)\right]}{\partial z}. \quad (2)$$

where f_c and f_χ are decomposer carbon and nutrient χ concentrations; $u(q,z)$ $(g\,g_c^{-1}\,t^{-1})$ is the decomposer growth rate per unit of substrate carbon; $e(q)$ is the decomposer efficiency; $D(q,q')$ (q^{-1}) is the dispersion function of quality; $\nu(q,z)$ $(cm\,y^{-1})$ is the velocity of the particles of organic matter.

This model considers continuous distributions in time, space and quality and requires few parameters describing soil physics and micro-biological activity. Despite these conceptual advantages, this particular approach was poorly used because of the absence of mathematical analysis. Therefore, Bosatta & Ågren have chosen to simplify the equations to obtain explicit solutions sufficient to describe a steady state. Here we extend their work from mathematical point of view.

The existence and the uniqueness of solutions were proved for the original model. A numerical method was also implemented to simulate SOM dynamics. The consequences of model simplification were numerically studied by comparing the complete model versus the simplified one. It results that model simplification is in general not relevant and may have strong drawbacks when studying the heterogeneity of SOM.

Our work was then an essential step to design a modeling toolbox able to investigate soil data already available, using few parameters for soil physics and microbiological activity, and suitable to various ecosystems. This work is included in a broader modelling framework aiming at building a predictive tool for growth & yield of forest ecosystems.

Reference [1] E Bosatta and GI Agren. Theoretical analyses of carbon and nutrient dynamics in soil profiles. Soil Biology and Biochemistry, 28(10-11):1523 - 1531, 1996.