Geophysical Research Abstracts, Vol. 8, 08272, 2006
SRef-ID: 1607-7962/gra/EGU06-A-08272


# Nonlinearities and eco-hydrological feedbacks in soil carbon and nitrogen cycles

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We review and compare analytical models of soil carbon and nitrogen cycles at different degrees of simplification to highlight the role of nonlinearities and soil hydrologic conditions in biologically-mediated processes. Although linear models of decomposition are generally used, the nonlinear coupling between microbial biomass and its substrate, due to the role of microbial exoenzymes in the organic-matter degradation, is essential for a complete accounting of both short- and long-term temporal dynamics of decomposition. The main difference between linear and nonlinear formulations of decomposition is that, in deterministic conditions, linear models behave like a pure decay function, while nonlinear models may show dynamic bifurcations between stable-node and stable-focus equilibria as a function of the climatic parameters (e.g., soil moisture and temperature). A second essential nonlinearity appears when the nitrogen-limitation feedback on decomposition is analyzed. Nitrogen limitation is established when microbial demand for inorganic nitrogen is high, due to nitrogen-poor substrate or inefficient assimilation of organic nitrogen (Mineralization-Immobilization Turnover hypothesis, MIT). On the contrary, when microbes are able to directly assimilate organic nitrogen (DIR hypothesis), the occurrence of N-limiting conditions is less likely. We include both these assimilation mechanisms in a flexible model framework (parallel hypothesis, PAR), and analyze how the different efficiencies of organic nitrogen assimilation affect plant-microbe competition and the seasonal patterns of mineral nitrogen availability under different soil moisture and temperature conditions.