Modelling of mechanisms affecting nitrogen and carbon cycles in soils subject to land use change

Batlle-Aguilar Jordi*, Brovelli Alessandro*, Porporato Amilcare**, Barry D. Andrew*

*Ecological Engineering Laboratory, Institute for Environmental Engineering, École Polytechnique Fédérale de Lausanne, Station 2, CH-1015, Switzerland (jordi.batlle@epfl.ch, alessandro.brovelli@epfl.ch, andrew.barry@epfl.ch)
** Civil and Environmental Engineering Department, Duke University, Durham, NC-27708, USA (amilcare@pratt.duke.edu)

In order to meet demands for crops, pasture and firewood, the rate of land use change from forested to agricultural uses steadily increased over several decades, resulting in an increased release of nutrients towards groundwater and surface water bodies. In parallel, the continuous degradation of natural ecosystems such as riparian zones, contribute to diminish their capacity to provide ecological services, i.e. reduce the impacts of deleterious human activities on both surface and groundwater. Land use changes and restoration practices are known to affect both soil nutrient dynamics and their transport to neighbouring areas.

Biogeochemical transformations in soils are heavily influenced by microbial decomposition of soil organic matter. Carbon and nutrient cycles are in turn strongly sensitive to environmental conditions, primarily to soil moisture. This physical variable affects the reaction rate of almost all soil biogeochemical transformations, including microbial and fungal activity, nutrient uptake and release from plants, etc. Soil water saturation is not constant neither in time nor in space, thus further complicating the picture. In order to interpret field experiments and elucidate the different mechanisms taking place, numerical tools are beneficial.

The impact of hydroclimatic variability (soil moisture in particular) on soil carbon and nitrogen cycles was highlighted along with the consequences of land use changes from forest to pasture and/or agriculture. To this end, a mechanistic model based on the compartment model of Porporato *et al*. (2003) was developed. The predictive capabilities of the model to forecast the effects of land use changes over carbon and nitrogen dynamics were shown, modelling four different scenarios, intertwining two different climate conditions (with and without seasonality) with two contrasting soils having physical properties that are representative of forest and agricultural soils. Synthetic time series of precipitation, and therefore soil moisture evolution in time, were generated using a stochastic approach. The model was subject to isothermal conditions and other considerations such as average values of carbon and nitrogen concentrations over the rooting depth. As well an average microbial organic decomposition rate was considered. Simulation results demonstrated higher concentrations of carbon and nitrogen in forests soils as a result of higher litter decomposition than in agricultural soils (Figure 1). High frequency changes in water saturation under seasonal climate scenarios were shown to be commensurate with carbon and nitrogen concentrations in agricultural soils.

Forest soils have different properties to agricultural soils, leading to an attenuation of the seasonal climate-induced frequency changes in water saturation, with accompanying changes in carbon and nitrogen concentrations.

The model was shown to be capable of simulating the long term effects of modified physical properties of agricultural soils as a consequence of tillage, ploughing and harvesting. It is, thus, a promising tool to predict carbon and nitrogen turnover changes due to changes in land use. These results encourage further model improvements aimed at accounting for the complexity of the soil system and its processes for better understanding soil nutrients turnover.

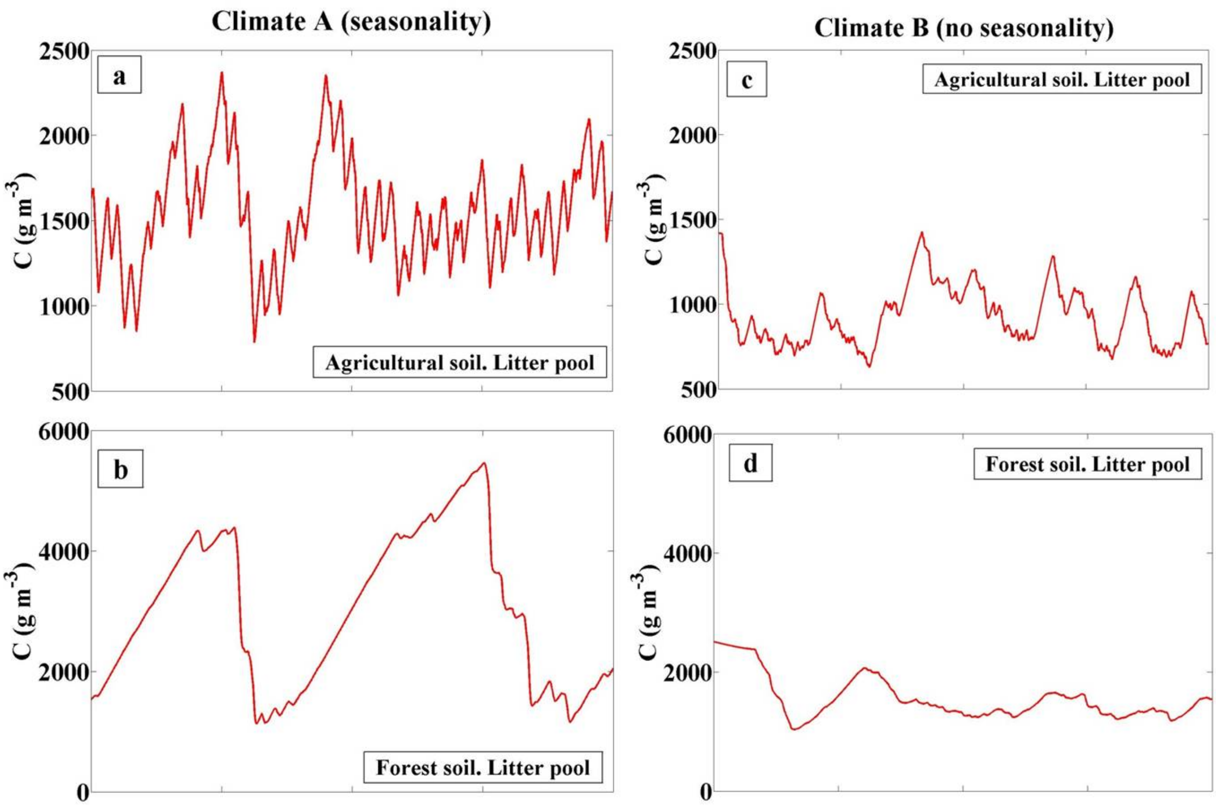

Figure 1. Simulated organic carbon concentrations in the litter pool for agricultural and forest soils under seasonal (left side) and no seasonal (right side) climate conditions.

REFERENCES

Porporato, A., D'Odorico, F., Laio, F. & Rodriguez-Iturbe, I. 2003: Hydrologic controls on soil carbon and nitrogen cycles. *Adv. Water Resour.*, 26, 45-58.