

## NONLINEAR DYNAMICS AND DETERMINISTIC CHAOS IN SOIL MICROBIAL ACTIVITY

N.A. Vasilyeva and A.A. Vladimirov

*Dokuchaev Soil Science Institute, Pyzhevsky per., 7, build. 2,  
119017 Moscow, Russian Federation. (nadezda.vasilyeva@gmail.com)*

### ABSTRACT

We applied cross-scale approach to model soil C with differential equations, starting from a microscale system of reaction-diffusion PDE with diffusion chaos solutions, demonstrate their application to describe experimental data of soil aggregate formation around roots and heterotrophic respiration as a result of complex patterns of microbial activity. In this approach the irregular dynamics of biomass with temperature and moisture was shown to be the possible key to increasing amplitude of uncertainty in experimental data. We upscaled them to local long-term equations (ODE) to describe decadal-scale field experiments, and further upscale to regional projections of carbon balance in a climate change scenario.

### INTRODUCTION

Soil organic carbon (C) dynamics largely contributes to biosphere C fluxes and ecosystems stability. It is largely acknowledged that soil microbial activity (particularly, heterotrophic respiration - decomposition of organic matter using enzymes) is responsible for the major part of C dynamics in soils. There is an ongoing discussion of the need and value of upscaling effects from soil microbial activity to improve Earth System Models [1]. However, it is not yet evident what are the most important mechanisms controlling such activity and how to best model them.

Population dynamics in ecology is frequently studied using nonlinear differential equations with deterministic chaos, but not specifically microbe communities in soil environments. Previously we investigated nonlinear interactions between microbial growth and physical factors (moisture, oxygen, pore size, diffusion), considering soil solution a viscous porous medium in a model of a spherical aggregate [2]. In this model a self-organization of soil environment was simulated as a result of interactions between microbial biomass, labile and resistant organic matter, oxygen and water. While nonlinear diffusion in contrast to linear was capable of simulating anaerobic spatial zones free from microbial self-oscillations due to limited oxygen diffusion. Presence of reducing conditions in natural soils is considered one of the factors of organic matter accumulation. Investigating the biological part of this model (without physical environment factors) there was shown the transition to diffusion chaos in accordance with the Feigenbaum–Sharkovskii–Magnitskii bifurcation theory [3].

Further in this study we summarize our investigations of the effect of biological traits on soil microbial activity in feedbacks with physical environment. It can potentially allow us to explain complex behavior of long-term soil C dynamics and understand the conditions for its resilience.

### METHODS

First, we modified our core model [2] to study the microbial competition mechanisms for substrates. For that we spitted microbes into 3 different functional types and studied their spatial patterns in 2 dimensions, while neglecting the physical environment. The model was applied to describe a laboratory experiment where all physical parameters (soil moisture, temperature, and aeration) were fixed. The biochemical cycle of the model includes 2 types of substrates - labile ( $M_1$ ), relatively resistant ( $M_2$ ) and 3 types of microbes:  $B_I$  – slow moving but generating exoenzymes to prime  $M_1$

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