Impacts of drought and flooding on the biological activities in sediments.

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Introduction:

Since 1970, trace gas emissions increased of 70% [1], with the consequent increase of 0.74•C in temperature. Climate scenarios indicate that if emission rates are not to be reduced, atmospheric temperature may increase between 1.1 and 6.4•C by the end of the century. If these scenarios actually occur, the impact on the environment and on human beings may be strong. As a consequence of global warming, frequency, intensity and duration of rainfalls, floods and droughts have already been observed by the IPCC [2]. All these phenomena taking place worldwide in the future will affect the spatial and temporal distribution of soil moisture. This would have strong consequences upon the redox zonation and bio-chemical transformations in the environment, which in turn determine the production of trace gases. Therefore, it is particular challenging to understand how bacteria will respond to the modification of biogeochemical conditions.

The impact of these effects is considered to be particularly important in the Mediterranean area, where changes, due to intensification of longer drought periods and intense rainfall, are expected to be enhanced.

In this work, we aim to study how different degrees of saturated conditions affect the biogeochemical cycles of carbon and nitrogen and their impact on the ecological and chemical status of water bodies. We present a mechanistic model which couple the bacteria activity with oxygen and soil moisture dynamic. The model accounts for N2O production from nitrification and denitrification, as well as the competition for nitrate by denitrification, dissimilatory reduction of nitrate to ammonium (DNRA).

Methods: In order to improve the current understanding of climate change impacts on biogeochemical cycling, we simulate saturated and unsaturated conditions on bacteria activity in sediments. In particular, the role of drying and wetting processes, and the extent of saturated conditions in biofilm formation is still poorly understood [3]. We focus on the nitrogen and carbon cycling and investigate the role of variable soil moisture on nitrification, denitrification and potential emissions of trace gases (nitrous oxide and carbon oxide) for different scenarios. We compare drought and flooding conditions, as well as rapid infiltration processes. The target is to understand which conditions favour bacteria activity and biofilm formation. The model accounts for ammonium, nitrate, DNRA and for two of carbon: one stable and one labile. Reaction rates are expressed as the products of the maximum potential rates, multiplied by limiting factors of soil moisture, temperature and dissolved oxygen concentrations.

Results: Our results indicate that biofilm growth affects porous media transport dynamics.

Preliminary results indicates that different hydrological conditions affect carbon and nitrogen cycling and the potential production for trace gases. In particular we find that unsaturated and saturated conditions alter differently the reaction rates of the biogeochemical cycling. This has important consequences on the management of surface infiltration ponds, since the bacteria activity is responsible, together with physical and chemical processes, for the changes in infiltration rates, which themselves alter the water quality. Further investigations are needed to understand the role of dessication/rewetting on biofilm formation. Our hypothesis is that bacteria activity is affected by variable soil moisture according to Figure 1, which illustrates the variation of biological activities for different soil moisture levels.

Figure 1 shows how the ratio between the time of infiltration and the time required by bacteria to adapt to the new soil moisture conditions [defined τ_θ / τ_{bio}], alter the biological activity level in the sediments.

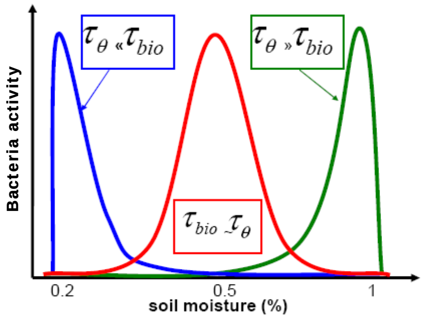

Fig. 1: Proposed relationship of bacteria activity as a function of the relative values of Infiltration time, τ_θ, and that required by bacteria to adapt to the new soil moisture conditions, τ_{bio}.

Discussion: Bacteria are present in sediments as vast communities of individuals, supported in small-scale habitats, connected or disconnected within saturated or unsaturated pores [4]. In moist soils, pore spaces are like to be better connected; as soils dry out, microbes may lose the liquid highways and water bridges that connect one soil particle to another (Shiemel *personal communication*). Our results suggest that changes in the N-cycle are related to the macro-scale processes, and the biogeochemical cycles are the result of processes happening at the micro-scale, in particular changes in the hydrological connectivity of the microbial landscape. Therefore more studies are needed to understand the effect of changes in soil moisture on bacteria and vice-versa [5]. Our preliminary results indicates that biofilm alter the quality of water in irrigation ponds. For that reason we think it would be interested to compare the measured potential activity in a model soil/sediment system before biofilm formation, and then again after biofilm is formed.

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