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Stochastic modelling of organic carbon sequestration from river ecomorphodynamic processes

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River floodplains act as natural sinks for the storage of organic carbon (OC). While in the past rivers were seen as passive pipes that convey OC to seas and oceans, recent research has indicated rivers as active components of the carbon cycle (active pipes) able to produce, convey, and also store OC within the active river corridor in several forms, including dead and living wood (above/below ground vegetation biomass) and aquatic biota. More recently, this concept has been extended by including the carbon exchange between the river channel and its riparian zone through hyporeic fluxes and processes related to erosion and deposition of sediments and vegetation biomass (the river carbon cycle). However, processes and related timescales of OC sequestration from river systems are still poorly understood, being quantitative predictive tools almost unavailable.

As a novelty, we develop a simplified stochastic model for the fate of riparian vegetation whose state is generally at an intermediate level being it subjected to frequent stress conditions which trigger its removal or burial. After the flooding, a fraction of the woody mass is removed (and stored through burial or conveyed downstream) and new biomass grows through re-sprout or colonization. This mechanism has often been neglected in the existing literature although it may help to shed light on the relevance of river ecomorphodynamic processes in the river carbon cycle.

We assume flow hydrology fluctuates as a Compound Poisson Process, and use this signal-over-threshold as a noise component forcing the dynamics of riparian vegetation. Hence, riparian vegetation grows continuously while being uprooted by sporadic flooding events, thus entering the river carbon cycle as dead wood. The stochastic model is solved analytically for the probability distribution and related moments of riparian wood removal. By comparing the dead wood production performed by river activity to the biomass that grows nearly undisturbed on the floodplain, we define a catalysis index that is useful to quantify the sequestration ratio of biomass between the floodplain and the river corridor. Thanks to the uprooting process, trees can be removed, thus providing room for the growth of new ones; this allows rivers to produce more OC compared to an equivalent vegetated area of the floodplain not prone to floods disturbances.

Supported by a preliminary analysis of remotely sensed river data, and numerical simulations, the model is able to provide insights into the likely hydrological and morphological controls of OC sequestration in river systems and therefore to predict the possible effects of climatic and anthropogenic forcing on such element of the global carbon cycle.