PhD in Civil and Environmental Engineering

Research Title: Rivers as catalysts of carbon sequestration

Funded by	Politecnico di Torino (Joint Research Projects with Top Universities)

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Context of the research activity	The focus of the project is on the capability of rivers to foster carbon sequestration, through a physically-based eco-geomorphological approach. Rivers represent delicate systems which exhibit a plethora of processes from geomorphology, ecology, hydraulics, engineering and social sciences. They provide an example of ecotone, i.e., the presence of two different communities, the terrestrial and aquatic ones, where biodiversity is maximized in the form of highly diverse, shifting mosaic of plant species maintained by intermediate frequency and magnitude of flooding. Although only 1% of the Earth surface is covered by inland waters, their collective contribution to global carbon fluxes is substantially similar to terrestrial and marine ecosystems. Inland waters transport, mineralize and bury about 2.7 Pg C yr^{-1} (1 Pg C =1 billion of tons of carbon), while the terrestrial carbon sink for anthropogenic emissions is of 2.8 Pg C yr^{-1}. Furthermore, nearly 20% of the carbon assumed to be buried in the terrestrial biomass is buried in inland water sediments (Nat. Geosci., 2009). A key open question of carbon cycle science is whether burial in inland waters represents a net increase in carbon sequestration rather than simply a translocation of a sink that would otherwise have occurred on land or, eventually, in the oceans. Through the use of two consolidated modeling approach, for which the joint partnership plays a reference role in the literature (i.e., stochastic modeling and computational morphodynamics) and the analysis of aerial lidar data, we will address the capability of river systems to behave as catalysts for the net primary production in riparian environments, where carbon is sequestred during low flow periods and it is stored through plant removal during flooding. Such a lurcking mechanism of "flood driven carbon storage" will be quantified at the basin and reach scale, in order to design optimal river corridors able to mine the anthropogenic carbon emissions. The PhD project is a joint collaboration between Politecnico di Torino and ETH Zurich, therefore the Ph.D student will stay 18 months at Politecnico di Torino and 18 months at ETH Zurich.

Objectives	The overall aim of the project is to address the implications of discharge randonmess and morphodynamic processes (erosion and sedimentation) on the CO_2 sequestration of fluvial environments through the development of phenomenolgical mathematical

	models (stochastic and numerical) and the analysis of field observations. The novelty of the work is to analyze a new mechanism that the existing literature in carbon cycle science has always neglected: the state of riparian vegetation is generally at an intermediate level, since it is 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 transported away) and new biomass grows through resprout or colonization. Rivers therefore behaves as activators of biomass growing, namely carbon sequestration from the atmosphere. Objective I. The project firstly aims to develop the following mathematical models: a) Stochastic model. We will develop reliable stochastic models through an approach that is well recognized in river science. b) Ecomorphodynamic numerical models are tools able to predict the evolution of the river bed as a result of the interaction between water flow, sediment transport and vegetation. The starting point of the project is an already available two-dimensional model (BASEveg) recently developed in ETH Zurich. The target is to include the effects of fine material in the recruitment processes and the investigation of different physically based mathematical relationships for the vegetation dynamics. c) Asexual reproduction benefits from physical damage to plants by fluvial processes and has therefore a different response to environmental conditions. The goal is to develop a simplified stochastic model that can be also implemented in the numerical model. --- Objective II. Understanding the role of unsteadiness through stochastic modeling Using the analytical and numerical models we will quantify how flow unsteadiness of water and sediment discharge affects: i) the vegetation growth; ii) the frequency of biomass removal; iii) the overall CO_2 sequestred by atmosphere. Such a modeling approach will be applied to straight rivers with vegetated alternate bars, meandering rivers with vegetated point bars and braided rivers characterized by well-know ipsometric distribution (i.e., the distribution of the elevation). Objective III. Comparison with real data and scale up from single reach to basin analysis. The temporal evolution of both vegetation and morphology of selected real rivers (both swiss and italians ones, such as Po' River, Alpine Rhine, Maggia) will be investigated. This will be done by analysing already available (aerial) LIDAR data and will allow us to numerically compute the woody biomass that is removed by floods.

Skills and competencies for the development of the activity	Knowledge of numerical or mathematical modeling and good preparation in river hydraulics