Ecomorphodynamic carbon pumping of world’s large tropical rivers

By

Luca Salerno

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Supervisors

Prof. Carlo Camporeale

Prof. Annunziato Siviglia

The role of inland waters in the carbon cycle has been re-evaluated in recent decades. In fact, the collective contribution of inland freshwater to the global carbon cycle was found to be comparable to that of terrestrial and marine ecosystems combined. Nevertheless, the quantification of lateral carbon fluxes from wetlands and riparian zones to freshwater is affected by high uncertainties and many processes are still poorly understood.

This thesis aims to investigate some unexplored fluxes of inland waters carbon derived from the interactions between river dynamics and riparian vegetation and evaluate the influence of river regulation on floodplain forests.

Rivers are dynamic entities that wander by spanning the floodplain back and forth. During this wandering, the carbon biomass stored in standing vegetation is recruited by flow erosion and partially stocked downstream by sediment burial. Bare landforms become available for atmospheric carbon to be captured by growing vegetation. This 'mowing' and 'stocking' mechanism was explored, quantifying its relevance as an efficient carbon pump for the world's largest tropical rivers.

We suggest that the high mobility of natural rivers plays a significant role in the carbon budget of fluvial corridors. A multi-temporal analysis of satellite data for all world's largest tropical rivers in the period 2000-2019, with 30 m resolution was carried out. Based on this data, quantification of a yet unexplored highly efficient Eco-Morphodynamic Carbon Pump (eCP) mechanism in riverine systems is provided. River morphodynamics is shown to drive carbon export from the riparian zone and to promote CO_2-sequestration. This is realized by an integrated process through floodplain rejuvenation and plant colonization. For tropical rivers larger than 200 m this pumping mechanism alone accounts for 12 ± 0.96 million tons per year of carbon mobilization. In this thesis, signatures of fluvial eco-morphological activity that provide a proxy for the carbon mobilization capability associated with river activity were identified. The magnitude of the carbon pump suggests that care is needed in breaking the river migration rate -- carbon mobilization nexus in the management of tropical rivers promoting innovative and sustainable management criteria.

Moreover, the regular natural flood pulse of large tropical rivers is the main driver of ecological and biogeochemical processes in large Amazonian floodplains. Endemic vegetation species developed adaptation to survive in seasonal flood environments and tune their vital process with periodic flood events, water levels, and sedimentary processes. The construction of hydroelectric dams also causes alterations of the natural hydrological regime and sediment supply, threatening downstream floodplain forests.

An assessment of river regulation impact on floodplain vegetation is crucial to developing a modern watershed management approach in the Neotropics aimed at mitigating alterations of the floodplain environment. Floodplain forest monitoring requires high--resolution mapping, as vegetation dynamics are in the narrow area at the interface between terrestrial and aquatic systems. The existing satellite images that afford land observations have limitations due to coarse resolution or gaps in data caused by the extreme cloudiness of tropical regions.

A new framework for high-resolution mapping and monitoring of a large-scale tropical forest in the aquatic-terrestrial zone of an Amazon basin is provided in this thesis. The main aim is to assess the vegetation status and the environmental degradation in a highly altered fluvial setting. To achieve the goal, a remote sensing processing chain, which couples hydrologic and vegetation data, was developed.

A map of high-resolution traditional vegetation indices and their non-linear generalization was derived from the high-resolution gap-free reflectance data obtained by combining Landsat and MODIS data, through the HISTARFM algorithm. Subsequently, hydrological modification within these areas was assessed by using a global water surface dataset.

In addition, the impact of river regulation on riverine forest carbon cycling was assessed through the analysis of interannual variability of the gross primary production of floodplain vegetation.

The framework was applied to analyze the last two decades of changes in the floodplain forest of Uatuma river (central Amazon basin), downstream of the Balbina hydropower dam built in 1987. The analysis showed the presence of vegetation degradation in areas of increased hydrologic stress and upland forest encroachment in areas no longer inundated.

The dam continues to have effects on vegetation even 30 years after its construction. The ongoing profound reshuffling of the floodplain forest and the impact on the carbon storage capacity of the floodplain forest suggest that the situation is far from a new environmental equilibrium.

The proposed high--resolution approach allows for a detailed mapping of riparian vegetation alterations, helping to develop a more careful management of the watershed through a better understanding of the human footprint on floodplain forests.