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A Half-Century Intensification of Lateral Carbon Transfer along the Congo Basin's Land–Ocean Aquatic Continuum

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ABSTRACT

The Congo Basin, home to the world's second largest tropical rainforest and river network, plays a crucial role in the global carbon (C) cycle. However, rapid population growth and land-use changes are intensifying geomorphic and biogeochemical disturbances. Consequently, the basin is experiencing accelerated soil redistribution, whose impacts on lateral C transfer along the land–ocean aquatic continuum (LOAC) remain largely unknown. By integrating the most comprehensive observation dataset available with a state-of-the-art land surface model (ORCHIDEE-C_{lateral}), this study quantified the magnitude and temporal evolution of lateral C fluxes in the forms of particulate organic carbon (POC), dissolved organic carbon (DOC), and carbon dioxide (CO₂) over the past five decades, and assessed the impact of these lateral C transfers on the terrestrial C budget.

The calibrated ORCHIDEE-C_{lateral} model explains 73%, 84%, 78%, and 84% of the spatial variation in observed river water discharge, sediment discharge, POC concentration, and DOC concentration in the Congo River network, respectively. It also captures well the seasonal variations in riverine water discharge, sediment discharges, water surface extent, and riverine CO₂ partial pressure. Using the calibrated model, we reconstructed the historical evolution of C fluxes and transformations along the LOAC. Since 1970, lateral C (i.e., POC, DOC, and CO₂) input from land to river has increased significantly (Mann–Kendall $P < 0.001$), with POC, DOC, and CO₂ rising by 51%, 20%, and 29%, respectively. The increase in POC is primarily driven by land-use change, followed by climate change and rising atmospheric CO₂. Of the terrestrial C entering the Congo River network, 61% of DOC and 67% of POC remain within the river–floodplain complex—approximately two and three times the proportion retained in the Amazon and European river networks, respectively. These results suggest that the majority (> 60%) of the laterally transported terrestrial C is stored or transformed inside the Congo Basin rather than being exported to the ocean or released to the atmosphere. With the projected rapid population growth and land-use expansion in the Congo Basin, lateral C fluxes along the LOAC are expected to intensify further, reinforcing the Congo Basin's role as a major inland C buffer that reshapes the regional land–ocean C balance.

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