

Land use and water chemistry as key controls on global carbon greenhouse gas emissions from ponds

JOVANA RADOSAVLJEVIC¹, ALI REZA SHAHVARAN¹,
ELODIE PASSEPORT², STEPHANIE SLOWINSKI¹,
FEREIDOUN REZANEZHAD¹, YAMIN DENG³ AND
PHILIPPE VAN CAPPELLEN¹

¹University of Waterloo

²Rutgers University

³China University of Geosciences

Small lakes and ponds are critical components of the global carbon cycle, acting as both organic carbon sinks and sources of greenhouse gases (GHG) like CO₂ and CH₄. Despite their importance, ponds (surface area <5 ha) are often excluded from large-scale GHG budgets due to data scarcity. To address this gap, we synthesized global datasets of mapped waterbodies to estimate the spatial distribution of ponds and compiled CO₂ plus CH₄ emission and water chemistry data from 950 ponds worldwide. Monte Carlo analysis revealed that ponds <1 ha emit 0.25–0.42 Pg C yr⁻¹, and those 1–5 ha emit 0.18–0.45 Pg C yr⁻¹, contributing up to 14% and 17%, respectively, of global carbon gas emissions from freshwater bodies. These results underscore the disproportionate role of ponds in GHG budgets. To identify drivers of emissions, we matched pond data with gridded hydrometeorological and socio-economic variables across HydroBASIN-delineated watersheds. Random Forest regression showed pH and watershed urbanization were key predictors of CO₂ emissions, while electrical conductivity (EC), surface area, and depth governed CH₄ fluxes. Urban ponds exhibited elevated pH, likely from alkaline construction materials, which suppress CO₂ emissions by retaining dissolved inorganic carbon under the form of aqueous bicarbonate. For CH₄, non-sulfate EC (a proxy for salinity) correlated positively with enhanced emissions, because reduced water column mixing and oxygenation promote methanogenesis while limiting CH₄ oxidation. This study highlights how land use (especially urbanization) and water chemistry regulate GHG dynamics in ponds. By integrating geospatial, chemical, and machine learning approaches, we provide a framework for scaling up pond emissions across watersheds. Our findings advance the understanding of biogeochemical cycling in understudied aquatic systems and emphasize the need to incorporate small water bodies into Earth system models to refine global carbon budgets.