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Editorial: Greenhouse gas emissions from terrestrial freshwater ecosystems: spatial and temporal hot spots

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Editorial on the Research Topic
Greenhouse gas emissions from terrestrial freshwater ecosystems: spatial and temporal hot spots

Terrestrial freshwater ecosystems are increasingly recognized as crucial components of the global carbon (C) and nitrogen (N) cycles. These cycles include matter transfer from terrestrial to aquatic compartments, sediment storage, biogeochemical turnover, and losses via downstream transport of dissolved and particulate species and gaseous emissions to the atmosphere (Beusen et al., 2005; Marx et al., 2017; Drake et al., 2018; Piatka et al., 2022; Zheng et al., 2022; Wang et al., 2023). Losses of gases are climate-critical when they concern greenhouse gases (GHGs), including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (Intergovernmental Panel on Climate Change, 2021, 2022). A recent synthesis study estimates yearly emissions of 8.3 (5.7–12.7) Pg CO_2-equivalents (CO_2-eq) from inland water bodies scaled over 100 years (Lauerwald et al., 2023). This number may still be severely underestimated due to excluding a poorly defined number of small lentic freshwater ecosystems and wetlands (Downing et al., 2012; Lauerwald et al., 2023). The collection of manuscripts in this Research Topic "*Greenhouse gas emissions from terrestrial freshwater ecosystems: spatial and temporal hot spots*" provides a schematic overview of GHG sources and turnover.

In recent centuries and decades, human activities have caused substantial changes in landscape hydrology, land use, and climate. These activities also affected the functioning of terrestrial freshwater ecosystems and GHG exchange (Piatka et al., 2021; Winkler et al., 2021; Pilla et al., 2022; Mwanake et al., 2023). Due to their sensitivity to these changing environmental conditions and their complex temporal and spatial nature, large-scale quantifications of current global freshwater GHG emissions are still subject to large uncertainties. The complexity of these processes, together with their quantitative uncertainties and feedback loops, call for improved biogeochemical, physical, and biological understanding and quantification of processes.

The manuscript by Mwanake et al. investigates a critical knowledge gap in our understanding of partitioning GHG sources in headwater streams on the catchment scale. Employing stable isotope ratios of oxygen (O) and hydrogen (H), they analyse the influence of mean residence times (MRTs) and young water fractions (YWFs) on GHG concentrations in 17 headwater streams with variable catchment characteristics that cover variable land use types and proportions and catchment drainage. Their work reveals that agriculture-dominated stream catchments can act as seasonal hotspots of GHGs. The work also shows that variable shorter and longer MRTs from inputs of precipitation-driven GHG-rich agricultural soils and nutrient-rich groundwaters can fuel in-stream GHG production.

Similarly strong impacts of temporally dynamic hydrological conditions and land use on GHG concentrations and respective emissions in a peatland-dominated headwater stream are also shown in the study of Piatka et al.. By applying a continuous measuring system for the three GHGs CO_2, CH_4, and N_2O over 5 months, this study shows increased mobilization of GHG-rich peatland porewaters to the stream network after rainfall events. Subsequent higher stream water levels enhanced GHG emissions that may be responsible for up to 59% of the total GHG budget.

Addressing the burgeoning aquaculture sector, the study by Vroom et al. investigates CH_4 emissions from freshwater fishponds in Brazil. The study reveals the dominance of CH_4 ebullition over diffusion. This finding emphasizes the significance of GHG emissions from managed and artificial ponds. These results challenge our understanding of CH_4 emission pathways in aquaculture ponds and call for management practices to minimize their carbon footprint.

Although mostly neglected, aquatic vegetation might also strongly contribute to the dynamics and magnitudes of CH_4 emissions from terrestrial freshwater ecosystems. This relationship is highlighted in the review by Bodmer et al.. In a literature synthesis, they present various pathways in which aquatic vegetation may influence CH_4 dynamics and emissions. They also assemble a variety of measurement methods to assess plant-associated CH_4 fluxes. Based on a complementary data analysis from the literature, the authors demonstrate that neglecting vegetated habitats may lead to a substantial underestimation of global CH_4 emissions from inland waters.

Specifically, water bodies with a higher impact of anthropogenic pressure caused by land use change are often major sources of GHGs, as various recent studies suggest (Hao et al., 2021; Li et al., 2021; Peacock et al., 2021; Rosentreter et al., 2021; Malerba et al., 2022).

Moreover, a new study by Zannella et al. investigates how harvesting forests affects the dynamics of CO_2 in man-made ditches in boreal watercourses. The researchers propose that light- and temperature-induced metabolism is important. They also point out the seasonal variations and diel cycles in CO_2 concentrations. This study emphasizes the significance of taking these dynamics into account when analyzing CO_2 emissions in boreal areas impacted by forestry.

The five manuscripts in this Research Topic add new data, concepts, knowledge and improved process understanding of GHG dynamics from catchment to freshwater habitat scales. All of these studies show that continental freshwaters are essential but increasingly scarce resources. They also show that societies and regulations need to value and reduce anthropogenic impacts on inland water bodies to minimize aquatic GHG emissions and maintain freshwater ecosystem services.

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