frontiers | Frontiers in Environmental Science

TYPE Editorial
PUBLISHED 02 November 2023
DOI 10.3389/fenvs.2023.1322708

OPEN ACCESS

EDITED AND REVIEWED BY
Vera I. Slaveykova,
University of Geneva, Switzerland

*CORRESPONDENCE
Xingyuan Chen,
Xingyuan.Chen@pnnl.gov

RECEIVED 16 October 2023
ACCEPTED 17 October 2023
PUBLISHED 02 November 2023

CITATION
Chen X, Dwivedi D and Michael HA (2023), Editorial: Hydrology, ecology, and nutrient biogeochemistry at the terrestrial-aquatic interface.
Front. Environ. Sci. 11:1322708.
doi: 10.3389/fenvs.2023.1322708

Editorial: Hydrology, ecology, and nutrient biogeochemistry at the terrestrial-aquatic interface

Xingyuan Chen[1]*, Dipankar Dwivedi[2] and Holly A. Michael

[1]Pacific Northwest National Laboratory, Richland, WA, United States, [2]Lawrence Berkeley National Laboratory, Berkeley, CA, United States, [3]Department of Earth Sciences, Department of Civil and Environmental Engineering, University of Delaware, Newark, DE, United States

KEYWORDS

terrestrial-aquatic interface, nutrient cycling, watershed modeling, data-model integration, perturbation

Editorial on the Research Topic
Hydrology, ecology, and nutrient biogeochemistry at the terrestrial-aquatic interface

Terrestrial-aquatic interfaces (TAI) play important roles in mediating the exchange of water and chemicals between land, surface and subsurface water systems, which is tightly coupled with biogeochemical transformations that influence water quality and ecosystem health (Harvey and Gooseff, 2015; Harvey et al., 2019). Understanding and predicting the interactions between the hydrologic, ecologic, and biogeochemical processes at those interfaces is crucial for the sustainable management of water resources and promotion of healthy ecosystems under different environmental stresses and disturbances, including climate change, human activities, and more frequent occurrence of extreme events. Both process-based and data-driven approaches have emerged to address critical challenges at TAIs as integral parts of the Earth system (e.g., Ward and Packman, 2019; Chen et al., 2021; Dwivedi et al., 2022). In this Research Topic, we sought research that advances the understanding of coupled hydrologic, ecologic, and biogeochemical processes along various TAIs from the summit to sea, e.g., river corridors and coastal TAI systems. We invited observational, experimental, theoretical, analytical, numerical, and data-driven research that aims to understand hydro-biogeochemical processes such as the redox dynamics and biogeochemical transformations of carbon, nutrients, and metals occurring at the TAIs and address their heterogeneity and scaling challenges.

Hydrologic exchange and the associated biogeochemical processes show significant spatial and temporal variability as the TAIs are subject to dynamic forcing over a wide range of timescales. Barczok et al. study variability in soil redox conditions in response to seasonal flooding in a vernal pond, which is a TAI that experiences intermittent flooding and drying. Redox potential was measured at multiple soil depths (2–48 cm below the soil surface) in shallow and deep sections within the lowland and upland zones. Measurements were taken at a 10-min frequency over a 5-month period from late spring through early autumn, capturing hydrologic shifts between drying and reflooding. It is found that the dynamic hydrological condition in the lowland results in more dynamic redox conditions compared to the upland. The intermittent reflooding resulted in multiple shifts between reducing and oxidizing conditions in the shallow lowland while the deep lowland remained in reducing condition following reflooding events. During the summer months, increases in redox potential lagged behind the drying out of surface water by up to weeks. In contrast, each reflooding event of the vernal pond in the fall led to almost immediate decreases in redox potential. Such heterogeneity and dynamics in redox conditions caused by drying and rewetting have significant impacts on multiple elemental cycling at the TAI, which in turn depends on many factors such as microbial activity, redox buffering capacity of the soil, and soil water retention properties. Similarly, Kaymak et al. examine riverine particulate organic matter (POM) along the TAI from the upper reaches of the Lyidere River in Turkey to its mouth at the Black Sea. The region is characterized by a steep topographic gradient driving high fluid and sediment fluxes along a river dotted with cascading dams set in a human-dominated landscape. They use statistical modeling of elemental and stable isotope analyses of carbon and nitrogen in POM collected at 8 sites along the river to discern the mechanisms that control spatio-temporal patterns in POM composition and source. They show that during wet season, hydrology dominates, homogenizing POM composition. During the dry season, however, the human impacts were evident. The spatial distribution of POM composition exhibited effects of agricultural and industrial activities, and differed upstream and downstream of dams. Importantly, this study highlights the critical role that humans play along the TAIs, in this case affecting riverine POM composition and fluxes that drive biogeochemical cycles and estuarine food webs, with implications for the global carbon budget.

Several other studies in this Research Topic further shed new light on the vast human impacts that are becoming increasingly more important but have been understudied. For example, Zong et al. address the important urban-river-lake interface in a low-income region, focusing on non-point source (NPS) nitrogen and phosphorous pollution in Mwanza City, Tanzania, which lies on the southern shore of Lake Victoria. There, as in other urban areas in Africa and globally, rapid population growth has led to development of informal settlements that include dense populations as well as agriculture and livestock production while lacking sustainable planning of water supply, sanitation, and drainage infrastructure. By integrating land-use classification with a pollution load model, they were able to analyze the spatial distribution of NPS pollution in the city and estimate nitrogen and phosphorous loads to urban surface waters. They show that the informal settlements were by far the largest contributor of NPS pollution, highlighting a major need for nutrient management in rapidly developing, low-income urban areas. For agricultural landscapes, Srivastava et al. provided an overview of various conservation practices and their effectiveness in reducing flooding and improving water quality across watershed and field scales. This review highlights that combinations of conservation practices often outperform individual methods, while their effectiveness varies with location and time. Assessing the effectiveness of future conservation practice is further complicated by the uncertainty in future climate projections.

In snow-dominated or snow-dependent regions, the accumulation and melting of snow is a primary control of streamflow seasonality and intermittency, directly impacting the biogeochemical processes in TAIs from the head water to coastal estuaries. Le et al. empirically explore the spatial and temporal links between snow persistence (SP) and streamflow hydrograph shape and variability during low-flow and high-flow conditions across gradients of aridity and seasonality within the North American continent. Their study found that SP is associated with lengthening the duration of high-flow events over space and time, especially in arid regions such as in the western US. More mechanistic representation of snow accumulation and ablation processes in watershed hydrologic and biogeochemical models will allow us to quantify alterations in hydrograph's flashiness, variability, and duration of low-flow and high-flow periods under future climate.

Maher and von Blanckenburg investigate how plants and regolith weathering and erosion control the cycling of nutrients. Regolith here refers to the weathered layer above the bedrock and includes both saprolite and soil. A simplified plant-growth model was linked with a regolith weathering model to track the fate of rock-derived nutrients (RDN), such as phosphorus, potassium, and calcium, from primary minerals in bedrock to their assimilation by plants and loss via erosion and chemical weathering. Operating under steady-state conditions, the study considers a range of regolith parameters that could affect both plant growth (e.g., thickness) and chemical weathering export (e.g., mineral dissolution rate, erosion rate and water flux). They found that higher plant growth rates were correlated with thicker regolith and lower water flow but were not significantly influenced by biogenic mineral dissolution. Moreover, the study revealed that biologically enhanced RDN dissolution mainly impacts chemical weathering exports at unusually high erosion rates—conditions that rarely occur on the surface of the Earth. These findings underscore the need to account for the complex interactions among the biosphere, regolith properties, and erosion rates when studying nutrient cycling.

Riparian zones serve as crucial links between terrestrial and aquatic ecosystems with key roles in nutrient cycling of carbon, nitrogen, and phosphorus. Stutter et al. introduce a new concept referred to as the Reactive Riparian Interface (RRI), which can be viewed as a dynamic "gatekeeper" for nutrient transfer within landscape spatio-temporal frameworks. They urge interdisciplinary research that effectively merges ecology, biogeochemistry, and climate science. They also stress the need to develop adequate spatial frameworks that capture multi-nutrient cycling to enable more accurate projections across multiple scales while considering climate sensitivities.

Collectively, there still exist major data and knowledge gaps in understanding the hydrologic and biogeochemical processes at TAIs, especially an interdisciplinary gap in linking carbon, nitrogen and phosphorus transformations. It is vital to consider the freshwater continuum beyond the channel network and shift towards interdisciplinary research that brings together expertise from ecology, soil science, biogeochemistry, climatology, geomorphology, and hydrology. Rapid progress in coordinated observations, experiments, modeling and their integration is needed to improve our understanding of the vulnerability of TAIs to natural and anthropogenic perturbations, and ultimately to build computational frameworks to handle topography–soil–water–climate physical and biogeochemical observations and modeling from plot to watershed to continental and global scales.

Author contributions

XC: Conceptualization, Funding acquisition, Resources, Writing–original draft, Writing–review and editing. DD:

 10.3389/fenvs.2023.1322708

Conceptualization, Funding acquisition, Resources, Writing–original draft, Writing–review and editing. HM: Conceptualization, Funding acquisition, Resources, Writing–original draft, Writing–review and editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This research was supported by the U.S. Department of Energy (DOE), Office of Biological and Environmental Research (BER), as part of BER's Environmental System Science Program (ESS) through the River Corridor Scientific Focus Area (SFA) at the Pacific Northwest National Laboratory (PNNL). PNNL is operated for DOE by Battelle Memorial Institute under contract DE-AC05-76RL01830. The efforts of DD were supported by the Watershed Function Scientific Focus Area (SFA) funded by the US Department of Energy, Office of Science, Office of Biological and Environmental Research under Award Number DE-AC02-05CH11231. HM was supported by the National Science Foundation (NSF) award numbers EAR2130602 and EAR2012484. This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Chen, X., Lee, R. M., Dwivedi, D., Son, K., Fang, Y., Zhang, X., et al. (2021). Integrating field observations and process-based modeling to predict watershed water quality under environmental perturbations. *J. Hydrology* 602, 125762. doi:10.1016/j.jhydrol.2020.125762

Dwivedi, D., Steefel, C. I., Arora, B., Banfield, J., Bargar, J., Boyanov, M. I., et al. (2022). From legacy contamination to watershed systems science: a review of scientific insights and technologies developed through doe-supported research in water and energy security. *Environ. Res. Lett.* 17, 043004. doi:10.1088/1748-9326/ac59a9

Harvey, J., Gomez-Velez, J., Schmadel, N., Scott, D., Boyer, E., Alexander, R., et al. (2019). How hydrologic connectivity regulates water quality in river corridors. *JAWRA J. Am. Water Resour. Assoc.* 55, 369–381. doi:10.1111/1752-1688.12691

Harvey, J., and Gooseff, M. (2015). River corridor science: hydrologic exchange and ecological consequences from bedforms to basins. *Water Resour. Res.* 51, 6893–6922. doi:10.1002/2015WR017617

Ward, A. S., and Packman, A. I. (2019). Advancing our predictive understanding of river corridor exchange. *Wiley Interdiscip. Rev. Water* 6, e1327. doi:10.1002/wat2.1327