frontiers | Frontiers in Earth Science

TYPE Editorial
PUBLISHED 07 March 2023
DOI 10.3389/feart.2023.1165061

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Hydrosphere, a section of the journal Frontiers in Earth Science

RECEIVED 13 February 2023
ACCEPTED 27 February 2023
PUBLISHED 07 March 2023

CITATION
Rosa E, Larocque M, Hatch CE and Springer AE (2023), Editorial: "Novel approaches for understanding groundwater dependent ecosystems in a changing environment".
Front. Earth Sci. 11:1165061.
doi: 10.3389/feart.2023.1165061

Editorial: "Novel approaches for understanding groundwater dependent ecosystems in a changing environment"

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KEYWORDS

groundwater dependent ecosystems (GDE), groundwater-surface water interactions, human impacts, climate change, environmental resilience

Editorial on the Research Topic
"Novel approaches for understanding groundwater dependent ecosystems in a changing environment"

Groundwater represents one of the largest reservoirs of freshwater on the planet (Oki and Kanae, 2006) and is the source of drinking water for 2.5 billion people (Grönwall and Danert, 2020). From the earliest evidence of groundwater-related knowledge dating back to antiquity, with the construction of qanats in the Middle East, to the contemporary use of artificial intelligence in support of aquifer studies, hydrogeological science has expanded rapidly (Fetter, 2004a; Fetter, 2004b; Niu et al., 2014). Other related disciplines such as hydrology, ecology, land use planning, and climatology, have experienced comparable booms. Yet, one of the downfalls of the rapid growth and specialization of different scientific disciplines is that the scientific community sometimes becomes split into groups with complementary expertise.

As a result, some challenges that should implicitly be addressed with holistic or multidisciplinary approaches have been neglected by the scientific community. This justifies pursuing the study of groundwater dependent ecosystems (GDEs). GDEs are ecosystems for which vegetation composition, structure, and functions are reliant on a given supply of groundwater (Kløve et al., 2011). GDE types are extremely varied and include springs, wetlands, and groundwater-fed terrestrial and aquatic environments (Bertrand et al., 2012). The study of GDEs is thus clearly positioned at the intersection of many disciplines (Figure 1).

Consider the example of a spring located in a valley. The geological perspective is needed for evaluating how the architecture of rock formations and overburden deposits influence the geometry of aquifers. The hydrogeological perspective is critical for documenting the characteristics of exfiltration zones in groundwater flow systems (e.g., Lambert et al.). The climate perspective is crucial to assess the inputs

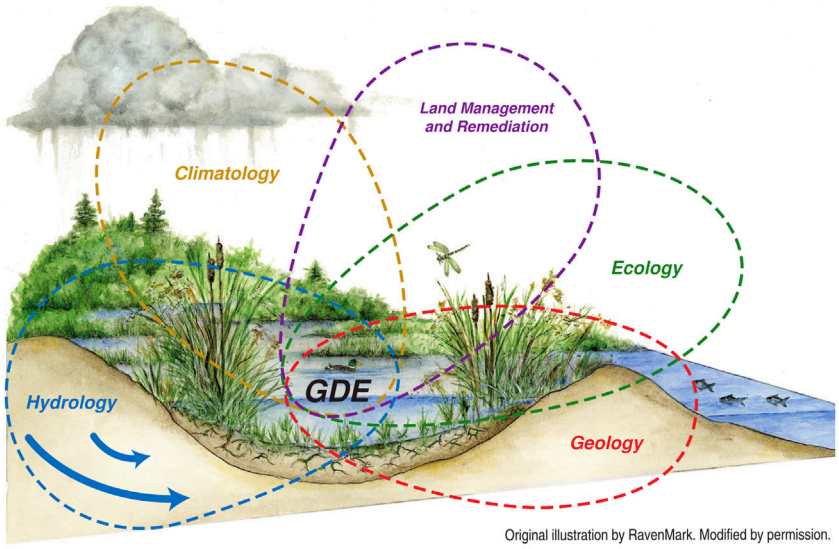

FIGURE 1
GDE-related research and its position among various areas of expertise. Original illustration (Living Observatory, 2020) by RavenMark, modified by C.E. Hatch by permission. © Creative Commons.

(precipitation) and outputs (evapotranspiration) of the flow systems (e.g., Rohde et al.). The ecological perspective is central to identify the faunal and floral species in discharge areas and document their dependence on the (eco) hydrological, thermal, and geochemical conditions maintained by groundwater flows (e.g., Mitton and Allen). Ultimately, land-use planning and rehabilitation approaches will be critical to ensure the protection and rehabilitation of GDEs under increasing human pressures (e.g., Hatch and Ito; Watts et al.).

This Research Topic brings together five original contributions that address critical issues concerning GDEs from the different perspectives illustrated in Figure 1. The studied environmental contexts range from relatively arid California, United States (Rohde et al.) to the boreal zone of the Province of Quebec, Canada (Lambert et al.), the humid continental zone of the northeastern United States (Hatch and Ito; Watts et al.) and the Lower Fraser Valley of British Columbia, Canada (Mitton and Allen). It is clear from the contributions collected here that assessing the sensitivity and resilience of GDEs to human pressures and climate change is of great importance.

Each contribution stands out for deploying innovative approaches to the study of GDEs. For example, Lambert et al. focused on the evaluation of the hydrogeological balance of peatlands *via* numerical hydrogeological models based on field measurements. Their work shows that the hydrogeomorphic environment surrounding boreal peatlands is a major factor to consider when assessing their sensitivity to climate change. The work of Rohde et al. is further based on hydrogeological observations (groundwater levels) complemented by climate data and satellite images. The machine learning approach they developed allows for an efficient landscape-scale assessment of GDEs at risk. The authors highlight the increased impacts suffered by GDEs located in areas where sustainable water management is not implemented. The approach taken by Mitton and Allen stands out. Thanks to the coupled use of hydrological measurements, habitat monitoring and the assessment of benthic macroinvertebrate communities. Their findings highlight the need to better characterize benthic habitat heterogeneity within intermittent streams, particularly in areas of groundwater discharge, with a view to better understanding the resilience of such GDEs to human pressures and climate change. Hatch and Ito and Watts et al. bring GDE resilience to another level, by considering the possibility of restoring these ecosystems. Hatch and Ito assess groundwater flow within an "anthropogenic aquifer" once created for cranberry cultivation to provide the knowledge required to restore the "natural" water regime of the GDE. Watts et al. further advance this work and deploy innovative thermal remote sensing approaches to assess groundwater exfiltration to the impacted wetland in the pre- and post-restoration phases. Ultimately, the insights from these studies will provide the knowledge needed to optimize approaches to regenerate GDEs at human-impacted sites.

Combining the studies presented in this Research Topic, not only contributes to disseminate innovative knowledge to better understand GDEs, but also contributes to draw the attention of the scientific community to the anthropogenic and climatic pressures to which they are exposed. This is a step towards better protecting GDEs for the benefit of current and future generations of humans and of the breadth of fauna and flora they sustain.

Author contributions

ML, ER, CH, and AS have coordinated the call for papers in this Research Topic. ML has coordinated its development with the Frontiers team. ER has written the first manuscript of the editorial. ML, CH and AS have contributed to editing the text.

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

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