frontiers | Frontiers in Environmental Science

TYPE Editorial
PUBLISHED 24 January 2025
DOI 10.3389/fenvs.2025.1557374

OPEN ACCESS

EDITED AND REVIEWED BY
Martin Siegert,
University of Exeter, United Kingdom

*CORRESPONDENCE
Ionut Minea,
ionutminea1979@yahoo.com

RECEIVED 08 January 2025
ACCEPTED 13 January 2025
PUBLISHED 24 January 2025

CITATION
Minea I, Boicu D, Negm A, Zelenakova M and Demirci M (2025) Editorial: Impact of climate changes on groundwater resources.
Front. Environ. Sci. 13:1557374.
doi: 10.3389/fenvs.2025.1557374

Editorial: Impact of climate changes on groundwater resources

Ionut Minea[1]*, Daniel Boicu[2], Abdelazim Negm[3], Martina Zelenakova[4] and Mustafa Demirci[5]

[1]Department of Geography, Faculty of Geography and Geology, "Alexandru Ioan Cuza" University of Iași, Iași, Romania, [2]Research Center with Integrated Techniques for Atmospheric Aerosol Investigation in Romania, Recent Air, Laboratory of Interdisciplinary Research in Geo-Chemistry of Rural Areas, Environmental Quality Monitoring Station for Geographic Research, Alexandru Ioan Cuza University of Iasi, Iai, Romania, [3]Department of Water and Water Structures Engineering, Faculty of Engineering, Zagazig University, Zagazig, Egypt, [4]Technical University of Košice, Košice, Slovakia, [5]Iskenderun Technical University Hatay, Hatay, Türkiye

KEYWORDS

groundwater, resources, climate changes, impact, management

Editorial on the Research Topic
Impact of climate changes on groundwater resources

In today's society, groundwater reserves are an essential resource for different communities globally from regions where problems associated with the depletion of groundwater resources are critical (the Mediterranean area, the Sahel area or the central part of India) to areas that have only come into the sights of researchers in the field in recent decades (the Arctic or Antarctic area) (Siegert et al., 2017). The excessive and unsustainable exploitation of these resources generates negative effects that are observable globally, with a greater incidence in developing countries and third-world regions (Wada et al., 2016). One of the main causes of pressure on groundwater is the rapid growth of the global population, which has quadrupled in the last century and continues to grow. In addition, this demographic expansion implies an increased demand for food, which causes the expansion of agricultural areas and increasing demand for irrigation resources (Changming et al., 2001; Asoka et al., 2017) and achievement of climate neutrality targets in sustainable water resources management (Ionescu et al., 2024).

The significant decline in groundwater resources cannot be explained solely by the increase in global population and water demand. Multiple studies have highlighted a link between climate variations and fluctuations in the level of underground water, especially in surface aquifers (de Graaf et al., 2017; Russo and Lall, 2017; Sivarajan et al., 2019; van der Knaap et al., 2015). The effects of rapid population growth, surface water pollution and increasing climate uncertainties will lead to increased dependence on groundwater in the future. At the same time, the impact of climate change and climate variability is a growing challenge for the current generation. It may become more severe in the future due to human interventions in nature (Minea et al., 2020; Swain et al., 2021).

Groundwater plays a crucial role in the global climate balance. However, the effects of climate change on these resources remain unclear due to the complex interactions and feedback processes specific to the atmosphere-hydrosphere system. Climate change influences groundwater resources in various ways. Within the hydrological cycle, they can affect soil infiltration rates, percolation at greater depths and, implicitly, groundwater recharge. In addition, rising temperatures increase evaporation at ground level, which reduces the amount of water available to recharge aquifers. In contrast, anthropogenic impacts on groundwater resources are mainly driven by water extraction through pumping and indirect impacts of irrigation and land use changes (Liesch and Wunsch, 2019; Munday et al., 2017).

Looking into the future, according to the data presented by the Intergovernmental Panel on Climate Change (IPCC), the average global temperature tends to increase between 2°C–4°C, an aspect that becomes even more plausible if you take into account that the average global surface temperature has already recorded since 1861 an increase of 0.6°C (Calvin et al., 2023). As a result of the increase in temperature, the hydrological processes can suffer profoundly, and the intensification of the water evaporation from the topographic surface and the transpiration of the plants takes shape even more. Consequently, climate change will influence the distribution, timing, and intensity of rainfall, indirectly affecting the distribution and storage of water.

Researchers use both specific hydrological models to assess the potential impact of climate change on surface and groundwater resources to determine groundwater recharge, including in the analysis data such as hydrological dynamics, soil, and surface structure, as well as methods that involve monitoring and evaluation of groundwater resources *in situ* or based on satellite data sets, developing index sets (Thomas et al., 2017). These methods provide valuable and cost-effective information, contributing to developing, evaluating and optimizing groundwater management strategies, policies, and projects.

The complexity of the components of the hydrological system and how climate change acts on groundwater resources induce the realization of analyzes that must take into account aspects related to the past, historical data, current problems, and future projections. Studies show that in addition to the anthropogenic impact, climate change, by increasing temperatures, changes in the precipitation regime, and the intensification of evaporation processes, governs the availability of water resources. Thus, it was found on the basis of the studies that a better understanding of the impact induced by climate change on groundwater resources is obtained through a large-scale analysis, both from a spatial and a temporal point of view. The analysis of the impact of climate change on underground water resources in various areas of the globe offers a complementary perspective in understanding the phenomenon through the lens of different analysis methodologies. Innovative methodologies such as the Time-Lapse Electrical Resistivity Imaging (TL-ERI) method and machine learning-based time series clustering (Puntu et al.) allow the monitoring of groundwater levels and the estimation of storage capacities, obtaining precise information about the seasonal changes of the underground level, allowing identifying critical areas where an aquifer is under pressure induced by climate variations. *In situ* observations are a tool that provides a clear perspective on the impact of climate change. An analysis of historical data on temperature and precipitation variations can provide valuable information on the vulnerability of surface water resources with subsequent effects on groundwater. The fluctuations of a lake in response to the temporal variation of climatic parameters can also be relevant for the study of underground reserves, reserves that can change in terms of recharge and discharge of neighboring aquifers (Li et al.). Anticipating the future impact of climate change on water availability for a given region, starting from reporting historical data to long-term simulations provides relevant information from the perspective of achieving an efficient management of groundwater and avoiding the induction of water stress through overloading of water resources in underground in periods of prolonged drought (Zhan et al.; Alrowais et al.). At the same time, technical solutions, based on three-dimensional numerical models on computational fluid dynamics must be identified to reduce the anthropogenic impact on groundwater quality (Minea et al., 2021).

Recent studies highlight climate change's significant and complex impact on groundwater, reducing aquifer recharge and storage capacity. The increase in the unpredictability of precipitation and its manifestation through seasonal changes, frequency variability, and intensity variation superimposed on the increase in temperatures and the intensification of evaporation generate the irregular recharge of the surface and deep aquifers. The adaptation and effective management of the groundwater resource, both globally, regionally and locally, is becoming a priority area in the context of current and future climate change.

Author contributions

IM: Conceptualization, Supervision, Writing–original draft. DB: Formal Analysis, Investigation, Writing–original draft. AN: Investigation, Supervision, Validation, Writing–review and editing. MZ: Conceptualization, Supervision, Validation, Writing–review and editing. MD: Supervision, Validation, Writing–review and editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

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.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Asoka, A., Gleeson, T., Wada, Y., and Mishra, V. (2017). Relative contribution of monsoon precipitation and pumping to changes in groundwater storage in India. *Nat. Geosci.* 10, 109–117. doi:10.1038/ngeo2869

Calvin, K., Dasgupta, D., Krinner, G., Mukherji, A., Thorne, P. W., Trisos, C., et al. (2023). "IPCC, 2023: climate change 2023: synthesis heport," in *Contribution of working groups I, II and III to the sixth assessment report of the intergovernmental Panel on climate change; core writing team*. Editors H. Lee and J. Romero (Geneva, Switzerland: IPCC). doi:10.59327/IPCC/AR6-9789291691647.00

Changming, L., Jingjie, Y., and Kendy, E. (2001). Groundwater exploitation and its impact on the Environment in the North China plain. *Water Int.* 26 (2), 265–272. doi:10.1080/02508060108686913

de Graaf, I. E. M., van Beek, R. L. P. H., Gleeson, T., Moosdorf, N., Schmitz, O., Sutanudjaja, E. H., et al. (2017). A global-scale Two-Layer Transient groundwater model: development and Application to groundwater depletion. *Adv. Water Resour.* 102, 53–67. doi:10.1016/j.advwatres.2017.01.011

Ionescu, R. V., Zlati, M. L., Antohi, V. M., Cristea, D. S., Petrea, Ș. M., and Forțea, C. (2024). Modelling the economic and environmental impacts of water resources in the context of climate neutrality in the EUSDR member states. *Front. Environ. Sci.* 12, 1353107. doi:10.3389/fenvs.2024.1353107

Liesch, T., and Wunsch, A. (2019). Aquifer responses to long-term climatic Periodicities. *J. Hydrol.*, 572, 226–242. doi:10.1016/j.jhydrol.2019.02.060

Minea, I., Iosub, M., and Boicu, D. (2020). Groundwater resources from Eastern Romania under human and climatic pressure. *Sustainability* 12 (24), 10341. doi:10.3390/su122410341

Minea, I., Iosub, M., and Boicu, D. (2021). Multi-scale approach for different type of drought in temperate climatic conditions. *Nat. Hazards* 110, 1153–1177. doi:10.1007/s11069-021-04985-2

Munday, P. L., Donelson, J. M., and Domingos, J. A. (2017). Potential for adaptation to climate change in a Coral Reef fish. *Glob. Chang. Biol.* 23, 307–317. doi:10.1111/gcb.13419

Russo, T., and Lall, U. (2017). Depletion and response of deep groundwater to climate-induced pumping variability. *Nat. Geosci.* 10, 105–108. doi:10.1038/ngeo2883

Siegert, M., Kulessa, B., Bougamont, M., Cristoffersen, P., Key, K., Andersen, K. R., et al. (2017). Antarctic subglacial groundwater: a concept paper on its measurement and potential influence on ice flow. *Geol. Soc.* 461, 197–213. doi:10.1144/sp461.8

Sivarajan, N. A., Mishra, A. K., Rafiq, M., Nagraju, V., and Chandra, S. (2019). Examining climate change impact on the variability of ground water level: a case study of Ahmednagar district, India. *J. Earth Syst. Sci.* 128, 122. doi:10.1007/s12040-019-1172-z

Swain, S., Mishra, S. K., and Pandey, A. (2021). A detailed assessment of meteorological drought characteristics using simplified rainfall index over Narmada River Basin India. *Environ. Earth Sci.* 80, 221. doi:10.1007/s12665-021-09523-8

Thomas, B. F., Famiglietti, J. S., Landerer, F. W., Wiese, D. N., Molotch, N. P., and Argus, D. F. (2017). GRACE groundwater drought index: evaluation of California central valley groundwater drought, *Remote Sens. Environ.*, 198, 384–392. doi:10.1016/j.rse.2017.06.026

van der Knaap, Y. A. M., de Graaf, M., van Ek, R., Witte, J. P. M., Aerts, R., Bierkens, M. F. P., et al. (2015). Potential impacts of groundwater conservation measures on catchment-wide vegetation patterns in a future climate. *Landsc. Ecol.* 30, 855–869. doi:10.1007/s10980-014-0142-8

Wada, Y. (2016). "Modeling groundwater depletion at regional and global scales: present state and future Prospects," in *Remote Sensing and water resources*. *Space sciences series of ISSI*. Editors A. Cazenave, N. Champollion, J. Benveniste, and J. Chen (Cham: Springer), Vol. 55, 229–261. doi:10.1007/978-3-319-32449-4_10