

## C O M M E N T A R Y

# Safe water in an unsafe climate: Artificial intelligence as a tool for planetary health

FRANCESCO TRIGGIANO<sup>1</sup>, SILVIA BRIGIDA<sup>2</sup>, VALENTINA SPAGNUOLO<sup>1</sup>, MARIA TERESA MONTAGNA<sup>1</sup>, OSVALDA DE GIGLIO<sup>1</sup>

*<sup>1</sup>Interdisciplinary Department of Medicine, Section of Hygiene, University of Bari Aldo Moro, Bari, Italy; <sup>2</sup>Geologist, University of Bari Aldo Moro, Bari, Italy.*

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Climate change is a global phenomenon that has different impacts on populations and geographical areas. Its effects are particularly evident in economic sectors that depend directly on natural ecosystems and the availability of freshwater, such as agriculture, hunting, fishing and the harvesting of non-wood forest products (1). These interconnected processes require urgent attention within the Planetary Health paradigm, which recognizes the profound interdependence between human well-being and the integrity of natural systems. One of the most urgent consequences of climate-driven environmental change is the alteration of global hydrological cycles through an increase in extreme weather events across the globe, including floods and prolonged dry periods (2). Changes in water availability and quality are already having a significant impact on public health, highlighting the urgent necessity of integrated strategies that address both ecological sustainability and human resilience. As articulated by the Rockefeller–Lancet Commission in 2015 (3), this framework emphasizes the importance of considering health within socio-ecological systems, restoring degraded ecosystems, anticipating ecological tipping points, and integrating equity considerations into

environmental and health policies. More recently, the United Nations World Water Development Report (4) warns of an imminent global water crisis, which is being exacerbated by climate change, population growth and the unsustainable use of water resources. Rising temperatures, altered precipitation patterns and more frequent extreme weather events, such as droughts, floods and heatwaves, are degrading water systems. This reduces the availability of freshwater, causes groundwater salinization and increases biological and chemical contamination (5,6). These changes undermine access to safe water, hygiene, and sanitation, thereby increasing the risk of waterborne diseases and limiting irrigation and food production. Contaminants introduced into the food chain via water used in agriculture further elevate health risks. Extreme weather events are increasingly overwhelming sanitation and wastewater infrastructure, allowing pathogens to infiltrate drinking water sources. Meanwhile, droughts reduce water flow and promote pathogen persistence, contributing to the spread of diseases such as cholera, dysentery and hepatitis A (7). These effects disproportionately impact vulnerable populations, particularly those in rural areas, low-income households,



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**Correspondence:** Francesco Triggiano / Interdisciplinary Department of Medicine, Section of Hygiene, University of Bari Aldo Moro, Bari Piazza Giulio Cesare 11, 70124, Bari, Italy / E-mail: francesco.triggiano@uniba.it  
ORCID: 0009-0007-3858-3669

and informal settlements, due to structural inequalities in access to water and sanitation services. Furthermore, climate-related disruptions are undermining agricultural systems, reducing crop yields, and exacerbating food insecurity and malnutrition. People living in low- and middle-income settings, who have limited access to safe and nutritious food, are particularly at risk. Inadequate diets have serious health consequences, particularly for children, older adults and individuals with pre-existing conditions (8). Meanwhile, climate-induced stressors such as water scarcity and the collapse of livelihoods in climate-sensitive sectors — most notably agriculture and fisheries — are contributing to displacement, the risk of social unrest, and widespread psychological distress. These cascading effects further strain mental health, particularly in already vulnerable communities. Such studies integrate methodologies and insights from environmental science, geoscience, ecology, and public health to elucidate the pathways through which ecological change impacts human health. Understanding the hydrogeological setting of overexploited or degraded aquifers is fundamental to the sustainable management of water resources worldwide. High-resolution hydrogeological mapping and systematic monitoring not only aid in preventing contamination and anticipating saline intrusion but also help to determine the optimal location for water infrastructure. This information is essential for developing water governance systems that can withstand climate change and protect public health. Incorporating these geoscientific considerations into planetary health strategies ensures that water management remains firmly anchored in the biophysical realities of local ecosystems. This approach promotes ecologically sustainable interventions that support health (9). In this context, artificial intelligence (AI) emerges as a promising tool for addressing the challenges arising from climate change and the growing demand for water within the Planetary Health framework (10). Drawing from computer science, mathematics, and cognitive science, AI is an interdisciplinary field that aims to replicate key human cognitive functions, such as learning, reasoning, perception, and natural language understanding, through algorithmic systems (11). Advanced AI models can analyze large, diverse datasets — ranging from satellite imagery and

climate projections to hydrogeological surveys and epidemiological records — to identify emerging risks and predict system tipping points more accurately. AI-driven surveillance systems integrating real-time environmental, hydrological, and health data can provide early warnings of disease outbreaks linked to water contamination or scarcity, enabling targeted responses (10). One of the most impactful branches of AI is Machine Learning (ML), which enables models to learn autonomously from data, identify patterns and improve predictive accuracy over time without explicit programming. ML models learn from data to make probabilistic predictions, estimate relationships, and classify inputs. The three fundamental components of ML are large datasets, learning algorithms, and optimization procedures based on a loss function (10). The integration of AI and ML into environmental and public health systems is evolving rapidly, providing more effective solutions to the challenges posed by climate change. Thanks to its ability to process large, diverse datasets — including weather forecasts, hydrogeological and geological surveys, and epidemiological data — AI plays a crucial role in analyzing the impact of climate variables on water quality. This technology can detect emerging risks and provide early warnings of environmental or health crises (12). AI techniques such as Artificial Neural Networks (ANNs) and Support Vector Machines (SVMs) have played a key role in overcoming challenges in water resource management in the context of climate change, population growth and rising water demand. AI models have produced promising results in regions with limited water resources by predicting groundwater levels and recharge rates, thus promoting more sustainable water management practices (13). Another issue of great concern is the degradation of groundwater quality resulting from agricultural techniques and industrial processes. Recently, AI applications have been used to enhance water management by offering real-time evaluations of water quality, estimating the presence of contaminants, and identifying sources of pollution (10). Machine learning models are particularly effective in enhancing hydrogeological mapping by identifying hidden patterns in subsurface data. This supports the development of more targeted and sustainable groundwater management strategies (9). In an

agricultural context, AI applications can support precision irrigation, reduce water waste, and evaluate the risk of contamination from agrochemicals. This contributes to the development of more resilient and sustainable food systems. Furthermore, integrating hydrological data (e.g. river flows, groundwater levels and precipitation trends) with cross-sectoral demand forecasts enables more adaptive and equitable water allocation across agriculture, industry and domestic use (10). From a public health perspective, AI can facilitate the development of advanced surveillance systems that integrate real-time environmental, hydrological, and health data. These systems provide early warnings of disease outbreaks related to water contamination or scarcity. Such tools are particularly valuable in regions vulnerable to climate change, as they enable rapid, evidence-based responses. AI also supports the identification of underserved or high-risk populations, thereby promoting more equitable governance and resource distribution (10). Another emerging application is AI-assisted water quality monitoring. Autonomous sensor networks equipped with intelligent algorithms can continuously analyze the physical, chemical, and biological parameters of bodies of water, detecting pollutants and identifying sources of contamination in real time. These early warning capabilities enhance environmental protection and human health by enabling rapid responses to pollution events and safeguarding aquatic ecosystems (10). Integrating artificial intelligence into a Planetary Health approach can facilitate more responsive, data-driven, system-oriented solutions that bridge the gap between environmental sustainability and human well-being. There are already practical examples of these applications being implemented. In Khelvachauri, Georgia, for instance, combining AI with hydraulic modelling (EPANET) and geographic information systems (GIS) in water infrastructure planning has resulted in significant improvements: water pressure has increased by over 25 meters, pump efficiency has increased by 15%, and leakage has decreased by 8%. This demonstrates how data-driven optimization can enhance the performance of water systems, even in settings with limited resources (14). On a broader scale, the AIWATERS project surveyed global water utilities to assess their capacity to adopt AI technologies. The study

identified several barriers to implementation, including shortages of technical skills, inadequate digital infrastructure, and concerns over data privacy and cybersecurity (15). In order to foster innovation in this area, testbeds such as the AI-driven Cyber-Physical Testbed for Intelligent Water Systems (ACWA) are being developed. These testbeds simulate smart water networks using real-time sensors, actuators, and digital twins. These testbeds provide open data resources that enable researchers and practitioners to trial adaptive solutions before deploying them in the real world (16). Furthermore, recent studies emphasize the increasing importance of deep learning in environmental monitoring. The combination of AI and remote sensing technologies has been demonstrated to be more effective than traditional methods in predicting water availability, identifying water quality issues, and forecasting hazards such as droughts, floods, and algal blooms (17). Addressing these complex challenges requires integrated, cross-sectoral strategies based on Planetary Health principles. Policies must systematically incorporate climate projections into water governance, strengthen infrastructure resilience, and prioritize nature-based solutions such as wetland restoration and watershed conservation that support both ecological and human health (18). Water Safety Plans must consider climate-related hazards such as salinization, flooding, and emerging contaminants such as microplastics, pharmaceuticals, and antimicrobial residues (7). Equity and environmental justice must lie at the heart of water policy, with access to clean water and sanitation being recognized as a human right. This requires dismantling structural barriers to access and enabling participatory governance that incorporates the voices of marginalized groups into decision-making processes (5). At a global level, behaviors and actions relating to mitigation and adaptation have been considered in an effort to control climate change. Mitigation is defined as ‘any action or effort undertaken to reduce or prevent the long-term risks of climate change to human life and property by reducing sources or increasing sinks of greenhouse gases’ (19). Key mitigation initiatives include reducing greenhouse gases in sectors such as energy, transport, agriculture, and water and sanitation; reducing methane (CH<sub>4</sub>) emissions through waste management and wastewater

treatment; adopting and promoting technologies that reduce or prevent anthropogenic greenhouse gases; and protecting and enhancing greenhouse gas sinks and reservoirs by sustainably managing and conserving forests, oceans, and wetlands; carrying out afforestation and reforestation; and rehabilitating areas affected by drought (20). Conversely, adaptation is defined as ‘any activity that aims to reduce the vulnerability of human or natural systems to the impacts of climate change and climate-related risks, while maintaining or increasing adaptive capacity and resilience’. Examples include promoting water conservation in areas subject to increased water stress and encouraging the use of water-saving irrigation methods in drought-prone regions such as the Sahara Desert. Other examples include implementing flood prevention and management measures (20). In conclusion, this paper highlights the urgent need to recognize the importance of water safety for public health, social equity, and ecological resilience, especially given the accelerating pace of climate change. Adopting a Planetary Health perspective necessitates promoting integrated strategies that prioritize water within climate adaptation and health equity initiatives. This involves expanding water security plans to address climate-related risks and emerging contaminants, prioritizing the restoration of ecosystems and nature-based solutions to protect hydrological systems, and incorporating equity, participation, and environmental justice principles into water governance. A coordinated, interdisciplinary approach that links climate science, geoscience and environmental monitoring with public health and that is supported by AI and data collection techniques is essential for anticipating and responding to the complex, interconnected risks posed by water insecurity. Taking proactive, systemic measures is crucial to preventing the knock-on effects of extreme weather events on disease transmission, food security, displacement, and social stability. Without urgent and equitable action, these effects will continue to disproportionately impact vulnerable populations.

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