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Systems-thinking innovations for water security

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The concept of water security has progressed from a narrow emphasis on water supply infrastructure, primarily viewed through an engineering lens, to a comprehensive perspective encompassing technological, economic, environmental, and governance dimensions. The evolution of the water security concept, as evidenced in the relevant literature briefly reviewed in this paper, signifies a significant shift. This shift is toward a more comprehensive consideration of diverse values, stakeholders, and viewpoints by representing in an equitable manner as possible human-centric and ecosystem-based priorities. It also underscores the pressing need for transdisciplinary and more integrated approaches, as the challenges in representing the water security notion more effectively continue to mount. In response to these pressing challenges, the Global Climate Hub (GCH) initiative, operating under the UN Sustainable Development Solutions Network, employs interdisciplinary approaches comprising optimal dynamic combinations of technologies, economic analysis, and policies to devise national and regional water security strategies through inclusion approaches with relevant actors and stakeholders.

KEYWORDS

integrated modeling, Global Climate Hub, systems innovation approach, human security, environmental economics, valuation

1 Introduction

The concept of water security has gained prominence in policy and academic discussions over the past two decades as a new framework to tackle the challenges posed by climate change, population growth, rapid urbanization, and ecosystem degradation affecting water resources (Grey and Sadoff, 2007; IPCC, 2023; MacAlister et al., 2023). Initially introduced during the Cold War, the water security concept was framed within the context of securitisation theory and depicted through a military lens to safeguard essential resources (Thapliyal, 2011). The traditional approach to addressing the securitisation issue focused on military capabilities, power distribution, and resources, emphasising the 'dangerous', 'threatening', and 'hazardous' aspects of national security (Stritzel, 2014).

The concept of water security has also been closely linked to the expansion of irrigation for agricultural production, particularly during the 60s and 70s, when the global area of irrigated land doubled from 94 million hectares to 198 million hectares by 1970. Central Asia exemplifies this significant transformation that occurred during the Soviet era, where 5 million hectares of previously arid land were irrigated as part of a "hydraulic mission" aimed at providing abundant water primarily for cotton cultivation (Abdullaev et al., 2020).

Other water security perspectives based on scarcity, green and blue water concepts and the fundamental role of ecosystem services have emerged from the pioneering scholar professor Malin Falkenmark since the early 80s by also emphasising the significance of socio-ecological resilience as an indispensable component of water security (Falkenmark, 1986; Falkenmark, 1989; Rockström et al., 2012).

It was not, however, until the early 90s that scholars, mainly from international relations, became known as the Copenhagen School and emphasized non-military aspects of security to understand the nature, reasons, and conditions of security issues, including water security (El-Sayed and Mansour, 2017). The significance of water security in geopolitical contexts was also explored in the late 90s, particularly in the Middle East and North Africa, due to scarcity, poor accessibility, and societal challenges (Albrecht and Gerlak, 2022; Gerlak et al., 2018).

The major concerns about water unavailability and scarcity were also stated by the UN Security Council in 2007 as imminent global risks, triggering more research and development initiatives on the consolidation of water security. Different definitions were proposed to address the UN Security Council's concerns, such as the one proposed by Grey and Sadoff (2007) "the availability of sufficient quantity and quality of water for livelihoods, health, ecosystems and production."

It was also another UN-related organization (UN Water) that attempted in 2013 to establish a universal definition of water security as a multidimensional principle that encompasses the availability, accessibility, and quality of water resources and signifies the need for integrated socio-ecological approaches for political stability[1] (Jenkins et al., 2021). The proposed UN definition initiated the development of various conceptual and operational approaches, methodologies, and frameworks to define and assess water security from multiple disciplines, scales, and scopes (Octavianti and Staddon, 2021). The UN definition also supported the interpretation of water-related Sustainable Development Goals (SDGs) proposed in the UN Conference on Sustainable Development in 2012 and formally adopted in 2015. The direct reference to clean water access in SDG6 and the interconnectedness with nearly all other SDGs accentuated the pivotal role of water security for sustainable development worldwide (Assubayeva and Marco, 2024).

The focus on clean water access and physical availability to freshwater resources has leveraged funding programs and mechanisms, mainly for developing countries and the Global South, toward water infrastructure solutions (Octavianti and Staddon, 2021). The broad spectrum of the UN water security concept was gradually interpreted as the need to prioritize clean and accessible water through the rehabilitation and development of new hydraulic infrastructure (e.g., dams, reservoirs, irrigation canals, and pumping stations) and the encouragement of inter-basin transfers to water-scarce regions (Bogardi et al., 2016).

1 As was stated by UN Water, water security is perceived as "the capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water related disasters, and for preserving ecosystems in a climate of peace and political stability" (UN Water, 2013).

The dominance of the technological interpretation of water security was largely justified by the yet underdeveloped drinking and wastewater facilities in many countries of the Global South, which supported global initiatives like the UN-Water, Sanitation, and Hygiene programme (WASH) and several other UN-supported, multilateral, public, and private-led initiatives in this direction (MacAlister et al., 2023).

The transboundary water challenges added another layer of complexity to the water security concept, especially among upstream and downstream riparian countries sharing river basins and catchments between borderline communities. There are cases where upstream countries, although endowed with physical water availability, are still water insecure due to poor and insufficient water infrastructure. Upstream countries can be challenged with water allocation and accessibility, such as Uganda, with the Nile basin in East Africa; Ecuador, with the Mira-Mataje basin in Latin America; and Afghanistan, with the Amu Darya basin in Central Asia. However, upstream countries sometimes harness the significant potential of hydropower energy (HPP) by developing large-scale hydraulic projects. For example, China is actively invested in the Mekong basin, financing HPP initiatives not only in its own territory but also in neighboring upstream countries like Laos, Myanmar, and Cambodia (Mirumachi, 2020; Xenarios et al., 2021).

Technological interventions, large infrastructure and projects in national and cross-regional basins have often improved the welfare of surrounding communities through increasing agricultural produce, water accessibility, and energy coverage, among others. However, there are cases where the exploitation of hydraulic interventions also had detrimental impacts on human wellbeing and the environment, as illustrated by the desiccation of the Aral Sea (Peterson, 2019). Ongoing irrigation, hydropower, and multipurpose projects in national and transboundary waters have intensified competing interests among different user groups, causing significant friction between local and border communities and sometimes resulting in fatalities (Pacific Institute, 2024).

Efforts have been made to implement more integrated approaches, develop technological solutions, and involve various stakeholder groups in the planning and decision-making processes to achieve a shared understanding of water security. The introduction of Integrated Water Resources Management (IWRM) to improve cross-sectoral coordination and the River Basin Management Plans (RBMPs) are the most widely used approaches to manage water resources based on a holistic perspective through hydrological boundaries, decentralized and adaptive water management to mitigate climate shocks and build resilience, water-energy-food nexus to reveal interdependencies and trade-offs, stakeholders' engagement and co-designing policy pathways to balance human needs and environmental sustainability (Allan, 2003; Assubayeva and Sehring, 2024; Falkenmark and Rockström, 2006; Jain et al., 2014; Hoff, 2011; Sehring et al., 2024).

Despite the significant advancements, water security still predominantly reflects a more techno-centric and infrastructural focus, often overlooking socioeconomic, governance and management aspects (Xenarios et al., 2020). Even when more inclusive approaches are introduced, the implementation remains limited due to lack of resources, poor capabilities and weak coordination (Sehring et al., 2024). Progress has been achieved in developing water policies and technologies for water resources management; however, their implementation has often been constrained by economic factors, social acceptance, local governance, and a lack of institutional mechanisms. Acknowledging and implementing holistic approaches is essential for ensuring water security. This involves ensuring reliable access to a sustainable and safe water supply for human needs while also safeguarding water-related ecosystem services and promoting economic prosperity through human-centred strategies.

Our Perspective supports this assertion by providing an overview of the evolution of water security, emphasizing transdisciplinarity and the incorporation of socioeconomic and human-centric dimensions. It does so by examining examples that highlight the necessity for system thinking and their growing prevalence. The aim of this paper is to ultimately showcase how these aspects can be effectively integrated into a comprehensive, innovative, and adaptable framework through the presentation of a research-driven endeavor aimed at fostering holistic and sustainable water management.

2 Toward transdisciplinary and human-centered approaches

It is essential to recognize that every country or region experiences water insecurity issues, albeit in varying forms and degrees. In developing nations, water insecurity is primarily linked to insufficient water supply and lack of access to safe drinking water. Contributing factors include limited infrastructure, shortages of skilled personnel in the water sector, chronic underfunding, underdeveloped regulatory frameworks, poor law enforcement, and a scarcity of open data and monitoring stations (Briscoe, 2009). Developed nations face challenges primarily associated with weak institutional structures, water quality and quantity issues, affordability concerns, and economic costs related to climate shocks (Dai et al., 2023; Meehan et al., 2020).

Despite the socioeconomic, technological and environmental differences, all countries encounter complex water security challenges, including competing water demands, climate variability, governance issues, cross-sectoral coordination, and interactions among science, policy, and society. These challenges can be addressed through transdisciplinary research, integration of economic considerations, and human-centric approaches.

2.1 Toward transdisciplinarity

The introductory section highlighted the evolving concept of water security, emphasising the increasing awareness of various contributing factors. This development is reflected in the relevant scientific literature, which underscores the need for better integrating technological factors with governance and stakeholders, policy-evidence interventions and the development of transdisciplinary frameworks through system-thinking approaches.

For instance, Wutich et al. (2021) focused on improving water security assessment by using information and communication technologies with stakeholder groups to enhance monitoring, which can help identify critical areas that require water infrastructure maintenance and investment. The study revealed the need for a more inclusive and pluralistic water infrastructure design, ensuring well-informed policy formulation and responsiveness to local contexts.

Other scholars emphasized the policy-evidence dimension by integrating water security indicators into national policy documents, strategies, and plans (Jensen and Huijuan, 2018; Oshakbaev et al., 2021). This integration was deemed crucial for attracting both technical and political attention, consequently advancing water security initiatives. There is also an increasing trend to enhance science-policy interfaces by identifying water security priorities with input from experts, policymakers, and practitioners through iterative communication processes (e.g., working groups, workshops, public hearings, etc.) (Cook and Bakker, 2012; Lutz-Ley et al., 2021). The need for grassroots engagement in water security designing is also highlighted in the literature by considering power dynamics and interdependencies among different actors (e.g., Adams et al., 2020).

The transdisciplinarity perspective of water security has become more apparent in recent years by emphasising the need for knowledge sharing and co-production of water security definitions among various domains (Brennan et al., 2021; Ziganshina and de Schutter, 2022). The transdisciplinary nature of water security is often focused on the water-energy-food (WEF) nexus as a practical and operational framework, allowing for a systems perspective to be integrated (Miller et al., 2021; Schmidt et al., 2022).

The integration of the environmental dimension in the nexus is also traced in the literature (WEFE) as an opportunity to better comprehend the water security priorities through modeling applications and inclusive approaches (Staupe-Delgado, 2020; Drenkhan et al., 2023; Trancon et al., 2024). Other studies underscore the necessity for commonly accepted definitions and operational systems among water experts and professionals on water security and nexus approaches to support regional planning (Assubayeva et al., 2022).

Although the above literature highlights do not comprise a detailed overview of the transdisciplinary pathways of water security, they indicate the emergence of relevant studies on the inclusion of scientific communication, science-policy interactions and systems thinking in bridging knowledge, modeling, and management gaps.

2.2 Integrating economic considerations

There is a growing body of literature that suggests a movement toward incorporating economic perspectives into well-informed policy decisions regarding water security. However, several other studies posit that economic factors, such as environmental valuation, are being disregarded (Roy and Das, 2023). Environmental valuation quantifies the economic value of water-related Ecosystem Services (ES), which are often not readily observable and quantifiable in monetary terms (Octavianti and Staddon, 2021). As water security encompasses maintaining healthy aquatic ecosystems, it is crucial to understand their total value and the benefits of each proposed policy (Koundouri et al., 2024a, 2024b).

Incorporating economic value into water security assessments is of utmost importance, as it can justify investments in nature-based solutions and the associated infrastructure. For instance, ecosystems like wetlands and forests provide valuable water-related services like flood regulation, water purification and groundwater recharge, frequently more cost-effectively than engineering-based conventional solutions (Alamanos and Papaioannou, 2020). The process of environmental valuation serves to quantify the advantages associated with natural infrastructure, providing a compelling economic rationale for investing in natural infrastructure for water security, either in conjunction with or in lieu of built infrastructure (Choi et al., 2021).

Interdisciplinary approaches already combine hydrological modeling with economic and ecosystem values, suggesting how decision-makers can allocate water resources in a socioeconomically consistent way (Jenkins et al., 2021). Ensuring equitable allocation of water resources is of paramount importance due to the multiple and often competing demands from various sectors. This equitable distribution has become increasingly crucial in scholarly discourse (Schulz et al., 2024; Koundouri et al., 2023).

2.3 Toward human-centred approaches

Two prominent themes in the literature emphasize the necessity of incorporating more human-centred approaches in water security planning: the benefits of implementing diverse and adaptable management strategies, which rely on social acceptance and expertise, and using human-centred security metrics. Several water management practices are pertinent to local contexts and initiated at the household level. For instance, Mapani et al. (2023) document for the country of Namibia and Currea et al. (2024) for the city of Bogotá. In another case, Achore et al. (2020) presented a comprehensive review of household water management practices, focusing particularly on those employed by impoverished and vulnerable populations. These practices range from water storage, rainwater harvesting, construction of alternative water sources to water sharing, illegal connections to public water networks, purchasing from private vendors, and poor treatment, frequently entailing adverse health or economic consequences. Achore et al. (2020) note that some economically affordable and easy-to-implement coping strategies, such as water conservation, reuse, and purification before consumption, could be initiated by households with little technical, economic support as supplementary but substantial alleviating measures to long-term solutions.

The importance lies in the efficacy of grassroots approaches, wherein households proactively secure water resources. It will be imperative to provide scientific support for such endeavors in the future to ensure their safe and advantageous implementation. Scaling these methodologies to the policy domain requires the consideration of the human element in scientific evaluations and policy formulation (Warner et al., 2024). The attainment of a more profound comprehension of individual and community viewpoints can result in the development of water management strategies that are more effective, acceptable and equitable (Eichelberger et al., 2020; Turley and Caretta, 2020). The study of Kosovac and Davidson (2020) supports this argument, as they highlight the importance of understanding and considering humans' psychological biases that can affect the risk assessments of water projects and the adoption of new measures and infrastructure. In their work, Smiley and Stoler (2020) underscore the intricate interplay of social, technical, institutional, and human factors, often articulated in the context of physical and mental wellbeing within the realm of water security. They suggest that potentially new human-tailored metrics can enable a richer assessment of water security, by capturing the diverse experiences and needs of different populations.

It is fruitful to delve into water security through the analytical lens of the Human Security approach. According to the UN Human Development Report (UN HDR, 1994), Human Security encompasses the core human concerns of "freedom from fear" and "freedom from want." Human Security emphasises the individuals and deviates from focusing on the national or macro level as the determinant of people's wellbeing, extending its scope beyond physical violence and destruction (Gasper, 2005). The notion of human security is conceptually intertwined with sustainable development and the Sustainable Development Goals (SDG) framework (Koundouri and Dellis, 2023).

Environmental security is one of the seven pillars of Human Security, encompassing safety from natural disasters and resource scarcity attendant upon environmental degradation. The availability and quality of water resources in a region are material for bolstering environmental quality and ecosystem services, thereby contributing to environmental security. Furthermore, water security is inextricably linked to the pillars of Health and Food security, as water scarcity, for example, can lead to elevated food insecurity and health crises. Finally, the adverse impacts of degraded human security might well include political instability, community upsets and related migration, thus touching upon political and community security aspects.

Therefore, it is imperative to consider water security assessments in the broader framework of Human Security, incorporate its measurement, and align targeted policies to a holistic security approach. By incorporating water security into the Human Security paradigm, policymakers can address individuals' and communities' vulnerabilities, particularly in marginalized and resource-poor areas.

3 Overcoming the obstacles: the approach of the Global Climate Hub

Section 2 underscores the importance of embracing comprehensive interdisciplinary approaches encompassing a broad spectrum of factors related to water security. Building on the findings from the previous sections, it becomes evident that methodologies for understanding water security should naturally account for diverse water uses, include economic considerations, and human elements. In addition to the recognition of the need of this integrated perspective and holistic approaches to address the multifaceted challenges of water security, the literature highlights that the solutions must include social and human angles. The formulation of solutions should necessitate the collaborative engagement of various key stakeholders, fostering a science-policy interface that supports the actual implementation and the sustainability of long-term solutions.

Under the United Nations Sustainable Development Solutions Network (UN SDSN), we developed the Global Climate Hub (GCH), an international research-led and research-funded initiative that has the potential to fill the gaps mentioned in section 2, while providing long-term sustainable and water secure pathways. It aims to act as an initiative for change, leveraging science-based solutions for a holistic and equitable transition toward a more resilient and sustainable world.

In particular, the GCH provides sustainable pathways addressing specific sustainability challenges, e.g., achieving water security (among others). These result from comprehensive modeling of natural water systems, their demand and availability, the implications to public health, as well as building resilience to climate change related extremes, and resilient and sustainable water-food-diet systems – all under thorough socioeconomic modeling, considering economic trade-offs, social acceptance, uptake and implementation of the solutions to maximize welfare (Alamanos, 2024b). We work closely with relevant stakeholders to develop together practical solutions through collaborative methods like living labs (interactive spaces where stakeholders—from local communities to policymakers—actively contribute to the design and testing of solutions). This approach fosters a sense of shared ownership and commitment to the successful implementation of the proposed strategies. Our efforts also include integrating innovative technologies to make these solutions practical and effective. To ensure their successful implementation, we focus on accelerating their adoption by addressing barriers such as funding, finding the necessary expertise, and capacity building. We develop education and training programs to equip local communities and organizations with the knowledge and skills needed to maintain and expand these solutions over the long term. This initiative can be tailored to each country and region and mobilized by local Hubs and dedicated research teams.

The GCH's approach is based on the combination of the following innovations (Figure 1):

I. The development of cutting-edge models (data-driven/mathematical simulations) describing cross-sectoral system dynamics for all major natural and infrastructure systems.
II. The support of a powerful digital AI-driven infrastructure that helps handle big data (associated with the simulations mentioned above), harmonize, update, and manage it, develop digital twins, and assist in coupling the various models and visualising the results.
III. The bridge between holistic scientific approaches and civil society for implementing fair, equitable and publicly acceptable sustainable pathways. This is achieved by developing case-specific' socioeconomic narratives' that enable the consideration of economic valuation and trade-offs in our analyses.
IV. Transformative participatory frameworks for stakeholder engagement through co-designing solutions and tailored sustainable pathways in a scientifically supported, human-centric, and socially acceptable way.
V. Analysing, co-designing, presenting and applying sustainable pathways underpinned by the principles of Open Science and Open Access to data, developed models, and general scientific infrastructure.

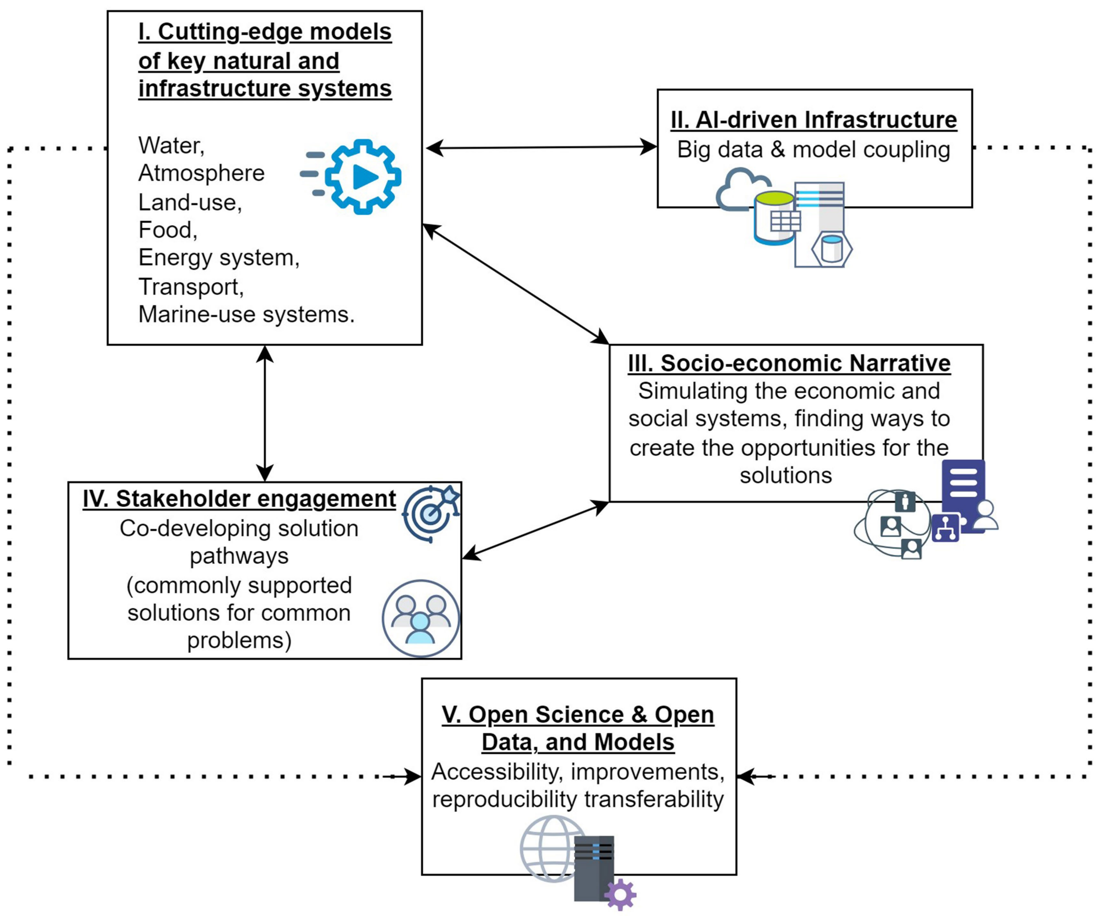

FIGURE 1
The five innovations of the GCH, summarising its approach to sustainability problems (not solely water security), in an indicative schematic showing their interactions: Integrated models are used/developed (I), which are coupled and updated (II) to simulate real-world scenarios. Based on their insights and the stakeholders' input, the socioeconomic narrative is developed, simulating the social and economic systems (III). The results so far are the basis for co-design solution pathways with the stakeholders (IV) within a two-way interaction with the models (I), ensuring a realistic representation of the problems and solutions. Data and models are publicly accessible to enhance reproducibility (V). Source: Koundouri et al. (2024c).

The GCH mobilises nine research units covering a wide range of expertise in digital applications, climate science, land-water-food-energy-biodiversity systems modeling, public health, solutions' application, policy, finance, labor markets, participatory approaches, education and training (Figure 2).

The coordinated work of these units provides a unique approach to holistically addressing all levels of the human-environmental interface for providing truly sustainable solutions tailored per case study or region (Koundouri et al., 2024c).

For example, in a water security–related problem, the coordinated work of several research units would be required. Indicatively:

a. The "climate science unit" provides climate change scenarios and detailed information on how key parameters might change in the future (e.g., temperature and precipitation). These projections are downscaled to the region of interest, allowing us to explore their impacts on key variables (e.g., impact of future temperature and precipitation on water availability, crop yields, water consumption, etc.). This practically can be achieved by downscaling Regional Circulation Models (RCMs), for instance, by providing sets of plausible future conditions in a studied region or area that can affect water security.
b. The "systems modeling unit" provides integrated assessments on land-water-food-biodiversity systems (considering land use changes, food production and needs, and biodiversity constraints). Several models can be used for such tasks, including remote sensing techniques, hydrological and water management models, the FABLE calculator (Mosnier et al., 2020), energy-emissions models such as LEAP (SEI, 2024) or Balmorel (Balmorel, 2013), to provide data-driven insights on multiple water security related parameters.
c. The "public health unit" considers the implications of various water security issues, future projections and management scenarios and develops mitigation strategies. This can be practically achieved through detailed econometric modeling and policy analysis.
d. The "economics unit" focuses on environmental valuation, incorporating ES in policy-making. Moreover, this unit develops solutions regarding finance opportunities or labor market interventions to support the implementation of the proposed pathways. Various economic models can be applied here, spanning from environmental economics to equilibrium approaches.
e. As part of the approach at this stage, it is worth mentioning another innovative aspect resulting from the GCH's approach, which is the development of Human Security metrics, allowing to measure of the 'personal security' angle, which reveals hidden elements (e.g., psychological, human health, living in healthy and resilient ecosystems, etc.) that seem to be crucial for managing the solutions in the long-term (Koundouri and Dellis, 2023).
f. These pathways are co-designed with stakeholders. The social perspective and the human-centric character of the approach are ensured by the continuous work of the "participation unit," which involves living labs with key diverse stakeholders, including public and private actors. Again, sophisticated tools like Living Lab Modeler (2024) and MIRO (2019) and technologies like Virtual Reality are used. Moreover, this unit develops human-security metrics to integrate the personal/human angle in developing sustainable pathways, an innovative approach to water security issues.
g. The solutions' application is achieved by the "innovation and acceleration unit" efforts, mobilising local governance, technology holders, start-ups, and all interested parties to uptake and become owners of the proposed sustainable pathways, ensuring a fair and equitable allocation of the benefits.
h. The "education unit" designs tailored training and upskilling programs to ensure the viability of the solutions run by the local actors in the long term.

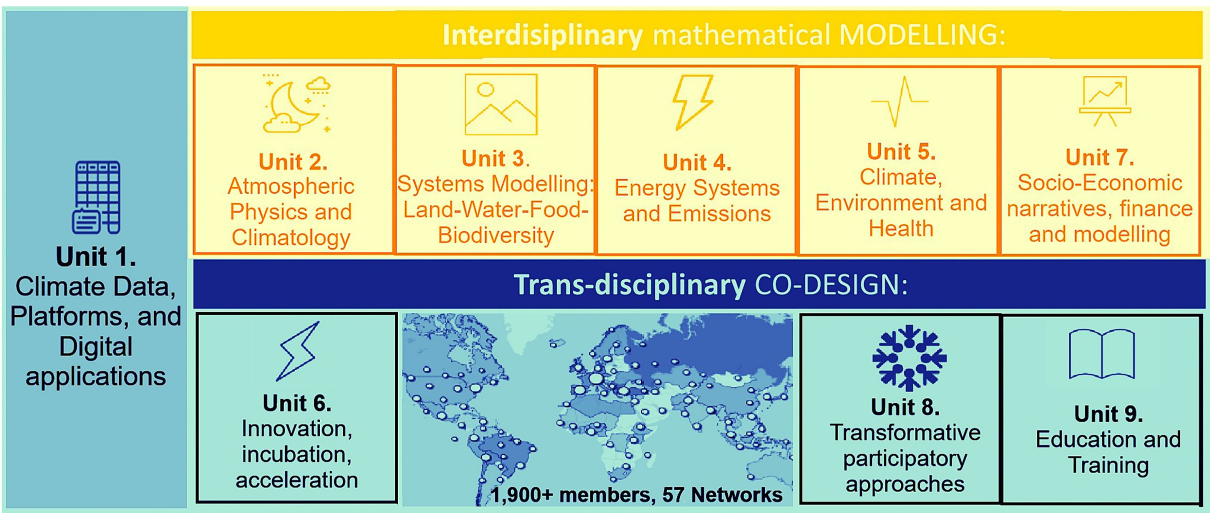

FIGURE 2
The nine research units of the GCH combining aspects of modeling, solutions design, and implementation.

The above points from (a) to (c) all refer to part “I. Cutting edge-models” of Figure 1, while (d) belongs to the “III. Socioeconomic narrative” (both supported by the “II. AI- infrastructure”), and the rest refer to the “IV. Stakeholder engagement” part (all according to “V. Open science” principles). That way, the GCH tries to apply a holistic and innovative approach to tackling modern water security challenges. This approach is by nature a unique feature of the GCH compared to other existing research approaches and initiatives. In particular, it combines elements of transdisciplinary integration (modeling, technological, environmental, economic, and social dimensions, moving beyond the conventional focus on just one of these disciplines), it uses tailored socioeconomic narratives and models together with scientists-stakeholders co-designing solutions, and it includes human security metrics addressing psychological, social, and health dimensions of water security. This level of integration among transdisciplinary and human-centric analyses is less emphasized in other frameworks that focus primarily on technical or policy aspects, while the participatory approach of the GCH’s living labs contrasts with more top-down methodologies in some existing initiatives. The GCH approach offers opportunities for in-depth analyses in each one of the fields involved in its Research Units (Figure 2), while being flexible for application in both local or regional scales, ensuring social acceptance.

4 Discussion

The GCH approach offers a distinctive, advanced, and comprehensive method that addresses significant deficiencies outlined in section 2: interdisciplinary collaboration, coordination between scientists and stakeholders, and the collaborative formulation of solutions and strategies. It also encompasses incorporating economic and human-centred perspectives into the suggested solutions. Currently, there are several projects underway considering this approach. Although none of them is complete yet, it would be useful to mention a recent example closely related to water security:

We are working closely with a large water supplier in Greece (regional scale, covering multiple basins in Central Greece), facing natural water scarcity and economic and administrative issues in managing its water resources effectively. We are coupling integrated climate-hydrological and water management modeling with economic modeling to develop a ‘space’ of possible solutions with the key stakeholders within living labs. The physical modeling refers to the natural water availability, demand and water balance, considering different sources and users. The economic modeling draws information from the ES valuation, assigning economic values to the ecosystems and the broader societal benefits from each solution. An novel point in this coupling, is using the ES valuation outputs to develop subsidies that will ensure the uptake of innovative measures by the local water suppliers. Such measures can include using solar (energy-autonomous) power units and enabling water reuse options for urban parks, irrigation, and industrial use. The participatory approach throughout the process builds a sense of ownership and understanding of the water security challenges and solutions. The process so far has bridged differences between stakeholders in the region on their water security priorities (mainly referring to water security’s environmental dimensions versus its economic dimension) by reaching a consensus that environmental health is necessary and a sustainable way to support economic activity (Alamanos, 2024a). Using Human Security metrics involving newly developed Key Performance Indicators (KPIs) and indicators by our team has helped policymakers consider the multiple benefits of working toward water security building while recognizing the positive feedback from civil society.

This Perspective provided a preliminary picture of our vision, a vision for more holistic assessments and solution-oriented approaches to water security. We believe that adopting similar approaches can potentially address pressing challenges like water security holistically. Mobilizing diverse research teams to participate in the GCH or the national and regional Hubs is crucial. This involvement should be continuous and consistent, engaging in local actions and supporting the implementation of research outcomes even after a project has ended. We hope this will be more often the case in the future, and more committed researchers will join this vision.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

AnA: Conceptualization, Investigation, Visualization, Writing – original draft, Writing – review & editing. SX: Conceptualization, Investigation, Writing – original draft, Writing – review & editing. AlA: Investigation, Writing – review & editing. CL: Conceptualization, Writing – review & editing. KD: Conceptualization, Writing – review & editing. PK: Conceptualization, Writing – review & editing.

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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.

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