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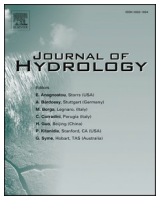

Research papers

Integrating socio-hydrology, and peace and conflict research

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ABSTRACT

Socio-hydrology strives to incorporate 'the social' into the understanding of hydrological processes, aiming to enrich the analysis of water systems by considering human interactions. While there is a broader interest in integrating socio-political processes into hydrology, our paper specifically emphasizes the significant contributions of peace and conflict research to understanding the complex social dynamics surrounding water. We conduct a brief review of key literature on interstate water sharing, international norms on water, and domestic water disputes, drawing extensively from empirical studies within peace and conflict research—a field with a rich tradition of examining the interplay of water systems and social dynamics. Building on this foundation, we propose ways to weave insights from peace research, especially environmental peacebuilding, into the realm of socio-hydrology. We also highlight the crucial role of power, politics, and social factors in shaping water-related interactions and conflicts. By fostering a dialogue between socio-hydrology and peace and conflict research, we advocate for a more nuanced understanding of water management and governance. This interdisciplinary approach, we argue, is essential for promoting sustainable and equitable water use, and for addressing the challenges posed by water-related conflicts in a rapidly changing global context.

1. Introduction

Managing water is essential for economic development, public health, and environmental sustainability, among many other things. Exchanges over water resources occur at various scales, for instance, in farmer communities, across transboundary watersheds, or between nation states. Sharing water has always meant to solve complex political and institutional conflicts. Thus, examining the interplay of water and society also means to consider multidisciplinary approaches, for instance to integrate socio-economic aspects within water research (Falkenmark, 1979). More recently, the field of socio-hydrology was introduced as one approach that can foster a deeper understanding of the complex interactions between humans and water systems while advocating for approaches to water resources management that truly integrate socio-economic and political factors (Sivapalan, Savenije, and Blöschl, 2012; Pande and Sivapalan, 2017; Yu et al., 2022; Wesselink, Kooy, and Warner, 2017; Di Baldassarre et al., 2015; Xu et al., 2018). We follow Pande and Sivaplan (2017, p.3), understanding socio-hydrology as a "[…] science that studies the interactions of society and water, seek[ing] regularities in social behavior or societal development that may emerge from their coevolution with the hydrological system". Socio-hydrology aims to address the complex aspects of social diversity, power dynamics, trust, cultural values, and cognitive biases that have a significant impact on how individuals modify and adapt to evolving hydrological systems. This includes developing common methodologies that can be shared across disciplines to better understand the interplay between water resources and society. Acknowledging the broader interest in integrating socio-political processes into hydrology research, this paper particularly emphasizes the contributions of peace and conflict research to understanding the complex social dynamics surrounding water.

Water research has required and will always need inter- or cross-disciplinary approaches, yet the great challenges remain also because of literature silos and methodological or epistemological divergence. For instance, socio-hydrology has been described as a more positivist leaning field (Pande and Sivapalan, 2017). Engaging with social science literature entails being more open about ontological differences as there is a great value in understanding insights from different approaches. Yet, this also means for socio-hydrologists to actively engage with existing scholarship in various fields within the social sciences (Xu et al., 2018;

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Linton and Budds, 2014). There is also further recognition of the need for cross-fertilization, and the questions arise on how social science research more generally should approach research within hydrology versus how hydrologists should approach water research within the social sciences (Rusca and Di Baldassarre, 2019; Ross and Chang, 2020). Others raise concerns over the feasibility of socio-hydrology, contending it might instead create less comprehensive and fewer interdisciplinary engagements (Madani and Shafiee-Jood, 2020). Here, we specifically call for engagement with peace and conflict research, itself also an interdisciplinary subfield that earlier emerged from Political Science and International Relations (Boulding, 1978; Galtung, 1969; Singer, 1973; Wallensteen, 2011).

Given the current challenges that link hydrology with several security concerns, we argue that understanding water research within peace and conflict research can help to better anchor socio-hydrology with other disciplines. In this article we contribute to the ongoing debate on the directions of socio-hydrology in four ways. First, we provide a brief overview of the history of water research within peace and conflict literature. Second, we highlight critical approaches to study the interplay of society and water within peace and conflict issues. Third, we summarize findings from empirically driven studies on water cooperation and conflict. Fourth, we outline environmental peacebuilding approaches as a key platform between socio-hydrology and peace research. The overall aim of this paper is to explore the intersection of socio-hydrology and peace and conflict research, particularly focusing on the potential for interdisciplinary approaches to address water-related conflicts. While a comprehensive literature is beyond the scope of this paper, we strive to highlight key works that illustrate intersection of socio-hydrology and peacebuilding as well as showcasing existing theoretical and methodological approaches which should be relevant for the ongoing development of socio-hydrology scholarship.

2. Roots of research on water within peace and conflict literature

Water scarcity has emerged as a critical global issue, posing significant challenges to human security, sustainable development, and international relations. Here we use a broad definition of water scarcity as an excess of water demand over available supply in a specific area (In line with FAO, 2012; Rijsberman, 2006; Ostrom, 1990). The increasing demand for water resources, combined with population growth, industrial development, and climate change, exacerbates the vulnerability of communities and nations, prompting an urgent need for effective solutions. Over time, water cooperation has helped to establish agreements, policies, and practices that promote sustainable and equitable management of shared water resources. In fact, some of the very first environmental agreements pertain to rivers and water use (Yao, 2022; Wolf, 1998). Scholarship across disciplinary boundaries has tried to explore potential solutions, their feasibility, and the emerging challenges, while taking into account the needs and constraints of present and future generations.

In the 1980s and early 1990s, global water scarcity issues gained increasing attention. Several scholars began to emphasize the need for urgent action from the international community (Shiklomanov, 1991; Falkenmark, 1989; Falkenmark, Lundqvist, and Widstrand, 1989). Those early research findings highlighted the challenges in resource availability to sustain the global population, argued from population pressure and pollution, especially in regions already facing water scarcity. This led to discussions both in policy but also within academia on whether we can define how much water humans need and finally leading to categorizations of global regions based on water stress, shortage, and scarcity. The scarcity of water had significant implications, particularly for food security (Allan, 1998; Gleditsch, 2001). Climatic changes further increased vulnerability (Vörösmarty et al., 2000), with the scarcity of surface and groundwater resources, pollution, and over-pumping having disastrous consequences (Lundqvist, 1998; Milly et al., 2010; Konikow and Kendy, 2005). The international system recognized the issue, culminating in high-level conferences such as the Dublin 1992 and Rio conferences in 1992, where water featured prominently.

The relationship between water resources and conflicts can be examined in two dimensions. Firstly, in an armed conflict, the targeting of dams and other water storage facilities may cause water scarcity or reduced water quality (Swain, 2004; Schillinger et al., 2020; Talhami and Zeitoun, 2020). Secondly, freshwater resources can cause or contribute to conflicts when shared internationally. Nearly 60 percent of the world's freshwater is found in 310 international rivers and over 500 transboundary aquifers (UNECE, 2021), and countries' dependence on external water supplies may require re-orientation of national security concerns to protect or preserve such availability (Gleick, 1993; Homer-Dixon, 1994; Swain, 2015). Political leaders, international civil servants, and policy analysts have suggested that the next war will be about water, given that disputes over shared rivers tend to be complex and difficult to address (Starr, 1991). Disagreements arise among riparian states over the quantity, quality, and/or control of transboundary water. Sharing water basins can increase competition and conflict, yet it can also lead to increased engagement and cooperation. Several competing riparian countries have established regimes and institutions for cooperation (Wolf, 1998). The signing of agreements over river use can significantly mitigate the risk of "water war" scenarios. The implementation of agreements however face challenges if they fail to materialize in institutional arrangements that can provide robust institutional support. The compliance aspect of shared water agreements poses real challenges, as the allotted water in existing sharing agreements is unable to meet the increasing demand, and global climate change limits the augmentation of river water. In some cases, downstream states challenge upstream rights over river flow, creating "hydro-hegemons" (Wolf 1999b; De Stefano et al., 2017).

It is key to note that water stress can lead to both conflict and cooperation. Recognizing the dangers and threats of water scarcity, groups and countries can engage in cooperation while protesting other's water use and abuse (Zeitoun and Mirumachi, 2008). Cooperation can turn a potentially destructive conflict into a productive one, because it implies a mutual will to resolve disagreements over water use through peaceful means. Water cooperation generates willingness among riparian countries to think creatively about their problems, consider mutual problem-solving mechanisms, and negotiate commitments. This has led to the emergence of research on analyzing secondary advantages of water cooperation to regional peace and security.

Water security is a crucial element of human security. Here the lack of access to safe water is argued to present multiple threats, including health hazards, livelihood insecurity, and forced relocation (Cleaver, 2005; Wolf, 2001). Water scarcity also impedes development and violates the human right to water (Mirosa and Harris, 2012; Tignino, 2023). In an everyday setting, security concerns regarding water relate to "low politics" and human security, which includes economic, food, health, environmental, personal, and community security (UNDP, 1994). This approach to security concerns focuses on immediate concerns and the everyday lives of people, rather than the state and military (Buzan and Wæver, 2009). While the concept of human security has been criticized for being too broad, it provides a vehicle for understanding the security implications of water scarcity in the development context (Paris, 2001; Shahrbanou and Chenoy, 2006). Failing to assure human security accompanies with global challenges in supporting development of the population suffering from underdevelopment. The importance of sustainable water management cannot be understated in such efforts.

The global community is facing an enormous challenge in managing the shared freshwater resources cooperatively and peacefully. Several factors, including a growing population, industrial development, food production, and climate variability, are contributing to increasing water insecurity around the world (Mishra et al., 2021). According to one estimate, nearly half of the world's croplands face water scarcity during

least five months a year, and farmlands in Sub-Saharan Africa, Eastern Europe, and Central Asia are disproportionately affected by scarcity posing risks to local and global food security (Rosa et al., 2020). Climate change is expected to affect water resources by altering the timing and distribution of precipitation, which may lead to increased drought in some areas and flooding in others, and by reducing water supply due to melting glaciers (IPCC, 2021). The governance of international freshwater resources is becoming increasingly volatile, particularly as the threat of global climate change undermines existing sharing arrangements (Cooley and Gleick, 2011; Earle et al., 2015).

Various solutions have been proposed, including large-scale desalination of seawater, inter-basin water transfers, and large-scale water trade (Aviram, Katz, and Shmueli, 2014; Mirumachi, 2015; Vij et al., 2020). However, these solutions are not without their challenges, particularly regarding financing and infrastructure. In addition, there are significant political and environmental costs associated with bulk water removal and long-distance water exports (Mirumachi, 2015). Virtual water trade, which involves exporting agricultural products that require large amounts of water, is also a controversial issue as it often leads to the displacement of local communities and political instability (Jägerskog and Kim, 2015).

To address these challenges, there have been attempts to formulate comprehensive policy frameworks and design effective international and basin-based institutions with relevant stakeholders (Kittikhoun and Schmeier, 2021). There are also several international organizations with focused efforts on water and water scarcity issues, for instance, United Nations Economic Commission for Europe (UNECE), The United Nations Regional Centre for Preventive Diplomacy for Central Asia (UNRCCA), and the Intergovernmental Authority on Development (IGAD). However, despite the many academic and policy research reports highlighting the future water security challenges, implementing tangible policy and institutional solutions to address them remains as a key challenge.

It has been more than ten years since the United Nations General Assembly has adopted a resolution that recognizes the human right to water and sanitation (A/RES/64/292), but many countries are still reluctant to provide legal rights to water due to financial and governance constraints (United Nations, 2023). Achieving sustainable water security requires a comprehensive approach that takes into account the many efforts required to ensure a safer environment for healthy and prosperous living for present and future generations.

The critical societal challenges regarding water security encompass multiple dimensions that highlight the role of political, institutional, and socio-economic factors. The subsequent sections highlight the contributions from the selected fields within the social sciences, namely critical approaches from political ecology among others, empirical peace and conflict research, and environmental peacebuilding research.

3. Building on critical approaches to socio-hydrology

Critical approaches have been instrumental in furthering the understanding of water's complex role in society, which in turn support policy development for tackling water-related challenges. Various fields of research offer conceptual and methodological tools that can explore hidden dimensions of water-society interactions. Here, we draw on a range of analytical frameworks, such as hydro-hegemony, water justice, and feminist political ecology, which allow us to closely investigate the role of politics, power, and social factors in water management at different scales, from transboundary conflicts to local allocation disputes.

In recent years, the study of the intricate relationship between water and society has gained significant attention, revealing the necessity to critically reflect on the political, social, and power dynamics at play. This field of research builds upon the body of work within political ecology but not limited to. Environmental justice research also similarly questions the sense of justice and contributes to critical knowledge production (Svarstad and Benjaminsen, 2020). Participatory action research and co-production methodologies have made similar contributions by contesting innate hierarchy in research practice (Bacon, Kelley, and Stewart, 2022). Aforementioned scholarship has critically examined the interplay of politics, social forces, and material structures that shape access to water resources and their impact on various social groups. By challenging conventional 'technical' perspectives that solely focus on engineering solutions, these approaches can help to uncover several often-overlooked aspects of water management, including the agency of local communities, power relations, intersectional identities, and social complexities that contribute to the multifaceted nature of water issues.

We argue that unpacking politics, power, and social complexity in the relationship between water and society can benefit from critical approaches towards existing paradigms and perspectives, which political ecology has supplied the research field over the years. The interplay of politics, social forces, and materiality structures in shaping the access to resources and the environment is a common theme in political ecology, which can be either defined as a coherent body of knowledge or "a community of practice" (Loftus, 2020, 141). Political ecology is an interdisciplinary research field that examines how political, socio-economic, and environmental drivers affect resource management and environmental change. There are various strands and approaches in political ecology, but the works similarly highlight the centrality of politics, power and social factors in shaping water's impact on society and differing impacts on social groups and individuals.

Important concepts such as the 'hydrosocial cycle' and 'hydrosocial territories' contribute to the field by expanding geographical and historical dimensions to it. The hydrosocial cycle focuses on a dynamic process that water and society mutually shape each other interplay between water and society over staples and time (Linton and Budds 2014). Additionally, hydrosocial territories concept considers water flows and management as encompassing physical, social, political, and symbolic dimensions. It intertwines these elements in specific configurations, actively constructing territoriality through techno-political and socio-ecological interactions (Boelens et al., 2016). Multi-dimensional and temporal aspects are relevant for analyzing the implication of water for peace and conflict as well.

Another common perspective that can be found in political ecology is highly critical towards solely "technical" viewpoints (Nightingale et al., 2020). Treating water scarcity and disputes as a primarily technical problem tends to prioritize technical solutions over political, social and governance interventions. The tendency of technical approaches can be found from transboundary to local water issues, resulting in a range of engineering solutions and hydrological equations without considering political barriers and uneven power relations.

Power and politics have always taken a central place in a range of research themes from hydro-hegemony to water justice (Cascão and Zeitoun, 2010; Sultana, 2018). The hydro-hegemony framework delves into the issues of power and sources of power to explain transboundary water politics (Mirumachi, 2015). Water justice is grounded on "principles of fairness, equity, participation and justice" when access to and distribution of water is concerned (Sultana, 2018, p. 487). Hydro-hegemony and water justice have been deployed as analytical frameworks in water research at various levels from transboundary water relations between countries to water allocation conflicts at the local level. Political aspirations and ideologies have shaped state-led water development in forms of hydropower and irrigation facilities (Selby, 2019; Suhardiman, 2016). When water development projects are undertaken in rivers that carry emotional meanings to a nation or a social group, 'water' issues become political issues (Kim, 2021). The strategic importance of transboundary waters can mount tensions and contribute to further politicization. Scholars with a political ecology lens have resisted the view that water management needs primarily technical solutions (Teisman et al., 2013; Sultana, 2018). Access to water, or the lack thereof, ***is*** an outcome of a political process. This is perhaps most evident in high-income countries where technology is readily available, but

water insecurity persists in economically marginalized communities. The failures to deliver clean water are intertwined with racialized discrimination, homelessness, and institutional failures (Meehan et al., 2020). Understanding about larger social contexts that shape unequal water distribution at national and local levels needs further academic engagement (Joy et al., 2014; Roa-García, 2017; Wagle, 2022).

Social sciences such as political ecology are indispensable to understand different access and use of water based on different social groups or people's intersectional identities. The primary example of gendered implications of water insecurity is the impact on women and girls whose daily tasks often include fetching water from far away sources. The disproportionate burden of water scarcity for women can be further disaggregated by age, class, ethnicity, and other social categories, which can influence women's access to water and how the changes in water availability can affect women, for instance, young women with lower within-household status (Sultana, 2009). Thinking about intersectionality, which can be defined as the interconnected nature of social categories, can be especially important when one analyzes social units such as household, communities and local. Feminist political ecology unpacks inequalities in labor and material relationships between members of these social units that are sometimes treated in uniform (Elmhirst, 2011). Understanding intersectionality in social vulnerability is important for researching practice and policy of water management.

Ethnography and fieldwork are essential methodologies in the works of political ecology and other related sub-fields of environmental social sciences concerning water. In addition to historical and discourse analysis, ethnographic methods including oral history, listening, and participatory map making have been increasingly used in the field (Sibanda, Mukwada, and Hansen, 2022; Bacon, Kelley, and Stewart, 2022; Wilson, 2019). More traditional methods of interviews and fieldwork can also be useful in understanding politics by in-depth description of the water-society relations. Participant observation, the core method of ethnography, can be applied to water research and provide researchers perspectives on everyday water politics and intersectionality, which may not be possible to be gained otherwise. When researchers adopt such methodologies, careful considerations should be given in the matter of representation and anonymization of indigenous and marginalized voices (Svalastog and Eriksson, 2010).

Additionally, ethnographic methodologies provide a nuanced understanding of everyday water political realities as well as the intersectionality in water-society relations that shape the experiences of diverse social groups. Ultimately, this research contributes to the evolving discourses on political ecology and water management. It does so by highlighting the importance of broader socio-political contexts in addition to unpacking power dynamics and inequalities within the water-society nexus.

4. Empirical approaches to cooperation and conflict over water

Water resources are critical to human well-being and socio-economic development, and their management plays a significant role in peace and conflict dynamics. Understanding water access, infrastructure, and conflict has long attracted attention from researchers across various scientific disciplines, such as hydrology, development studies, public health, and economics. This research often relies on more positivist-learning methodologies when synthesizing the complex relationships between water resources and different types of conflicts, including civil wars, social unrest, and communal violence. While overall this literature could be argued to focus on conflict outcomes, the role of peaceful water sharing is also a crucial aspect of this research.

In the field of peace and conflict research, there exist both a long-standing tradition and a strong interest to collaborate and reach across disciplines. This involves incorporating methodologies from natural sciences, quantitative data, statistical methods, comparative approaches, experimental designs, surveys, among other things (Wallensteen, 2011; Boulding, 1978). Consequently, peace research has actively engaged with arguments and findings from various scientific disciplines, including findings from hydrology. This approach aligns with the peace and conflict research tradition of exploring questions related to water resources (Falkenmark, 1990; Wallensteen and Swain, 1997).

Studying the interaction of water and the role for socio-economic development means to follow in the footsteps of influential scholarship on water, spanning areas such as anthropology, economics, geography, health research, and sociology. Examples of such research include studies on cooperation issues over water allocation generally (Falkenmark, 1990), groundwater use (Ostrom, 1990), or access to safe water (Duflo et al., 2015). The differentiation between socio-hydrologists and other scholars studying water, such as historians, political scientists, and anthropologists, initially lies in their disciplinary entry points (see Table 1). Historians aim to better understand contexts of water management and conflicts, political scientists may examine the governance structures and power dynamics surrounding water resources, etc. In this context, the boundaries between disciplines can blur, leading to a rich interdisciplinary exploration where the final scholarly products may exhibit a convergence in understanding and approach. Socio-hydrologists, with their grounding in both hydrological and social sciences, can serve as bridges in this interdisciplinary endeavor, facilitating a holistic and systems-oriented understanding of water challenges. Likewise, the study of water infrastructure effects merges fields such as development studies, public health, and economics. For instance, Duflo and Pande (2007) discovered that the impact of dam construction on poverty is influenced by existing property rights. In Western Kenya, research indicates that communal property norms for water sharing have been more effective than private property access to water systems (Kremer et al., 2011). These are just a few examples of the overarching cross-disciplinary approaches. Below, we focus on research on peace and conflict-related outcomes.

Numerous recent comprehensive reviews and *meta*-analyses have explored the links between violence and climate factors (e.g. Daoudy, Sowers, and Weinthal, 2022; Gilmore and Buhaug, 2021; von Uexkull and Buhaug, 2021; Koubi, 2019; Scartozzi, 2020; Vesco et al., 2020; Kim and Garcia, 2023). While this body of research lacks robust evidence connecting climate change impacts to inter-state violence, it has rather examined the role of water shortage in various intra-state conflicts, such as civil war-related violence, social unrest, protests, and other non-state actors.

The literature often highlights climate-induced changes as external catalysts for conflicts (Miguel, Satyanath, and Sergenti 2004) and further examines conflict dynamics, i.e., what happens in ongoing conflicts. One important factor for changing conflict trajectories can be ethnic group exclusion, especially in combination with agricultural dependence (von Uexkull et al. 2016; Vesco et al. 2021). Only a few studies address water access's role in deliberate acts of violence against civilians and we therefore have more limited, conflicting results (Harari and La Ferrara, 2018; Landis et al. 2017).

Literature on water and unrest also provide mixed findings, but this could be due to very different ways of operationalizing such social phenomena. Some research suggests that local droughts do not impact rioting (Harari and La Ferrara, 2018). In contrast, others find dry spells increase the likelihood of rioting, particularly in areas with lower water supply or competing ethnic groups (Almer, Laurent-Lucchetti, and Oechslin, 2017; Unfried, Kis-Katos, and Poser, 2022). Flooding has been specifically linked to lowered political trust or conflict over water issues in less democratic countries and where institutions are weak (Ghimire, Ferreira, and Dorfman, 2015; Petrova, 2022; Petrova and Rosvold, 2024; von Uexkull, Loy, and d'Errico, 2023). Yet, external shocks from climate-related events can also result in non-violent campaigns (Ide, Kristensen, and Bartusevičius 2021; Koren, Bagozzi, and Benson, 2021). This has also been examined in the context of hydro-dam construction. While dams can mitigate the effects of climate extremes on poverty

Table 1
Selected fields relevant to peace and conflict research on water issues.

Field	Conceptual Framework (Examples)	Methods (Examples)	Related Disciplines	Case example: Nile River Basin
Peace and Conflict Research	Conflict Resolution, Peacebuilding, Environmental Peacemaking	Conflict Analysis, including mediation or negotiation; various other methods	International Relations, Development Studies, Security Studies	Investigating transboundary water conflicts and peacebuilding initiatives among riparian states
Socio-Hydrology	Systems Thinking, Integrated Water Resources Management (IWRM)	Hydrological Modeling, Social Network Analysis, Stakeholder Analysis	Hydrology, Social Sciences, Environmental Sciences	Studying the impacts of the Grand Ethiopian Renaissance Dam (GERD) on downstream countries and local communities
Anthropology	Cultural Ecology, Political Ecology	Ethnography, Participant Observation, Interviews	Sociology, Cultural Studies, Human Geography	Exploring cultural perceptions and social impacts of water resource management across different communities in the basin
Economics	Resource Economics, Environmental Economics	Cost-benefit Analysis, Econometric Analysis	Business, Development Studies, Environmental Studies	Assessing the economic implications of water resource allocation and utilization among riparian states
History	Environmental History, Water History	Archival Research, Oral Histories, Comparative Historical Analysis	Archaeology, Geography, Environmental Studies	Examining historical water agreements and their implications on current water governance
Political Science	Governance, Power Analysis, International Relations	Case Studies, Policy Analysis, Comparative Analysis	Law, International Studies, Public Administration	Analyzing the political dynamics and governance structures surrounding the Nile waters
Sociology	Social Capital, Environmental Justice	Surveys, Interviews, Case Studies	Anthropology, Political Science, Environmental Studies	Evaluating social equity and justice in water resource management across the basin

NOTE: This is a simplified overview, therefore not including an exhaustive list of all fields, nor does the table provide a comprehensive list of all frameworks or methods for each field.

downstream, they may threaten livelihoods in the areas where dams are built (Duflo and Pande, 2007). This could explain social unrest linked to hydro-projects, as protests often directly address the irreversible impact of dams on local livelihoods (Del Bene, Scheidel, and Temper, 2018; Kim, 2021).

A great source of cross-case empirical studies has been dataset projects that capture different events or features of transboundary water relations. These datasets for example include the Transboundary Freshwater Dispute Database (TFDD) (Wolf 1999a), the Basins at Risk data (BAR) (Yoffe, Wolf, and Giordano, 2003), the International River Conflict and Cooperation dataset (IRCC) (Kalbhenn and Bernauer, 2012), the Water Relations in Central Asia Dataset (WRCAD) (Menga, 2016), the Water Conflict Chronology (Gleick, 1993), the Water-Related Intrastate Conflict and Cooperation (WARICC) data (Bernauer et al., 2012), and the Issue Correlates of War (ICOW) dataset (Hensel and Mitchell, 2014)). We also note efforts to combine existing data sources (Kåresdotter et al., 2023). Some of these datasets have been updated irregularly; here, socio-hydrology takes an eminent role in further developing existing database or providing new data on water treaties, river organizations and general water governance, including more systematic use of hydrological variables.

Approaches using large datasets have allowed for empirical comparisons across river basins, leading to nuanced inferences about water disputes. Notably, outright water wars are not typically fought between or within countries, thus direct military actions rarely feature when solving water issues (Furlong, Gleditsch, and Hegre, 2006; Tir and Stinnett, 2012; Barquet, Lujala, and Rød, 2014; Bernauer and Böhmelt, 2014; Schmidt, Lee, and Mitchell, 2021). Democratic institutions play a vital role in water service provision and therefore are crucial features for peace development (Gizelis and Wooden, 2010; Povitkina and Bolkavadze, 2019; Döring, 2020). While upstream–downstream power asymmetries are often-cited as a source of international water conflict, based on larger dataset approaches, there is much more evidence that such relationships do not lead to water conflict (Beck et al., 2014; Bernauer and Böhmelt, 2020).

This type of literature frequently integrates observational data from various social science-based datasets with hydrological data. While numerous examples are apparent where social scientists already collaborate with hydrologists, this can at times be primarily for data access purposes and therefore misses to incorporate hydrology-specific knowledge to elucidate social processes. Overall, the body of literature employs a diverse range of research designs, including surveys, formal modeling, agent-based modeling, frequentist and Bayesian statistical analysis of observational data, or forecasting methods. In relation to the noted methods, interview material is utilized to a lesser degree in these studies.

5. Environmental peacebuilding and water?

In recent years, the crucial role of water management in fostering sustainable peace in post-conflict societies has gained increasing attention from both researchers and policymakers. The emerging field of environmental peacebuilding seeks to understand how the restoration, management, and protection of water resources can contribute to conflict resolution and long-term stability. We briefly explain how this approach can help to explain complex relationships between water management, sustainable development, and peacebuilding efforts in war-torn societies. We argue that particularly environmental peacebuilding approaches can be key channels of engagement for socio-hydrology. By analyzing the intricate nexus between water, economic development, and peace, these approaches can shed light on the holistic, environmentally sustainable ways of building peace in post-conflict societies.

Sustainable and peaceful management of water often requires cooperation between states, sub-state authorities, and communities as water bodies are transboundary. The combination of water management and sustainable development in post-war/ peacebuilding societies is a crucial aspect of sustainable peacebuilding that cannot be neglected (Matthew, 2014; Collier, 2007; Krampe 2017a; Mach et al., 2020; Jensen and Lonergan, 2012; Aggestam and Sundell-Eklund, 2013; Ide, 2018; Ide et al., 2021; Swain and Öjendal, 2018; Conca and Dabelko, 2002; Krampe, Hegazi, and VanDeveer, 2021). An often-cited example is UNEPs initiative within the Iraqi marshlands. Faced with severe environmental deterioration that affected livelihoods of the Marshland communities, this project implemented eco-friendly approaches to restoring wetlands (Aoki, Al-Lami, and Kugaprasatham, 2011). While these measures improved water quality and supply to rural communities, it also created tensions in relation to governance (Al-Ali, 2014). Environmental peacebuilding has increasingly become a major field of research that studies water as a source of cooperation, with the long-term aim of contributing to peace (Wolf 1999b; Ide and Detges, 2018; Swain et al., 2023). Yet, there are also related issues with potential selection biases or streetlight effects within this literature (Adams et al., 2018; Hendrix and Poinsatte, 2019).

Water-specific research within environmental peacebuilding focuses on the potential of water use for conflict resolution (Aggestam and Sundell-Eklund, 2013; Krampe 2017b; Swain, 2016; Swain and Öjendal, 2018; Weinthal, Troell, and Nakayama, 2011), Sustainable management of water is a major challenge for peacebuilding efforts for economic recovery and preventing future conflict over water (Swain, 2016). Similarly, Conca and Wallace argue, 'failure to respond to environmental needs of war-torn societies may greatly complicate the difficult tasks of peacebuilding'(Conca and Wallace, 2009). Water bears the potential for a swift economic recovery, while equally being considered triggers for conflicts if not managed smartly (Lujala and Rustad, 2012; Jensen and Lonergan, 2012). Decisions about the restoration, management, and protection of water are considered to have vital consequences for short-term stability, long-term sustainable development and successful peacebuilding. For example, community empowerment has been shown to improve sustainable water management by fostering economic recovery, improving public health, and promoting peace in Afghanistan, Democratic Republic of Congo, and Liberia (Burt and Keiru, 2011). To solve challenges around water sharing and access, parties in conflict can also be motivated to cooperate while an antagonistic relationship between them persists otherwise. There is wide recognition that water scarcity and mismanagement could contribute to violent conflict (Adger, Barnett, and Dabelko, 2013; Swain, 1993) and this accentuates the potential significance as pathways for cooperation and the consolidation of peace in conflict-affected societies (Conca, 2002; UNEP, 2009).

Although peacebuilding strategies cannot completely eradicate the root causes of violent conflict, they aim to identify and provide technical and non-technical capacities that post-conflict countries lack, which serve as a foundation for recovery, stability, and sustainable development. This also relates to human rights-based approaches that can set recognized standards for water access in post-war environments (Tignino, 2011). Sadly however, peacebuilding efforts in post-conflict societies have had limited success, partially due to neglecting the sustainability of post-conflict reconstruction and narrowly-defined developmental goals. Liberal peacebuilding as a dominant paradigm has been argued to hamper attempts to broaden the peacebuilding efforts that address the root causes of conflict, which may include environmental degradation (Kostić, Krampe, and Swain, 2012). It is key to note that sustainable peacebuilding can be a driver for management, restoration, and protection of natural resources. The policies and overall decision-making on restoration, management, and protection of natural resources has significant consequences for short-term stability, longer-term sustainable development, and therefore also successful peacebuilding. Especially rebuilding trust is important in such cases and here actors ought to swiftly act as poor water resource management can severely complicate the peacebuilding process and hinder poverty reduction.

Clearly, managing critical natural resources such as freshwater is a main challenge when pursuing sustainable policies for growth and development. Effective management of water resources is crucial for economic recovery, e.g. through irrigation and flood control, or with hydropower potentially providing reliable energy (Swain, 2016). In addition, providing clean water and sanitation facilities is essential for a healthier society, particularly for women and children (Nunbogu and Elliott, 2022). However, post-conflict environments often prioritize building large water infrastructure for faster economic recovery (Stec et al., 2011; Kostić, Krampe, and Swain, 2012). This might go hand in hand with increased foreign investment, e.g. in hydropower or farmland, and thereby potentially creates tensions over controlling water resources (Kim, 2021). Without considering social and environmental factors, these projects can exacerbate existing inequalities between competing groups and revive old conflicts or create new ones.

To reiterate from before, the wider literature finds that water shortages can create disputes between riparian actors, but the majority of these incompatibilities result in non-violent outcomes (Fischhendler, 2008; Brochmann and Hensel, 2009; Dinar, 2020; Ovodenko, 2016; Owsiak and Mitchell, 2019; Dinar, 2020). Especially track-based negotiations have played an important role in hydro-diplomacy, and explicit research on water diplomacy has only recently started to emerge (Zareie, Bozorg-Haddad, and Loáiciga, 2020; Islam and Susskind, 2018; Grech-Madin et al., 2018; Klimes et al., 2019; Salmoral et al., 2019). Here, socio-hydrology has an important role to play as diplomatic efforts require integrated approaches and analyses.

Peacebuilding is not just about the absence of violent conflict, but also about tackling the root causes of violent conflict. International agencies have emphasized the importance of constructing or strengthening legitimate governmental institutions in fragile and conflict-affected states. State-building is now an integral part of peacebuilding efforts, with the goal of creating or reconstructing institutions of governance that can provide citizens with physical and economic security. Despite criticisms and ongoing challenges, liberal peacebuilding remains the dominant strategy of the international community for conflict prevention and post-conflict reconstruction. However, peacebuilding projects often fail to consider the environmental limits of fragile societies, leading to concerns about the lack of attention to environmental issues in peacebuilding strategies. This is also where socio-hydrology can further provide important impetus to policy and bring forward better understanding for environmental peacebuilding.

In summary, while state-building has become a crucial component of peacebuilding efforts, the failure to consider the environmental limits of fragile societies can greatly complicate the task of building and sustaining peace. It is important for peacebuilding strategies to consider and respond to the environmental needs of post-conflict societies to achieve sustainable peace.

6. Conclusions

The sustainable management of water resources plays a pivotal role in building and maintaining peace in post-conflict societies. Here socio-hydrology can play a pivotal role to inform research and policy communities. In this paper we have explored the multifaceted relationship between water management, sustainable development, and peacebuilding, underscoring the importance of cooperation between states, sub-state authorities, and communities in addressing transboundary water challenges. We have argued that sustainable peacebuilding entails not only the absence of violent conflict but also the prevention of potential conflicts, making the inclusion of environmental considerations crucial in peacebuilding strategies. We also emphasized the importance of taking into account varying methodological and theoretical approaches. For instance, political ecology can improve our understanding by focusing on politics, power, and social factors. A key point includes the centrality of power and politics, the resistance to primarily technical solutions for water management, the need to address intersectionality in social vulnerability, and the importance of ethnographic methods for understanding water-society relations. It is vital to expand the scope of socio-hydrology to encompass a diverse array of phenomena, this includes integrating qualitative and quantitative analyses. This can help researchers to gain a deeper understanding of the present socio-political, economic, and cultural contexts across various regions. We encourage researchers to more deeply consider knowledge about the larger social contexts that shape unequal water distribution at national and local levels. While we encourage socio-hydrology to more deeply engage with social science, we also stress that social scientists have a responsibility to contribute their insights to socio-hydrology.

This paper also gave a snapshot of the interdisciplinary nature of peace and conflict research, with a particular focus on water resources and their role in socio-economic development. Overall this underscores the significance of environmental peacebuilding and hydro-politics in understanding water conflicts and cooperation. We see a strong need for a more comprehensive understanding of the complex interplay between water management and peacebuilding. Addressing the environmental needs of war-torn societies helps to avoid complicating the already

challenging tasks of peace, reconciliation, political institutionalization, and economic reconstruction. In light of these arguments, we advocate for a holistic and environmentally-informed approach to peacebuilding that encompasses effective water resource management and the restoration and protection of natural resources.

There are also other aspects which were outside the scope of this paper but which are equally important for further engagement with socio-hydrology. For instance, there is a growing literature that considers how water resources are affected by armed conflicts and what that means for those affected during and after conflict (Schillinger et al., 2020; Zeitoun and Talhami, 2016; Döring, 2020; Döring and Hall, 2023). This also in part relates to aspects of gender and water. While this type of research has been more prominent recently, there are still many gaps in the literature on gender issues in relation to water and security issues. For instance, we know that gender inequality is higher in the WASH sector, climate-resilient farming, and general water service provisions (Perez et al., 2015; Romanello et al., 2022) and that women and girls face a disproportionate burden from water scarcity, with societal taboos making them more reluctant to bring attention to issues with sanitation access (Kadir, Shenoda, and Goldhagen, 2019; Mafuta, Zuwarimwe, and Mwale, 2021). Yet much more insights are needed on these topics and we encourage socio-hydrology to consider focusing on several widerresearch areas.

CRediT authorship contribution statement

Stefan Döring: Writing – review & editing, Writing – original draft, Project administration, Funding acquisition, Conceptualization. **Kyungmee Kim:** Writing – review & editing, Writing – original draft. **Ashok Swain:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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