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# Interdisciplinary Critical Geographies of Water: Capturing the Mutual Shaping of Society and Hydrological Flows

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**Abstract:** In light of recent calls for an increased commitment to interdisciplinary endeavors, this paper reflects on the implications of a critical geography of water that crosses social and natural sciences. Questions on how to best research the relationship between water and society have been raised both in the field of critical geographies of water and sociohydrology. Yet, there has been little crossover between these disciplinary perspectives. This, we argue, may be partly explained by the fact that interdisciplinary research is both advocated and antagonized. On the one hand, interdisciplinarity is argued to deliver more in terms of effectively informing policy processes and developing theoretical perspectives that can reform and regenerate knowledge. On the other hand, natural and social sciences are often presented as ontologically, epistemologically, and methodologically incompatible. Drawing on our own research experience and expertise, this paper focuses on the multiple ways in which critical geographies of water and sociohydrology are convergent, compatible, and complementary. We reflect on the existing theoretical instruments to engage in interdisciplinary research and question some of the assumptions on the methodological and epistemological incompatibility between natural and social sciences. We then propose that an interdisciplinary resource geography can further understandings of how power and the non-human co-constitute the social world and hydrological flows and advance conceptualizations of water as socationatures.

**Keywords:** critical geography; interdisciplinary studies; socationatures; hydrosocial cycle; sociohydrology

## 1. Introduction

“The specialist who forever stays at home and digs and delves within his [sic] private enclosure has all the advantages of intensive cultivation—except one; and the thing he [sic] misses is cross-fertilization”. [1] (p. 122)

“The theory we need, which fails to come together because the necessary critical moment does not occur, and which therefore falls back into the state of bits and pieces of knowledge, might well be called, by analogy, ‘a unitary theory’: the aim is to discover or construct a theoretical unity between fields which are apprehended separately”. [2] (p. 11)

“For a whole variety of reasons, the carving-up of the world and of scientific endeavor between disciplines has been experienced recently as increasingly untenable”. [3] (p. 261)

“Global Change research (and politics) is entering a formative moment, and it’s important that a range of epistemic communities shape its content and tenor looking ahead”. [4] (p. 301)

The passages above reveal the long history in geography of seeking disciplinary ‘cross-fertilization’. Whilst Gilbert’s scientific “trespass” [1] (p. 122) entailed an engagement with adjacent fields, more recently the idea of deeper integration between physical and human geography has gained traction. Lefebvre critiqued disciplinary oversimplifications and abstract notions of space of social practice. He advanced a conceptualization of space that is context specific, historical, and comprehensive of social relations, products of imagination, and material forces. In this light, he argues for a unitary theory that captures the conjunction of the social, the physical, and the conceptual/psychological. Although focused on theoretical ambitions, Lefebvre’s argument carries strong methodological significance as the theoretical project entails a commitment to multi or interdisciplinary approaches. As aptly illustrated by Massey’s quote [3] (p. 261), although disciplinary boundaries are “increasingly untenable”, the separation between the ‘human’ and the ‘physical’ sciences remains the “best-fortified” divide in science.

Today, there is growing recognition that “humans are (literally) writing themselves into Earth history” [4] (p. 302). In the Anthropocene, the need of integrating natural and social sciences to better address widespread phenomena caused by the interconnected social-natural systems has become even more evident [5–7]. Social sciences and geosciences scholars increasingly argue that interdisciplinary research can deliver more in terms of generating knowledge on global environmental change and effectively informing policy processes [8,9]. To illustrate, as a sub-field of hydrology, sociohydrology is dedicated to unravelling the interactions and feedbacks between human and water systems. Scholars in this field increasingly invoke a mutual obligation of hydrologist and social scientists to collaborate to deliver research that advances science in new directions and contributes to addressing grand societal challenges posed by global environmental changes [10–12].

Although convincingly argued on a conceptual level, research that crosses the natural-social science divide remains little practiced [3,5]. This, we suggest, is the result of a constant oscillation between promoting integration of natural and social sciences, and presenting them as ontologically, epistemologically, and methodologically incompatible. There is a wealth of literature invoking interdisciplinarity [4–9]. Yet, much of this scholarship tends to fall back on discussions on the epistemological and methodological differences that constrain these collaborations. This is particularly evident when it comes to integration between qualitative social sciences and quantitative natural sciences [9,13–18]. The unspoken assumption of the ‘superiority’ of quantitative methods, many social scientists argue, has led to the marginalization of qualitative social sciences [13–16]. Critical social scientists often lament asymmetrical integration, in which social sciences are placed in a “service” [17] (p. 291) or “end-of-pipe” role [9] (p. 208). Perceptions of the irreconcilable differences and of asymmetrical collaborations between natural and social sciences deter opportunities of meaningful collaborations.

In the attempt of contributing to a more fruitful dialogue between disciplines, we focus on the multiple ways in which critical social sciences and geosciences are convergent, compatible, or complementary by drawing on our research expertise and experience in critical geographies of water and sociohydrology. To do so, we first demonstrate how both sociohydrology and critical water geographies, albeit with differences in language, methodological approaches, and points of departure (socio-political processes and hydrology, respectively), have both questioned the ontological separation between water and society. We suggest that, despite this, challenges of working across different epistemologies and methodological approaches persist for both critical water geographers and sociohydrologists [19,20]. We then reflect on the potential of an interdisciplinary water resource geography integrating critical social sciences and hydrological sciences, by developing three arguments. First, we argue that (some) of the scientific challenges of crossing the natural and social science divide are contextual and grounded on preconceived and caricaturized ideas of what different disciplines entail. We do so by contextualizing the critique of quantitative methods in critical geographies

and by showing that numbers can be compatible with and instrumental to progressive geographies (Section 3.1). Secondly, we show that integration is already occurring and, drawing on different research projects, we tease out different approaches to cross-disciplinary collaborations. We suggest that within each discipline, academics hold different and even opposing ontological, epistemological or methodological positions. On this spectrum, some may be more aligned with scholars from other disciplinary backgrounds. These overlaps create, in our experience, the most productive spaces for collaboration (Section 3.2). Third, we suggest that an interdisciplinary water resources geography is well placed to develop analyses of phenomena and processes that account for both time and space (Section 3.3). We then conclude that although interdisciplinary critical water geographies are sparse, they demonstrate that discipline-bridging studies can further understandings of how power and the non-human co-constitute the social world and hydrological flows at different spatial and temporal scales.

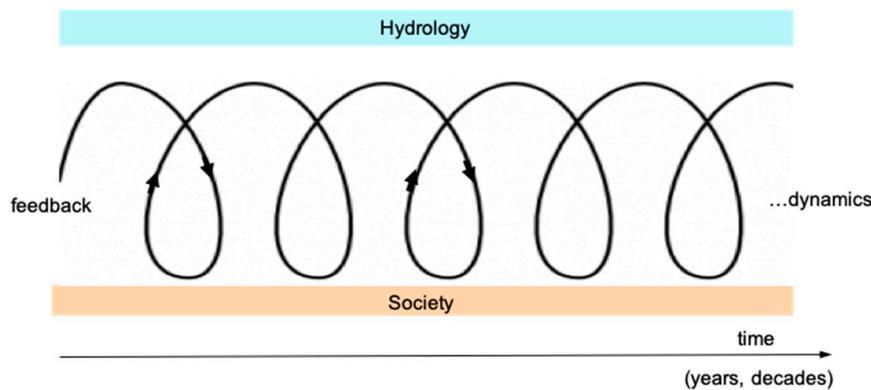
## 2. Converging Paths: Theorizing the Interplay between Water and Society

On a conceptual level, critical water resource geographies and sociohydrology have developed the philosophical foundation for integration across disciplines. Geographers claim their discipline is at the nexus of social and natural sciences and, thus, well positioned to “lead the search for synthesis” of human and physical phenomena [21] (p. 1), [22,23]. Scholars in critical water geographies have advanced multiple interrelated conceptualizations of the interplay between water and society. Political ecologies of water, for instance, have conceptualized the interweaving of water and society as a “restless hybrid” that materializes in historically produced uneven waterscapes or as a hydrosocial cycle [24] (p. 461), [25–30]. Bakker [26] (p. 774) aptly describes this relationship as “a physical flow (the circulation of H<sub>2</sub>O) and a socially and discursively mediated thing implicated in that flow”. The hydrosocial cycle, Linton and Budds [27] (p. 170) argue, expresses the geographical and historical process through which “water and society make and remake each other over space and time”. Central to these conceptualizations are the choreographies of power through which water is controlled and distributed and broader concerns of water (in)justice [31–38].

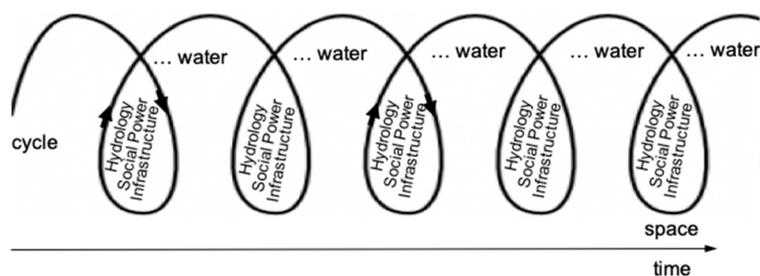
Similarly, sociohydrology is well positioned to play a catalytic role in developing collaborations between the social and hydrological sciences [10,39–41]. Sociohydrology questions the idea of an observable ‘natural’ hydrological cycle as a distinct separate entity. ‘Traditional’ hydrology has been criticized by critical geography scholars because of its conceptualization of water as uniform, consistent, and universal [27,29]. Sociohydrology, on the other hand, acknowledges human agency, and the importance of place and context. Humans shape hydrological flows, deliberately or not [42]. Savenije et al. [43] identified four main types of human influence: (i) direct diversion of water flows, such as water supplies to cities, industries, and agriculture; (ii) physical transformation of the water storage, such as the one caused by dams and reservoirs; (iii) changing river basin characteristics, including deforestation, urbanization, drainage of wetlands, and agricultural practices; and (iv) alteration of the regional or global climate via greenhouse gas emissions and land cover changes. Hydrological flows and their extremes (floods and droughts) are experienced or perceived by human beings that respond to hydrological change. Such responses include spontaneous or informal processes, including migration (from drought affected areas), and more formal change in water resources management, including the construction of a new dam that will then feedback on hydrological flows. Ontologically, therefore, sociohydrology conceptualizes the hydrological cycle as more than H<sub>2</sub>O: it embodies the agency of humans and (urban) infrastructures acting on it and shaping its flows.

Whilst departing from a different focus (humans and hydrology, respectively), critical water geographies and sociohydrology question the ontological separation between water and society and invite to consider the relations to, and enmeshment of humans with infrastructural configurations and hydrological flows. There are, however, differences in the way these theoretical perspectives conceptualize the interplay between water and society. Importantly, sociohydrology characterizes the relationship between water and society as ‘external’. Hydrology and society are independent

entities that co-evolve through a feedback mechanism (see Figure 1). In contrast, the hydrosocial cycle conceptualizes water and society as “internally related” [27] (p. 175). In this perspective, water is “not external to social relations but rather embeds and expresses them” [27] (p. 174). In other words, different social relations produce different flows and forms of water [27,29,44] (see Figure 2). This hybridity, “resists the rigidity of any fixed and static categories” rendering polarizations of water and society and physical and human geography untenable [23] (p. 758). A second difference concerns the conceptualization of society. In sociohydrology the focus is on features such as settlement patterns, demographics, economics, technology, and industry, mostly quantitatively described and analyzed [10,20]. Hydrosocial scholars have mostly focused on qualitative analyses of the articulation of social power and H<sub>2</sub>O (i.e., the material properties of water) in the production of ‘water’ (i.e., socially constructed water) and on the “politics of hydrology” [27], [45] (p. 167).



**Figure 1.** Authors’ interpretation of sociohydrology, adapted from Di Baldassare et al. [42]. The feedback loops represent the interplay between water and society. The relationship between water and society is external.



**Figure 2.** Authors’ interpretation of the hydrosocial cycle, adapted from Linton and Budds [27]. The series of loops reflects process of cyclic remaking of the hydrosocial cycle over time. The relationship between water and society is internal.

Whilst convincingly argued on a theoretical level, the challenge of an interdisciplinary water resource geography remains. Sociohydrology is still dominated by hydrologists [11,13]. Quantitative approaches such as measurements and long-term averages predominantly shape knowledge production [46,47]. Similarly, genuinely interdisciplinary collaborations across different epistemologies, methodological approaches, and disciplines are limited in critical water resource geography [19,20].

Below we attempt to identify elements of convergence and complementarities between natural and social science disciplines to contribute developing what Pickett (in Gober [21]) defines as new “habits of the mind” that are more favorable to critical and interdisciplinary research. What we aim to achieve (or at least encourage) here, borrowing from Barnes and Hannah [48] (p. 383), is a critical water resource geography that cuts across “the divides between the social-cultural and the spatial-analytical, the qualitative and the quantitative, the critical and the technical, and the social-scientific and the

arts-and-humanities". In the sections that follows, we thus discuss the opportunities and strategies for furthering this synthesis.

### 3. The Quest for a Synthesis: The Potential of an Interdisciplinary Water Resource Geography

#### 3.1. *Compatibility: The Power of Quantitative Data for Progressive Geographies*

Critical water resource geographers, as proposed by the editors of this special issue, engage into "a politicized practice of scholarship", critiquing processes of exploitation and domination. Studies focus on the way different dimensions of differentiation, including race, gender, sexuality, and class, intersect in the production of differentiated access to water and uneven vulnerabilities to hydrological extremes. The aim of this scholarship is not only to describe the production of unequal waterscapes, but also to engage with the ethical responsibilities of an increasingly unequal world [4,49]. Blomley [50] (p. 285) describes this as "the melding of theory and political action".

The commitment to emancipatory politics is often seen as contrasting with quantitative approaches. These are associated with conservative agendas and the production of inequalities through the capitalistic system [51,52]. This association has been strongly influenced by Harvey's representation of spatial science as 'counter-revolutionary'. For Harvey [53] (p. 11), not only do quantitative data "tell[s] us less and less about anything of great interest", but the quantitative revolution also contributes to perpetuate the capitalistic system by leaving it unchallenged. He, thus, concluded that "we cannot afford to plan for the future on the basis of positivist theory for to do so would merely be to reinforce the status quo". The idea that numbers are mobilized to sustain conservative agendas persists in critical geography. The immediate consequence is a disengagement of critical geographers with numbers. This, in turn, inhibited collaborations with geoscientists [4].

More recently, quantitative geographers have come to question the philosophical assumptions that critical geographies cannot be done with numbers. They suggest that although Harvey "cast his net wider", his critique was intended to a specific branch of quantitative analyses: neoclassic economics [51,54]. These scholars reclaim a role for quantitative approaches in critical geographies, contending that doing critical geography without mobilizing the mainstream language of numbers and their visualizations may frustrate any attempt to achieve social justice [52,54,55]. Further, quantitative approaches are not indissolubly linked to positivism and critical geographers can strategically mobilize numbers for normative commitments [29], [52] (p. 461), [56].

Critical geographers that disengage with statistics, dismissing them as socially constructed, miss on the opportunity of influencing their 'construction' and of mobilizing them for progressive purposes [51]. Numbers and models are key tools in city planning and are, thus, central in defining people's life and in shaping social reality [48,56]. As suggested by Pullan et al. [57], spatially mapping uneven access to water and sanitation services is crucial to identify marginalized groups and monitor progress in access. To illustrate, the Millennium Development Goals (MDGs) and the Sustainable Development Goals (SDGs) measure progress in access to water and sanitation with quantifiable and 'simple' targets, while qualitative data are overlooked [58]. Disengaging with these data carries the immediate risk of weakening critical geography's influence on what is measured, why and on how it is interpreted. A critical geography 'of numbers' may be best placed to both examine and critique quantitative data through analyses of different stratifiers and to reveal patterns of distributive injustice [59]. The MDGs, for instance, are claimed to have been successful in meeting the water and sanitation targets. Langford and Winkler [58], however, found that the targets did not create incentives to eliminate poverty and to support the most marginalized. As a result, ethnic minorities, girls and women, and indigenous peoples remained excluded from access to basic services. Quantitative analyses, therefore, can work to both conceal and reveal vulnerability and marginalization of individuals and groups. Geographers working on distributional justice can play an important role in ensuring that these numbers are effectively used for a progressive agenda. Quantitative methods can also significantly contribute to a progressive agenda by shedding light on local knowledge [60]. To illustrate, surveys can systematically

map farmers' perceptions on differentiated access to irrigation water and exposure to hydrological hazards. This, Mustafa argues ([60] p. 103), contributes to capturing "local-level subjectivities" that are important to but often overlooked by political ecology studies.

Despite the challenges in deconstructing the relationship between quantitative methods and conservative agenda [51,56], promising efforts to mobilize quantitative analyses for critical resource geography have emerged. The potential of quantitative approaches for critical geographical inquiries is discussed in a study on plumbing poverty in the US [61]. The study draws on census data on presence/absence and completeness of plumbing at household level to measure water insecurity. It proposes plumbing poverty as a methodological device to reveal geographic inequalities. Similarly, Wutich and colleagues have worked on quantifying the "stressful lived experience of water insecurity" [62] (p. 1), [63,64]. Others have used surveys to measure acceptability of wastewaters for different everyday practices [65]. Critical resource geographies research reaching out to geoscience are also explored by a study on uneven distribution of drinking water contamination in Lilongwe, the capital of Malawi [19,66]. Combining qualitative analyses on uneven urban development with a quantitative assessment of water quality, these scholars argue, advances understandings of the production of water contamination and its uneven spatial distribution [19]. Concurrently, it serves to further understandings of water and society that are more attentive to the materiality and the multiple ontologies of water [19,27,67–69]. It thus serves to deepen and broaden post-humanist perspectives invoking ideas of socio-materiality, assemblages, and re-materialization of political ecologies of water [70–74].

In this perspective, quantitative sociohydrology can provide important insights on inequalities, vulnerabilities, and exposure to hydrological risk. First, several studies have undertaken quantitative examinations of the relationship between human activities and frequency and intensity of floods. This research importantly reveals that flood control infrastructures such as levees may exacerbate exposure to floods as perception of risk decreases and human settlements get closer to rivers [75,76]. While these assessments further understandings of how floods are perceived and 'controlled' and their relation to hydrological change, they may also serve to tease out questions of power and uneven distribution of risk across spaces. For instance, sociohydrology has examined a flood canal (Banjir) in Jakarta (Indonesia), built to protect the European colonial population from flood risk in the capital city. Settlements emerged informally along the banks of this high-risk canal, mostly because of its proximity to water and low potential for more productive land uses [77]. In today's Jakarta, these informal settlements are exposed to high flood risk, as the canal capacity has decreased because of dumping of solid waste while flows have increased due to wastewater discharge from households [78]. Although sparse, these studies reveal the significant potential of engaging with quantitative data to tease out, measure, and visualize inequalities and their spatial distribution, as well as to further conceptualizations of the waterscape and the hydrosocial cycle.

### 3.2. *Integration: Case Studies, GIS, Predictive Models, and Social Justice*

Scholars across natural and social sciences describe integration of quantitative analytical approaches and interpretative social sciences as one of the major methodological challenges in interdisciplinary collaborations [5,10,20,79]. Analytical geographers focusing on generalizable quantitative data regard critical studies invoking the importance of context and using qualitative information as anecdotal, fuzzy, and too complex [52]. On the other hand, critical geographers from Marxist, feminist, and post-structuralist perspectives, criticize quantitative approaches for their tendency toward universality, the essentialist analysis of human agency, the reductionism, the claimed objectivity, and the inability to relate empirical observations to the underlying structural processes [52,56]. As a result, efforts of integrating geoscience and social sciences in global environmental research have mostly focused on quantitative social sciences and economics. These are seen as immediately compatible with the epistemologies and ontologies of geoscientists [4,79]. Although the methodological dualism between quantitative and qualitative approaches has rarely

been challenged [56], there are several reasons to question their incompatibility. We propose that rather than being grounded on fundamental differences, the arguments on the incompatibility of quantitative and qualitative approaches are often based on a caricatured portrayal of disciplines. First, quantitative geographies are not tied to “essentialist categorizations, absolute notions of space and time, and linear causalities” [56] (p. 461). Many hydrologists, for instance, recognize the presence of multiple working hypotheses [80,81] and the “unavoidable subjectivity” in modelling. Pappenberger et al. [82] (p. 275) have argued for the need of “identifying, characterizing and discussing the uncertainties inherent in our understanding of sociohydrological systems” while raising awareness of “different perceptions of uncertainty” [83] (p. 1711).

Secondly, we suggest that rather than opposing fields, natural and social scientists are on a spectrum, where academics holding different positionalities align in some epistemological or methodological approaches and differ in others. In this spectrum, as suggested by human geographer Massey [3], certain debates are shared with at least some academics from different disciplinary backgrounds. Our experience is that collaboration is easier between critical geographers that value quantitative data and hydrologists that call for a deeper engagement with question of power, than with academics from the same or adjacent field that favor specialization. A recent study in sociohydrology, for instance, invokes a deeper engagement with “power relations, trust, cultural beliefs, and cognitive biases, which strongly influence the way in which people alter, and adapt to, changing hydrological regimes” [10,46,84]. This, the authors suggest, entails integrating political economy analyses in explanations of changes in hydrological regimes and, in turn, collaborations with critical social scientists. Such collaborations may lead to both developing interdisciplinary case studies that examine how human activities alter the hydrological cycle and incorporating power and heterogeneity in sociohydrological modelling.

Thirdly, we question the correlation between epistemological and methodological differences and disciplinary incompatibility. We argue that the ambition of generalizing in the natural sciences and the specificity of social contexts in qualitative interpretative social sciences are not intrinsically incompatible. Integration can take multiple forms. In line with this position, Gober [21] (p. 8) claims: “would anyone seriously argue that a census-based analysis cannot be informed by ethnography, that quantitative and qualitative methods are mutually exclusive, or that humanists have little to say to physical geographers and vice versa?”. Several multi-sited ethnographies and ethnologies of water (in)security, for instance, employ meta analyses to capture themes across sites [85,86].

We, thus, propose that integration can be achieved by preserving methodological and epistemological differences. The studies on uneven water contamination in Lilongwe discussed earlier [19,60], for instance, are grounded on a case study design envisioning symmetrical integration between qualitative interpretative social sciences and a microbiological analysis of drinking water. This approach allowed maintaining core themes of critical geography scholarship, such as the role of power, gender, class, and race in directing and shaping water flows, whilst using a quantitative assessment of drinking water to measure and quantify uneven distribution of contamination in the city. Whilst the quantitative assessment tells us *who* is exposed to water contamination and to *what extent*, the qualitative analysis examines *why*. Another example of interdisciplinary (water) geographies encompasses the use of critical GIS to challenge inequalities and an uneven development [52]. Tiwale et al. [87] used GIS to map reservoirs built in the city of Lilongwe, Malawi, over a period of 50 years. The study traced uneven reservoir developments and the lived experiences of water scarcity in low-income neighborhoods. It then linked the analysis of the location of reservoirs and the identification of hot spots of population growth. Based on this, the authors conclude that over time infrastructures and water resources were developed to improve continuity of higher income residents, rather than to serve the growing unserved urban population in informal settlements.

Last, although some political ecologists see hydrology as an ‘orthodox’ science in “search for universally applicable ‘laws’ of nature based upon practices that guarantee accuracy and lack of political bias” (Forsyth 2003 in [29]), much has changed in this field over the past decades. While there are some general principles guiding hydrological research (e.g., the role of gravity in shaping water

flows), the specificity of context is also widely recognized [88]. This notion implicitly questions the idea of the hydrological cycle as immanent and universal (see [28,29] for a critique of hydrology). Moreover, the modelling of human-water systems includes numerous equations and formula that can (or, actually, should) be integrated with socio-political analyses and questions of (in)justice [84]. The sociohydrological model of human-flood interactions presented by Viglione et al. [89], for example, simulate the interplay between collective memory, risk-taking attitude, and trust. This model exercise would benefit from empirical insights from case studies, while at the same time, the structuring of case studies can benefit from the theoretical framework provided by the model [20].

We, thus, suggest that rather than assuming certain methods or epistemologies are incompatible, the focus should be on the research problem and on axiology (i.e., purpose of the research/knowledge). In our experience, methodological and epistemological differences are not always an obstacle to integration. Researchers from different disciplinary backgrounds can cross disciplinary boundaries when they are driven by similar or complementary research questions or objectives. In the case of an interdisciplinary resource geography, questions should include and prioritize understandings of the production of inequalities in water access, distribution, and contamination as well as uneven exposure to hydrological risks.

### 3.3. Complementarity: Space-Time in the Water and Society Interplay

Human and physical geographers have called for analyses that account for both time and space in seeking explanation of different phenomena and processes [3,90,91]. For Massey, the conceptualization of time-space can lead to interdisciplinary dialogues with physical geographers. Inspired by physicists Livigstone and Raper (1995 in Massey [3]), who propose the notion of relative space and time for environmental modelling, Massey argues that also human geographers “had been struggling to understand space (and space-time) as constituted through the social, rather than as dimensions defining an arena within which the social takes place” [3] (p. 262). Integrating the temporal dimension in geographic analyses also carries the potential of engaging with notions of timing, duration, and rhythm, which shape “subjective experiences of time and, in turn, of marginalization”. [91] (p. 1079).

Reconciling time and space is central to conceptualizations of the interplay of water and society as coupled systems. Water and society co-constitute and reconstitute each other in moments in time and in a given place. As such, the hydrosocial cycle is both a historical and a geographical process (therefore we chose to represent it as a series of consecutive loops in Figure 2) [27]. Physical geographer Lane [90] argues that the concerns raised by Massey are central to capturing the physical world as well. Practices defined by time and space are the foundation for how practices will be performed in future. In the same way, contingency shapes fluvial processes and co-determines future fluvial events. Lane [90] illustrates his argument with the example of the state of a river reach, which is dependent on the characteristics of the place that are likely to be transformed over time. Time also matters for condition of access to water. In the periphery of Maputo and Lilongwe, for instance, water is only supplied at night. Timing here matters perhaps even more than distance in shaping women’s experiences of fear and violence with which water access becomes associated [92,93]. Concurrently, time of storage and discontinuity of flow fundamentally change the quality of water and, in turn, increase risks of its contamination [66,94].

Sociohydrology has mainly focused on the time domain, but there is an increasing interest to explore phenomena that manifest in the space domain or in space-time [95–97]. First, many scholars argued that there is much that can be learned by comparing and contrasting phenomena that arise in different places and in different contexts, and by seeking common explanations. This was done by Srinivasan et al. [98] in terms of water syndromes (e.g., ecological destruction, depletion of groundwater resources, conflicts driven by droughts, unmet livelihood needs, elite capture, and reallocation of water to nature). Second, many scholars examine the spatial distribution of hydrological risks to shed light on inequalities in the way different social groups are able to prevent, cope with, and recover from droughts and floods [99].

An interdisciplinary water resource geography provides an opportunity to develop a more complex understanding of space-time by complementing and integrating work on time undertaken by sociohydrology and that of the production of space of critical (water) geographies. To illustrate, hydrology works with long time remote sensing and hydrological data, which can be combined with social data to further understandings of complex interactions between water and society at different scales, contexts, and climatic conditions [75].

In concluding this section, we suggest that the engagement of critical water studies with sociohydrology is fruitful to further understandings of the production of uneven water flows and hydrological risks at different spatial and temporal scales. Barriers to engaging in these collaborations are often contingent and contextual. We suggested that epistemological and methodological differences do not necessarily entail disciplinary incompatibility and that academics of different disciplinary backgrounds often hold converging or compatible ontological, epistemological, or methodological perspectives. These academics are well placed to undertake discipline-bridging research in the field of critical water resource geography.

#### 4. Cooperation: Practicing Interdisciplinary Collaborations

A genuine interdisciplinary resource geography requires developing meaningful practices of collaboration. In this perspective, catalyzing collaboration entails shifting away from an academic culture that seems to value geosciences over the social sciences [18]. Experiences of asymmetrical collaborations are common among interpretivist social scientists. Yet, critical social scientists may need to reflect on their role in producing asymmetrical relations. First, if their disengagement from geosciences protects critical geographers from the risk of being co-opted for conservative agendas, it also contributes to preserving these agendas [100]. Secondly, critical researchers must themselves get rid of the assumption of an academic hierarchy lead by geosciences. Otherwise it is unlikely that they will be able to re-balance power relations in interdisciplinary collaborations [100].

We propose that integration is only possible between academics that are willing to and see a value in disciplinary ‘trespassing’. These collaborations are unlikely to be successful when engaging with scholars that are keener on specialization. Some sociohydrology scholars, for instance, proposed reconceptualizing research problems and developing broader scientific questions to increase interest of and, thus, collaborations with social scientists [9,11]. At the ‘other end of the spectrum’ critical scholar engaging with materiality of water and infrastructure have seek collaboration with hydrologists and water quality engineers on questions of volume, hydrological flows and biochemical and microbiological transformations (see for instance [19,101,102]). These practices, we argue, suggest an attempt of developing constructive interdisciplinary engagements.

As aptly illustrated through the quotation from Gilbert [1] with which we commenced this paper, specialization within and across disciplines can lead to fragmentation. Integration, on the other hand, can contribute to creating new perspectives and lines of inquiry: “the trespasser brings with him a mental attitude and a mental equipment which are new to the subject, and whether or not the idea he contributes eventually “makes good”, its contribution creates a new category for observation and opens a new avenue of inquiry” [1] (p 122).

Over the past years, sociohydrologists have described and modelled various phenomena (for a full review see [10]) including:

- Safe-development paradox, when structural protection measures generate a false sense of security that reduce coping capacities thereby increasing social vulnerability.
- Aggregation effect, when undesirable outcomes at the human-water system scale emerge from aggregated optimal decisions at the individual scale (or desirable outcomes at the system scale from aggregated inequalities at the individual scale).
- Supply-demand cycle, when increasing water supply enables growth that in turn generates higher water demands offsetting the initial benefits.

- Adaptation effect, when frequent extreme events increase coping capacities thereby reducing social vulnerability.
- Pendulum swing, when changing priorities from pursuing economic prosperity or environmental protection.
- Irrigation efficiency paradox, when increasing the efficiency of irrigation systems leads to higher water consumptions because of rebound effects.

These phenomena provide new research questions and “categories” [1] (p 122) for critical geographers to explore, integrate and critique. Geography’s critical contribution here could encompass analyzing these phenomena from a justice perspective, highlighting stratification and differentiation in society, how these phenomena are produced and, in turn, how their costs and benefits are distributed.

## 5. Conclusions: Interdisciplinary Resource Geography in the Anthropocene

The academic world (as every other sector) is at a turn. The Anthropocene marks the recognition of human’s role in altering the biosphere, hydrosphere, and hydrological cycle [103]. This recognition has implications for academics of all disciplines that, more than ever before, are called to unravel social-natural phenomena at different scales. Critical scholarship can and should play a major role in shedding light on the relationship between processes of uneven development and global environmental change [104]. Worryingly, as research on global environmental changes enters a formative phase, it is overwhelmingly shaped by geosciences [4]. This urges critical geographers to reflect on their positionality, the knowledge they produce, and if the impact they have is satisfactory and in line with their moral obligation as scientists aspiring to change (rather than only interpret) the world.

With this in mind, this paper has reflected on the potential of an interdisciplinary water resource geography that accounts for the mutual shaping of society and hydrological flows. We have shown that rather than being grounded on unsurmountable methodological differences, several of the assumed challenges to interdisciplinary research are determined by contextual barriers and beliefs of what a discipline or a given method entail. We propose that rather than in opposing fields natural and social scientist are on a spectrum. Within each discipline, academics may hold different and even opposing ontological, epistemological or methodological positions. Their methodological and epistemological assumptions may be more aligned with (some) scholars from other disciplinary backgrounds. These scholars are best placed for doing interdisciplinary research. Additionally, meaningful interdisciplinary resource geography is not about mimicking or complying with different methodological and epistemological positions, but rather about recognizing the limitations of each discipline and method, the added value of other approaches and the way they (potentially) complement each other.

Concurrently, we have discussed what an interdisciplinary water resource geography can do differently from a human geography that focuses on water. Although critical water geographies engaging with hydrological sciences are sparse, they demonstrate that an interdisciplinary approach can further understandings of how power and the non-human co-constitute the social world and hydrological flows and advance conceptualizations of water as socio-natures. In this perspective, hydrology can work to measure and reveal non-human axes of power as well as the power concealed in hydrological flows. Conversely, sociohydrology can be enriched by more complex understandings of human behavior and power asymmetries shaping uneven water flows. This, in first instance, entails unpacking the concept of society, which cannot be understood as “undifferentiated whole” [104] (p. 595). Further, an interdisciplinary resource geography could address scientific questions that are relevant to both disciplinary perspectives. Scientific problems that combine political economy of water and hydrological change, for instance, could focus on the distinctive hydrological flows (and uneven distribution of risks thereof) produced through capitalist processes in the Anthropocene. These collaborations are likely to place geographers in a less favorable position to critically examine the role of hydrological science and its contribution to development policies (see [28,29]). On the other hand, transcending disciplinary boundaries provides an opportunity to develop research that

speaks to a wider audience. After all, governments and practitioners in the water sector mostly rely on water quality and resources assessment for policy making. Translating inequalities to the mainstream language of numbers and their visualizations may be more appealing to decision makers and, in turn, could have positive implications in terms of communication of research results and political transformation.

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