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The Pluralistic Water Research Concept: A New Human-Water System Research Approach

Mariele Evers [1,*], Britta Höllermann [1], Adrian Delos Santos Almoradie [1], Glenda Garcia Santos [2] and Linda Taft [1]

[1] Department of Geography, University of Bonn, Meckenheimer Allee166, 53115 Bonn, Germany; bhoellermann@uni-bonn.de (B.H.); adrian.almoradie@uni-bonn.de (A.D.S.A.); ltaft@uni-bonn.de (L.T.)
[2] Department of Geography and Regional Studies, Alpen-Adria-University Klagenfurt, Universitätsstrasse 65-67, 9020 Klagenfurt, Austria; Glenda.GarciaSantos@aau.at
* Correspondence: mariele.evers@uni-bonn.de; Tel.: +49-0228-73-3526

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Abstract: The use and management of water systems is influenced by a number of factors, such as economic growth, global change (e.g., urbanization, hydrological-climatic changes), politics, history and culture. Despite noteworthy efforts to develop integrative approaches to analyze water-related problems, human-water research remains a major challenge for scholars and decision makers due to the increasing complexity of human and water systems interactions. Although existing concepts try to integrate the social and water dimensions, they usually have a disciplinary starting point and perspective, which can represent an obstacle to true integration in human-water research. Hence, a pluralistic approach is required to better understand the interactions between human and water systems. This paper discusses prominent human-water concepts (Integrated Water Resources Management (IWRM), socio-hydrology, and political ecology/hydrosocial approach) and presents a newly developed concept termed pluralistic water research (PWR). This is not only a pluralistic but also an integrative and interdisciplinary approach which aims to coherently and comprehensively integrate human-water dimensions. The different concepts are illustrated in a synopsis, and diverse framing of research questions are exemplified. The PWR concept integrates physical and social sciences, which enables a comprehensive analysis of human-water interactions and relations. This can lead to a better understanding of water-related issues and potentially sustainable trajectories.

Keywords: human-water research; socio-hydrology; pluralistic approach; conceptual model

1. Introduction

Sustainable water resource management has been and still is a major challenge for decision makers, even though integrative approaches and concepts have been developed to address problems related to floods, droughts, water quality, environment and ecology [1–3]. Part of this complexity arises from the fact that the interactions between human and water systems have become increasingly complex with the growth of population and urbanization, which modifies the demand for water resources. Furthermore, the use and management of a water system is influenced by a number of factors such as economic growth, urbanization, land-use change, hydrological-climatic changes, technological advances, history, political and, to some extent, traditional practices based on religious and cultural beliefs and attitudes. Water-related problems are, thus, interlinked, and solvable only by interactions among diverse scientific disciplines [4]. The use of water resources for households, industry and agriculture, mitigating the impact of floods and the preservation of ecosystems are some of many examples of the way humans and water systems are highly interlinked and intertwined.

Hence, understanding the co-evolution or interaction of human-water systems and its social dimensions is essential to effectively tackle the shortcomings in sustainable water management. In this context, several research concepts (e.g., Integrated Water Resources Management (IWRM), socio-hydrology, and the political ecology/hydrosocial approach) have been developed; these have their roots in a variety of disciplines such as hydrology, engineering, social sciences, and geography. Each of these concepts not only has a different thematic or systematic focus, they are also based on distinct understandings which arise mainly from different epistemologies, ontologies, methodologies, and axiologies [5]. Thus, they differ significantly in their goal, their disciplinary background, their applicability, the temporal and spatial scale addressed, and their conceptualization of water and human systems.

The value of human-water-research concepts such as socio-hydrology and hydrosocial analysis, as well as the potentials of conceptual models for water-related research, has been discussed in detail by several authors [5–8]. Nevertheless, although these concepts represent integrative approaches to water-related problems and, to some extent, include or involve society in planning and management, they still lack some vital components of the social dimensions needed to understand the coevolution or interaction of human and water systems. For instance, economic, technological and political aspects, as well as feedback mechanisms, are often neglected [6]. Moreover, the existing concepts usually have a tendency to favor a single epistemological and disciplinary perspective, which can represent an obstacle to true integration in human-water research. Hence, a pluralistic perspective is required for enhancing our understanding of the interactions between human and water systems [9]. This need is emphasized by Wesselink et al. [5], who highlights the relevance of pluralistic perspectives and plural formulations during the problem definition stage.

This article aims to present and debate a conceptual model which could be used for including different paradigms, epistemologies, and methodologies in human-water-research from a pluralistic perspective. The paper discusses (1) existing human-water concepts such as the IWRM, socio-hydrology, and the political ecology/waterscape; (2) presents the newly developed concept termed pluralistic water research (PWR), which is not only a pluralistic but also an integrative and interdisciplinary approach aiming to coherently and comprehensively integrate the social and water dimensions; (3) shows differences in perspectives on humans, water and its integration in a synopsis; (4) illustrates the central idea of the concept by framing different research questions, respectively, in relation to the discussed concepts; and (5) resumes the benefits of the PRW in human-water research.

2. Reflections on Human-Water Research Concepts

In this section, we describe three prominent human-water concepts (IWRM, socio-hydrology, and political ecology/waterscape) which were developed both on a scientific and/or political level to aid the analysis of water-related problems. We aim to show how educational background and way of thinking shape the perspective of the agents of the human-water system, drive research questions, and present only one of many views on the research subject. The concepts are discussed in the scientific discourse with regard to the extent to which they are able to integrate physical and human dimensions.

2.1. Integrated Water Resources Management (IWRM)—A Political and Management Concept

The Integrated Water Resources Management (IWRM) concept has become well known as a conceptual approach to the complex problems of water management. It was originally promoted in the political arena, but today it is also acknowledged, applied and discussed in science [10,11]. According to the definition of the Global Water Partnership, IWRM can be understood as “a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” [12]. Although this definition provides a general understanding of IWRM, it is not tangible enough to tackle concrete water management problems [13]. IWRM is often regarded as the only possible solution to water management challenges [14]. However, this status needs to be considered carefully: undoubtedly, the IWRM approach bears significant potential for dealing with water management problems successfully and in a sustainable way, but the vagueness of the concept itself, as well as problems in its implementation, raise questions about its usability and benefits [13,15,16]. Furthermore, it also entails the danger of free-riding because it is not tangible enough for water management to tackle concrete water management problems [13].

The application of IWRM to the specific local conditions has gained significance in recent years [17–19]. In order to reduce the operationalization and implementation deficits of IWRM a "light approach" is recommended [16], which is applied locally, encourages intra-sectoral integration, and builds on existing institutions and participation mechanisms. A further criticism of IWRM is the integration, as there is no consensus on fundamental issues such as what aspects should be integrated how and by whom, or even if such integration in a wider sense is possible [13]. With regard to human-water research, we see the most interesting aspects of IWRM in the discussion on how integration should be carried out, and on what aspects should be considered for integration. In this context, the integration axes suggested by Cardwell et al. [20] seem to be of substantial relevance (1) goal objective integration, which relates to the harmonization of management activities to achieve optimized objectives in a variety of fields (e.g., flood control, water supply, recreation); (2) spatial integration, which relates to both geographical space and the vertical stratification of space; (3) institutional integration, which refers to the coordination of several organizations to achieve common objectives; and (4) temporal integration to establish appropriate timescales for the planned management measures.

2.2. Socio-Hydrology as a Natural Science and Engineering Concept Including Social Aspects

One approach that attempts to include the human dimension or social aspects in water research and tackles the holistic integration of the socioeconomic and environmental facets of hydrology is socio-hydrology. Socio-hydrology is an emerging field that aims to observe, understand and predict the future co-evolution of coupled human water-systems, and to address sustainability problems through the integration of existing scientific theories and methods, while at the same time creating new knowledge and understanding of system dynamics [6,7,21–24].

The theoretical framework of socio-hydrology builds on the relationships among three crucial aspects: (1) multi-scale water system structures and dynamics; (2) water-related human outcomes (well-being); and (3) normative goals and values. This framework is intended to formalize the feedbacks between human and water systems in an explicit way to help us explain the past, understand the present, and illuminate sustainable possible future trajectories of their coevolution. All three aspects are closely linked and influenced by the extent of the uncertainties involved [21].

Following this concept, a number of studies have attempted to develop generic conceptual frameworks addressing different case studies. Van Emmerik et al. [25] focused on tailored case-specific coupled model formulations. Elshafei et al. [24] outlined a generic framework to examine the coupled dynamics of integrated agricultural socio-hydrology catchment systems to enable targeted policies and management strategies that promote sustainable water resource management. Sivapalan et al. [22] proposed socio-hydrology as a use-inspired scientific discipline to study real-world systems across gradients of climate, socioeconomic status, ecological degradation and human management. More recently, Binder et al. [26] proposed the first spatially explicit coupled behavioral, hydrological and fate-of-pesticide model able to consider the impact of farmers training policies at the catchment level. Mount et al. [27] synthesized opportunities and challenges that socio-hydrology presents for data-driven modelling adaptation and community learning are implemented through the behavioral model. Van Emmerik et al. [26] investigated the irrigation in the Murrumbidgee River system in Australia and analyzed the interrelationship in the use of water resource from downstream to upstream. Baldassarre et al. [6] looked into understanding human-flood interaction in the flood plain by investigating the "levee effect".

These examples illustrate the complex and interlinked nature of interactions within human-water systems, such as: (1) the migration and resettlement of populations from flood risk areas for which decisions are heavily influenced not only by hazard or risk, but also, for example, by economic activities, opportunities and politics; and (2) the resilience of the system (stability and threshold behavior from one state to another and the magnitude of the feedbacks), time scales and lags, and the degree of adaptation and learning of the human system.

Although socio-hydrology somehow captures the typical patterns of human-water interactions, there remain a number of shortcomings that need to be addressed when integrating social systems into hydrological models. The socio-hydrology community still struggles to formalize realistic hypotheses which are capable of capturing the basic driving mechanisms of the dynamic human-water system, as, for example, the societal values and experiences with flooding may lead to divergent policy responses [7]. Troy et al. [7] doubt the correctness of the two-way feedbacks between human and water systems without acknowledging that these feedbacks are embedded in a complex web of cause and effect represented by socio-ecologic systems; they suggest that interactions are multifaceted, difficult to isolate, variable from system to system and nested in terms of both spatial and temporal scales. In this regard, Pande and Sivapalan [8] highlight the need to extend socio-hydrology to explore phenomena in space and in space-time, as the world becomes increasingly globalized and human-water systems become highly interconnected.

Another criticism is that current socio-hydrology approaches neglect potentially significant aspects related to the heterogeneity of human societies (e.g., some population groups have fewer resources than others) [6]. Also, according to Seidl and Barthel [28], socio-hydrology is dominated by hydrologists, who have adopted a perceived hegemonic attitude toward interdisciplinary collaboration with social scientists. Challenges still remain in developing the socio-hydrological approach for different catchment conditions [21,25]. Grober et al. [23] suggested that there is a need for governance mechanisms to link science and policy to the socio-hydrology agenda.

2.3. Human Geography/Political Ecology Concepts: The Example of Waterscape as a Hydrosocial Perspective

In contrast to the socio-hydrology concept, social aspects and the human dimension are a central part of the human geography and political ecology perspective. This viewpoint studies the impacts of social interactions with its social, political, economic and cultural power relations and its constitution within the hydrological system, thus broadening the view on human water related issues. Human geography and political ecology stress the importance of linking water to power, politics and governance in order to analyze human-water/human-environment relations [29]. From a social science perspective, political ecology tries to understand failures in approaches to minimizing environmental degradation by asking new questions such as "what enables, encourages or compels people to mismanage their physical environment" [30]. In so doing, scholars from this field highlight a new dimension in environmental problems by engaging thinking and methods from multiple social sciences such as anthropology, sociology, and political science and providing or reorganizing a framework in which the discourse on the subjects and objects of natural and social sciences are renegotiated [31].

Social and political processes on all spatial scales provide the grounds for environmental problems within this politicized environment. Here, unequal power relations among actors and the subsequent inequalities (e.g., political, economic, and social), which control access to resources are resembled within the physical environment (e.g., dams and reservoirs). Analyzing the history of power asymmetries, discourses, perception and knowledge of environmental and human-water processes fosters a deconstruction and reconstruction of current practices [32].

In line with this thinking, Swyngedouw [33] applied this perspective to analyze the human water/society water relations in Spain from 1890 to 1930. He proposed the term "Waterscape" to describe the hybrid character of the socio-natural landscape, where power relations and practices co-produce a socio-natural space. This historical and on-going production concerns the social content and the physical-environmental qualities [34]. The Waterscape is not only another scale, but a constituted "socio-spatial configuration". Thus, Budds and Hinojosa [35] question the spatial approach of water governance because the focus on the watershed may, for example, omit aspects of social and economic life and does not reflect the multi-scalar processes of the co-production of Waterscapes.

Focusing on the processes enables an understanding of the co-production rather than simply analyzing the way how social aspects affect the physical environment, and vice versa [29,36].

By using this line of research on human-water interaction and the waterscape, the term "hydrosocial" became popular more recently to describe the research focus of this community [5]. Hence, to sum up, the human geography/political ecology/hydrosocial research perspective (1) helps to understand that changes in the socio-hydrological systems are closely related to power asymmetries; (2) acknowledges the impact of the discourse on water management strategies; and (3) highlights the contested and contestable political organization of the hydrological cycle [34]. Furthermore, focusing on the socio-hydrological processes of co-production offers a new perspective on the scales to consider.

We therefore conclude that a pluralistic research approach to human-water relations benefits the holistic understanding of this complex system. The value of such an approach is discussed in the following.

2.4. The Need for a Pluralistic Research Approach to Incorporate Human-Water Relations

The scientific discipline of geography considers multiple possible interpretations, alternative framings of the status quo, possible development paths and potentially desirable futures. It is, hence, more than an integrated understanding of the relationship between society and the environment, where the human response to environmental change is determined and projected by using agent-based, behavior or green economy models [37]. The acknowledgement of multi-spatial perspectives of different actors and entities, and their incorporation into the physical system requires the integration of natural and social science concepts, theories and methods [38,39].

Nevertheless, the integration of physical and social sciences is challenging with regard to the different epistemologies and perspectives involved: the positivist thinking common in the natural sciences and engineering, and the constructivist conceptualization common in the social sciences. Here, space and time are key factors to understand human-water interactions. The spatial and temporal delimitation of, for example, flooding areas, follows a positivist approach [38], which is supported by the modelling of the processes, their feedbacks, and interactions across scales with regard to vulnerabilities and responses to perturbations. This approach thus provides valuable and fundamental information for decision-making [40]. However, flooding area is also a social construct based on regulations based on norms and values, and hence is negotiated as a result of socio-political and engineering discourses [38]. Thus, the perspective on the hydrologic cycle differs with respect to the disciplines. Even though there is a growing body of literature on human-water relations from a human geography and political ecology perspective (see Section 2.3) and a number of contributions on socio-hydrology by engineers and hydrologists (see Section 2.2) aware of the need to integrate humans into the water cycle, these two lines of research do not cross. Nevertheless, mutual recognition and acknowledgement of the different epistemologies, concepts, methods and knowledges produced could foster a true integration of the disciplines [41] in a relational sense [42].

The advantages of a pluralistic research environment, where the findings are discussed in relation to one another are highlighted by several authors [9,43]. The PWR concept elaborated in the following sections draws on this pluralistic view. This concept aims for a more comprehensive analysis and understanding of human-water interactions and encourages interdisciplinary work.

3. The Pluralistic Water Research (PWR) Concept

As discussed previously, the integration of physical and social sciences with their different epistemologies and perspectives is crucial from a pluralistic point of view. The central challenge is to integrate the different schools and approaches used in these fields. Hence, the major shortcoming in the described human-water concepts is that they either do not consider both schools or do not explicitly support the integration of both. To fill this gap, the aim of our PWR concept is to enable the integration of physical and social sciences in water-related research. This integration goes beyond the approach of natural and/or engineering scientists to apply practices and techniques from the social sciences as described in Lund [44]. We intend to engage the perspective of both sciences in a discourse on water-related issues where reciprocal learning is a key component.

The PWR concept basically refers to sources and users of water as the core agents of human water relations (Figure 1). Sources of water are, for example, rivers, reservoirs, groundwater, and users of water are humans and their demands on agriculture, energy production, and minimum ecological flow requirements, to name just a few. The interactions among and between sources and users of water are shaped by external influencing factors called boundary conditions (e.g., climate change, cultural values) [45]. These conditions provide the setting for analysing water-related issues, which thus involves not only physical space, but also the interaction of actors and entities [40]. We call this setting human-hydro-scape, where sources shape, produce and/or co-produce users, and vice versa. The term human-hydro-scape implies the relevance of human and natural influencing factors and processes in a certain space or landscape. It is defined by reciprocal physical and human boundary conditions which enable the analysis of multiple meanings and alternative framings.

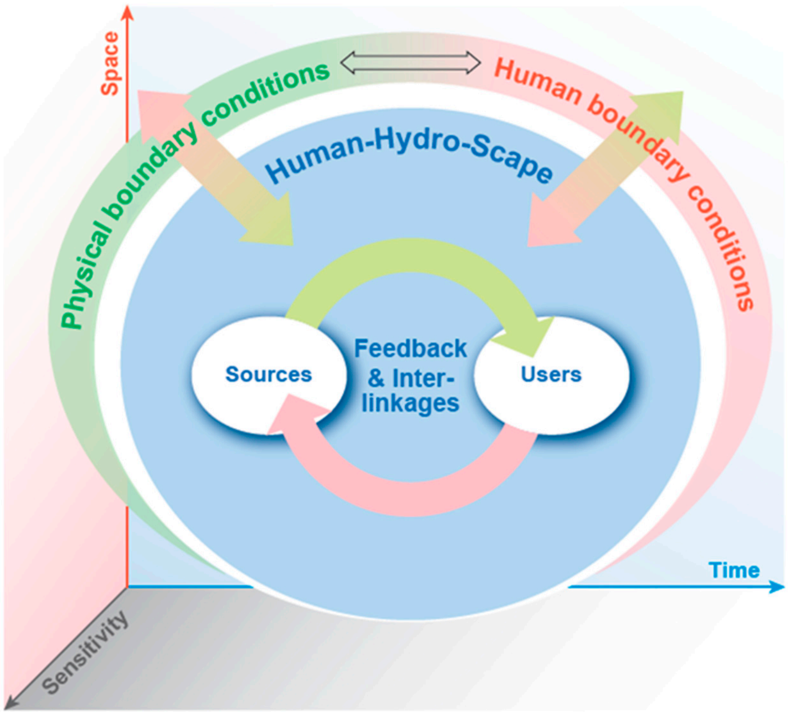

Figure 1. Conceptual model of the Pluralistic Water Research (PWR) concept. Within this framework, sources of water are, for example, rivers, reservoirs or groundwater, while users are humans and their demands. The sources and users are shaped by reciprocal physical and human boundary conditions, in a setting called human-hydro-scape. Space, time and sensitivity are regarded as key factors in human-water interactions and processes of feedback and interlinkages. Figure developed by the authors.

Space and time are two key factors in human-water interactions, and the PWR approach presents a multi-spatial perspective on water and its projection into space. IWRM and socio-hydrology consider the hydrological catchment as the main unit for analysis and management in contrast to the human geography/political ecology approach, where other units such for example a community are possible units. In another perspective, Pahl-Wostl et al. [46] see water as a key structuring element for landscape management. Hence, from the PWR perspective, it is important to understand current landscape patterns by integrating the developments and interrelations of these patterns into human-water research. The setting where these patterns and processes are revealed is the landscape [40]. However, landscapes characterized by water are not just "there", but constructed and (re-)produced. Kasala and Sifta [47] explain the history and development of constructivist views on regions. Wardenga [48] is applying the constructivist approach to landscapes. For her, the landscape is not only a container with different related elements, but also a system of positional (topological) relationships of material objects, with the emphasis on the importance of locations, location relations and distances for the creation of social realities. Furthermore, landscapes can be seen as a category of sensory perception and, therefore, as "forms of intuition" that help individuals and institutions classify their perception and differentiate in space. Lastly, landscapes can be interpreted in the perspective of their social, technical and political constructiveness by asking who and under what conditions and for what interests they are continuously produced by everyday actions and reproduced. Thus, the PWR concept regards landscape as an important reflection level and considers the socio-natural processes within the human-hydro-scape.

Furthermore, the PWR concept pays special attention to the sensitivity of the human-hydro- scape by looking at the processes of feedback and interlinkages between users and sources. By regarding the degree of feedback loops, it is possible to detect sensitive system and process parameters which may be time and/or space dependent (e.g., temperature, precipitation or groundwater extraction). Identifying these parameters enables the emergence of sets of multiple framings and possible development paths. The PWR concept accepts that different possible development paths and potentially desirable futures exist. We argue that—in contrast to the suggested principle of optimality or entropy [6,21]—the search for one solution or best practice does not serve the purpose of integrating the human-water system as there is no single best answer [40], and the human dimension is also guided by perceptions, preferences, benefits and costs governing actions, and reactions.

The PWR concept with its human-hydro-scape and physical and human boundary conditions enables the integration of knowledge from both natural and social sciences by acknowledging their different epistemologies, concepts and methods. PWR thus provides ground for and fosters true integration of the disciplines in a discursive manner. It highlights the co-production of the human-hydro-scape and its socio-natural processes, and acknowledges the multiple meanings and alternative framings of the status quo and the history of water-related issues. At the core of the PWR concept is the exploration of the human-hydro-scape by asking research questions from different disciplinary and transdisciplinary perspectives, thereby allowing and fostering multiple sets of answers. These allow for broader discourse on research results, embedding one's own human-hydro-scape results within the holistic understanding of the human-hydro-scape and pushing limits in disciplinary thinking by cross-stimulation of knowledge and ideas.

4. Framing Research Questions by Different Perspectives

The range of concepts described and discussed in Section 2 revealed different perspectives and understandings of human-water research. Table 1 gives an overview of these concepts, focusing on the perspectives taken with regards to humans and water, and their view concerning human-water interactions.

Table 1. Human-water concepts and their perspective on humans, water and interactions between the two.

	IWRM	Socio-Hydrology	Political Ecology/Waterscapes	PWR
Perspective on HUMANS	• Anthropocentric approach • Sees humans as users who want to maximize economic and social welfare	• Water-related human outcomes (well-being) influenced by norms and values in using and understanding the water source	• Social aspects and human dimension are central to the study perspective • Social interactions and power relations are key issues	• Humans are water users who are embedded in a human-hydro-scape which is influenced by human and physical boundary conditions
Perspective on WATER	• Water is a resource which should be managed for the needs of human beings with respect to environmental conditions and sustainability	• Human-modified multi-scale water system structures and dynamics • Water use and management are influenced by the users' culture, norms and values	• Unequal power relations and inequalities are mirrored within the hydrological system	• Water is a source embedded in a human-hydro-scape. Its quantity, quality, availability and accessibility are re-shaped and influenced by human and physical boundary conditions
Perspective on INTERACTION	• Focuses on the sustainable interaction between different users (people, agriculture, nature, industry) and their water demands • Promotes a coordinated development and management of resources by enabling environment, institutionalising and implementing management instruments • The integration of interacting sectors is a key factor • Interaction builds on ecology, efficiency and equity	• Explains and understands the co-evolution (the two-way feedback) of the human and water systems with their observable feedbacks, relationships and driving mechanism in the past, present and future • Models the interaction by using mathematical and optimization models	• Strong focus on how power asymmetries, discourse, perception and knowledge of water and/or human-water processes constitute practices and foster de- and re-construction of practices • Reflection on the process of co-production of social "content" and physical-environmental qualities rather than impact study on how social aspects affect physical environment and vice versa	• Space, time and feedback loops are key factors to understand interactions • Analysis of interactions, feedbacks and external influencing factors between and within the physical space and the human system with its arena of interacting actors and entities • Reciprocal acknowledgement of human and physical boundary conditions allows integration of knowledge, epistemologies and concepts from natural and social sciences

The synopsis in Table 1 shows that the disciplinary background (natural sciences and social sciences) and research focus (problem—vs. solution-based or problem—and solution-based) of the IWRM, Socio-Hydrology and Waterscape approaches distinguish their view on the role of humans, water and their interaction; it also shows overlapping aspects. One general common aspect is that humans are part of the system and agents that contribute to the state of the system. However, their role is assessed differently depending on whether they are exploiting water resources, interacting with the water resources system, or humans constituting practices and fostering deconstruction and reconstruction of practices of the water system.

Researchers from the different schools stay focused in their disciplinary thinking, for example, for socio-hydrology, mathematics and optimizing is key for formalizing interactions, whereas waterscape focuses on the re- and co-constitution of practices of different groups of society, attaching minor importance to the physical system itself. By contrasting the three existing approaches, we can show how educational background (political sciences, engineering, and geography) and way of thinking shapes the perspective on the agents in the human-water system, and presents only one of many views on the research subject. Furthermore, it becomes clear that human-water relations are embedded in a complex system and a holistic understanding of this system requires the acknowledgement of a plurality of perspectives.

In order to illustrate the different perspectives of the concepts, Table 2 shows how potential research questions could be formulated for water-related problems. For this purpose, we use a fictive research project on the impact of global change on water availability in a certain region X which suffers already temporarily under water scarcity.

Table 2. Possible guiding research questions for a fictive project on the impact of changes on water availability.

Concept	Possible Questions
IWRM	How can management and governance structures be adapted to decreased water availability? How can vertical and horizontal integration be realized to optimize water management and meet the goal of xy liters/day of water supply? What should be integrated, why and how? What indicators are suitable to evaluate current state/measures/success?
Socio-Hydrology	What are the most important driving mechanisms of human-water interactions that could impact the future trajectory of the system? How could the human-water-interaction be optimized to human behavior in order to meet a certain level of distributed water/water availability?
Political Ecology/Waterscape	Which social aspects, agents and knowledge are mirrored in current management practices and the state of the physical system? How are practices constituted? What factors influence and (re)shape the co-production of social "content" and hydrological system? How did the power asymmetries changed in time in response to decreasing water availability?
PWR	How is the human-hydro-scape constructed by reciprocal boundary conditions? Which values and norms or mechanism or group of agents are relevant? What are key system elements, sensitive control variables and feedback loops? Which potential set of factors and/or agents led to the current situation? What are desirable futures and whose future?

To answer these questions, natural scientific and quantitative methods could be used as well as social scientific and qualitative methods. Both approaches are needed to describe the reciprocal boundary conditions which created and create the human-water-scape. Prominent analysis steps are to identify the relevance and role of time and space and the key factors of the system in order to identify sensitivity elements.

With the PWR concept, we make use of these perspectives by proposing an interdisciplinary framework: the human-hydro-scape. Within this framework, researchers from different disciplines can approach their research subject with the premise that they acknowledge the reciprocal physical and human boundary conditions. This leads to an emergence of different sets of frames, which can link social sciences with hydrology and can provide a holistic description of the past, present and future human-water systems. These sets also allow for broader discourse on research results, embedding scientists' own research results within the holistic understanding of the human-hydro- scape and pushing limits in disciplinary thinking by cross-stimulation of knowledge and ideas.

PWR does not see people as objects linked to water nor does it seek for optimization. The PWR concept allows for the inclusion of people's norms and values as boundary conditions and of uncertainty in people's behavior in space and time. The PWR concept could also be used as a framework for participatory or transdisciplinary research as described by Krueger et al. [49] to co-produce water knowledge. The validity of our assumptions should be further explored via comparative analysis of diverse case studies, across scales, levels of human impact and different cultures.

5. Conclusions

We observed that different understanding, approaches and concepts in human-water-research such as socio-hydrology or waterscapes normally do not cross, although it could be fruitful to integrate the pluralistic perspectives and plural formulations of problem definition. Thus, we propose the PWR conceptual model which allows co-existence and combination without neglecting the respective epistemologies, ontologies and methodologies. The PWR concept helps human-water research in that it identifies key elements and sensitivity in the system by looking at interactions and feedback loops of system elements in space and time. This would give scholars and decision makers a better understanding of the way the system functioned in the past and functions now that could provide the basis for future planning or mitigation. In so doing, PWR integrates physical and socially constructed space and the arena of actors and entities interacting. It also looks at the processes to better understand the co-production (human-hydro-scapes) of the system, and is defined by reciprocal boundary conditions which enable the integration of knowledge from both the natural and social sciences by acknowledging their different epistemologies, concepts and methods. Moreover, by considering uncertainties, the approach allows for alternative framings of manifold potentially desirable futures.

Thus, the PWR provides an integrative framing which will enable a more comprehensive analysis and understanding of human-water interactions and relations that could lead to better understanding of water-related issues and potentially sustainable trajectories. The conceptual PWR model can include approaches both from positivistic approaches as socio-hydrology, as well as constructivism approaches such as hydrosocial analysis and the waterscape concept.

The PWR concept can provide support for inter- and transdisciplinary research, as well as for social learning as defined by Reed et al. [50]: "a change in understanding that goes beyond the individual to become situated within social units or communities of practice through social interactions between actors within social networks".

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