XXIII SIMPÓSIO BRASILEIRO DE RECURSOS HIDRÍCOS

WHY SHOULD BRAZILIAN RESEARCHERS JOIN SOCIO-HYDROLOGICAL RESEARCH OPPORTUNITIES?

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ABSTRACT– Socio-hydrological studies aim at unravelling coupled human-water feedbacks. It has gained attention by worldwide researchers since its first publication, in 2012. Although hydrological and social experts in water resources domain have published several relevant findings, the lack of Brazilian case studies and Brazilian researchers in this field is noteworthy. The aim of this manuscript is to ascertain if the absence of Brazilian contributions to high impact journals exists, identify what domains of water resources have been investigated by international and what gaps in the Brazilian context should be better understood. To do so, the present study performs a bibliometric study on previous socio-hydrological manuscripts and on-going Brazilian projects that focus on socio-hydrological analysis. The results reveal that investigators from South America are under-represented in socio-hydrological publications in international journals. We conclude that although the Brazilian scientists have put efforts to contribute to the development of socio-hydrology, more local case-studies can be explored and provide an important contribution to this emerging science.

KEY WORDS: Socio-hydrology; water security; coupled human-water systems; socio-hydrological observatory; water resources management.

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INTRODUCTION

Every society needs to provide water for food production, economic development, energy generation and human existence. Thus, this basic human need has also driven water resources research. The way that scientists and specifically hydrologists, have dealt with the scientific comprehension of transformations in water cycle ranges according to the technology available and also the trends in the scientific methods. For instance, at the very early stages of development of water science and engineering, ancient civilizations were concerned about having sufficient water for household supply and agricultural uses. In the modern era, scientists have addressed the concept of integrated water resources management to a more holistic governance of water, which aims at social equity, economic efficiency and ecosystem sustainability. However, global challenges and similarities of place-based water problems have brought scientists to rethink how humans are affecting the natural system and to make such interactions a focus of scientific analysis.

In the context of coupling anthropogenic activity to the bio-physical water cycle system, socio-hydrological scientists have addressed a number of problems to explore two-way feedbacks in these coupled systems. Initially, Sivapalan, Savenije, & Blöschl (2012) argue that this new science must consider human social and behavioral processes as equally important to traditional hydrological processes in water resources research in order to better understand interactions and feedbacks. However, Gober, White, Quay, Sampson, & Kirkwood (2017) note that this attempt to mix social and hydrological sciences is not new, but it had not included the knowledge transfer process so far. So, socio-hydrology research presented a relevant evolution over the last years (Konar, Garcia, Sanderson, Yu, & Sivapalan, 2018) and still should be explored in order to find generalized models across different study cases (Sivapalan & Blöschl, 2015).

Since the international science community has recognized socio-hydrology as a new and exciting field seeking to explore human-water dynamics, the aim of this paper is to verify in what way Brazilian researchers have explored and contributed to this research. To do so, we perform a bibliometric analysis to describe the national and international state-of-the-art in socio-hydrological research. In following sections, we present the results of our analysis, discuss what has been explored by national researchers, and what opportunities still can be explored.

METRICS OF SOCIO-HYDROLOGY AND BRAZILIAN PARTICIPATION IN SOCIO-HYDROLOGICAL RESEARCH

We performed a bibliometric research of the keywords “socio-hydrology”, “sociohydrology” and “socio-hydrological” in the Scopus database, which is considered the most extensive database

of peer-reviewed scientific publications (Elsevier, 2019) in order to analyze the metrics of publications related to socio-hydrology in international journals. Since the first socio-hydrological manuscript was released in 2012 (Sivapalan et al., 2012), we limited our research to works published after this year and we established the end of 2018 as our boundary for analysis.

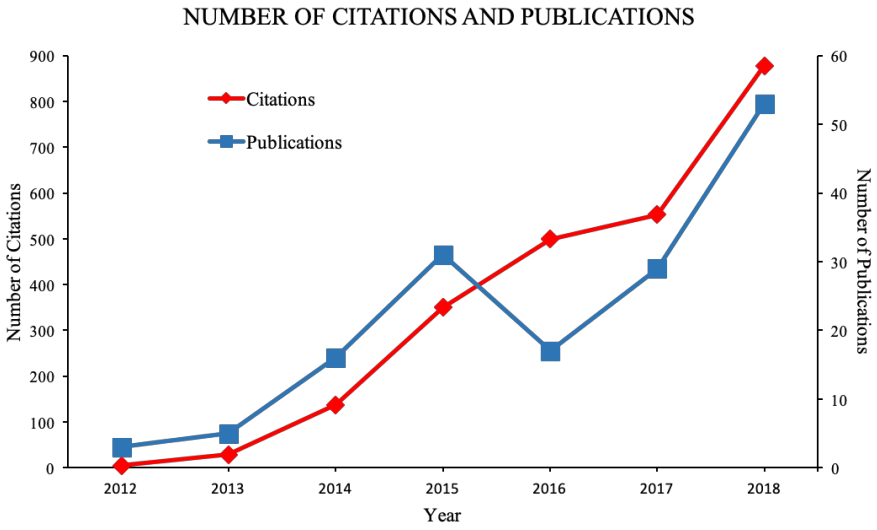

Figure 1: Number of citations and publications of socio-hydrological publications in the Scopus database from between years 2012 and 2018.

The bibliometric analysis revealed important aspects regarding the increase of socio-hydrological publications and their respective authorships. First, the annual number of publications showed substantial growth during the study period. The number of citations has also grown (Figure 1). Although the number of publications decreased between 2015 and 2016, the number of citations presented substantial growth over the time, what reveals that this science is becoming accepted and embraced by the scientific community and international funding agencies. Secondly, the left hand side of Figure 2 presents the number of publications for the keywords "socio-hydrology"; "sociohydrology" and "socio-hydrological", accordingly to authors' origin. Not surprisingly, the North American and European countries lead the number of publications on socio-hydrological research. However, the bibliometric analysis was able to find only one Brazilian publication associated with the aforementioned keywords (Neto, Scott, Lima, Montenegro, & Cirilo, 2014) and another Chilean publication (Hunter, Gironás, Bolster, & Karavitis, 2015).

This result reveals that South American researchers have a very limited participation on socio-hydrological research in comparison to other regions of the world. In order to check if local researchers are not only under engaged in socio-hydrological research, but also in water resources sciences, we performed another research on the keywords "hydrology", "water resources", "hydrological modeling" and "water management". The right-hand-side of Figure 2 shows that the performance of Brazilian researchers presented a considerably improvement in comparison to the

previous analysis. The position based on number of publication jumped from the 27th to the 12th position.

Some factors can explain such low participation. First, European and North American conferences on earth sciences and engineering research have offered the opportunity to discuss socio-hydrology development in dedicated sections almost every year since 2015, while the Brazilian Water Resources Association has not offered such an opportunity thus far. Adding to this, local funding agencies in those regions have been supporting projects, studies, workshops and scholarships under the socio-hydrology thematic field. Meanwhile, Brazilian researchers need to associate with other trending topics related to water resources in order to receive financial support, such as climate change, water security and water management. A first movement towards socio-hydrology research was taken in 2019 by the School of Advanced Studies of Water & Societies under Changed, funded by CAPES (see acknowledgments), whose main objective was offering the opportunity to Brazilian scientific community attend classes lead by foreign socio-hydrology researchers.

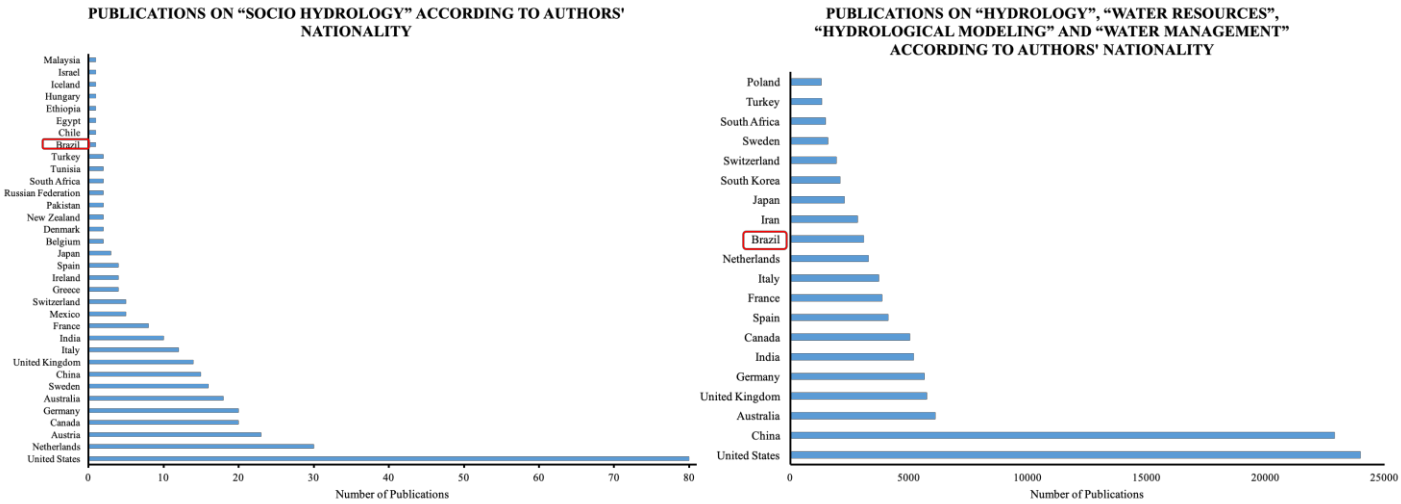

Figure 2: Number socio-hydrological publications according to researchers' affiliation in the Scopus database from 2012 to 2018.

In addition, our bibliometric analysis enabled us to map what fields those foreign socio-hydrologists are investigating based on the most frequent key words. Figure 3 illustrates the topics that have been explored more than ten times in international socio-hydrological studies. This reveals that studies focused on the comprehension of the dynamics involving flood events and societies have been explored very often. Indeed, these studies are frequently associated with mathematical modelling, which permits the translation of socio-hydrological variables into the humans' actions facing the risk of floods. Such mathematical models, or socio-hydrological modelling (Elshafei, Sivapalan, Tonts, & Hipsey, 2014), had their purposes and methodologies opportunities broadly discussed by Blair & Buytaert (2016). Those models were employed to understand the dynamics in

a range of water resources fields, such as water use in urban environments (Garcia, Portney, & Islam, 2016; Garcia, Islam, & Garcia, 2019; Klassert, Sigel, Gawel, & Klauer, 2015; Srinivasan, 2015; Srinivasan, Konar, & Sivapalan, 2017), drought propagation (Apurv, Sivapalan, & Cai, 2017; Kuil, Carr, Viglione, Prskawetz, & Blöschl, 2016), ground water exploitation (Apurv et al., 2017; Hund, Allen, Morillas, & Johnson, 2018), and engagement of stakeholders in decision making processes (Farjad, Pooyandeh, Gupta, & Motamedi, 2017; Flint, Jones, & Horsburgh, 2017; Haeffner, Jackson-Smith, & Flint, 2018; Wilson, Walter, & Waterhouse, 2015). The latter topic evoked social scientists' participation in socio-hydrology projects, which is one of the highlighted key word in Figure 3. Although Xu, Gober, Wheater, & Kajikawa (2018) argue that the participation of social scientists is still insufficient, traditional concepts from social sciences, such as demography, land use and economic indexes, have been supplemented by new ones, such as memories, norms, beliefs, awareness and institutions. This interdisciplinary approach represents an important step forward in water sciences because it permits a two way coupled understanding of how humans modify water in nature, and how they react to changes caused by nature and by their own activities at the same time.

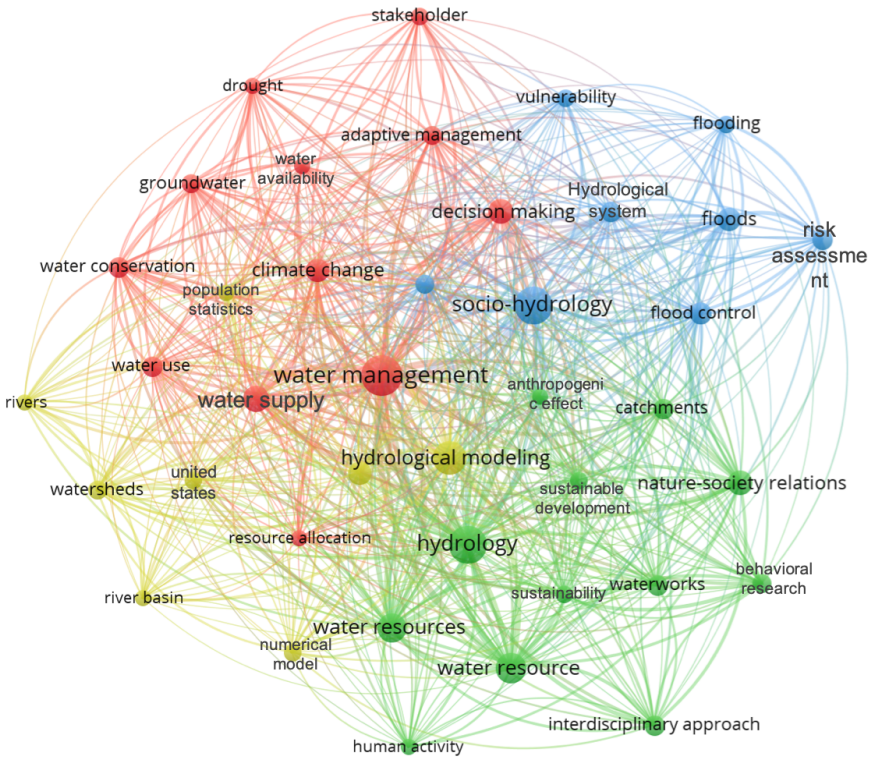

Figure 3: Co-occurrence matrix regarding the keywords associated to socio-hydrological research in the Scopus database. The colors classify the keywords that usually come up together.

SOCIO-HYDROLOGY IN BRAZIL

In Brazil, socio-hydrological research has reached the country, but at a lower intensity than internationally. Based on a search of the same keywords, "socio-hydrology", "sociohydrology" and

"socio-hydrological" on the Lattes platform -- a Brazilian database of national researchers -- we identified only three projects from national researchers that were inspired by previous socio-hydrological studies. The results of these projects have not yet been published because they are still being conducted or they were submitted to international journals, but they are under review.

The first case study, entitled Socio-Hydrological Observatory for Water Security combines the definitions of three scientific fields: Water Security, which is well known by hydrologists; Citizen Observatories, a procedure of acquiring data from tasks proposed to anonymous volunteers and; Socio-Hydrology, our emerging field. In this study, Souza (2019) aims at unravelling changes in projected water demand in the city of São Carlos. To do so, the author employs the Water Footprint Assessment (Hoekstra, Chapagain, Aldaya, & Mekonnen, 2011) in order to capture a more holistic comprehension of direct and indirect demands for water. The scenarios for years 2030 and 2050 are built by making a comparison between recommended values of individual's consumption, statistical analysis on time series and asking volunteers how they imagine that their patterns of individual and collective demands will change in the future. The results described in this work (Souza, 2019) reveal that São Carlos residents are aware of water insecurity risks, believe that their consumption will decrease in the future, and believe that local authorities will pay more attention to sanitation systems in the future.

The second study, entitled "Understanding Flood Risk and Enigma of Peoples' Memory: A Socio-Hydrological Learning at the Gregorio Creek, Brazil" (Sarmento, 2019), aims at analyzing the effects of social memories of floods in the flood risk variation over time. In this project, Sarmento (2019) analyzes the Gregório Creek Basin located in downtown of São Carlos city, in São Paulo state, a very urbanized region where commercial establishments are settled for many years and have always dealt with floods. The author uses flood depth data extracted from local newspaper articles as input to the socio-hydrological model developed by (Baldassarre et al., 2015) to understand the role of social memory in the context of flood risk and to propose measures for managing this risk.

The project entitled "Urban Water Supply Assessment in São Paulo Metropolitan Area by a Socio-Hydrological Model" (Souza, 2019) focuses on the analysis of time series of water availability, water consumption and initiatives to control domestic demands. This project is in its very early stages and aims at creating a socio-hydrological model to understand the effects of the recent collapse of the Cantareira Supply System on the local population. The authors aim to test if a rebound effect (Gonzales & Ajami, 2017) occurred in the region and to assess the effectiveness of policies promoting water conservation.

Table 01 – Some ongoing projects incorporating socio-hydrological concepts

Name of project	**Socio-hydrological Observatory for Water Security: Conceptualization and Study Case in São Carlos, Brazil**	**Understanding Flood Risk and Enigma of Peoples' Memory: A Social-Hydrological Learning at the Gregorio Creek, Brazil**	**Urban Water Supply Assessment in São Paulo Metropolitan Area by a Socio-Hydrological Model**
Purpose	Investigate future patterns of water demands	Understand the role of social memory of floods in the flood risk variation over time	Understand how households demands change accordingly to water availability
Spatial Scale	Municipal scale Scenarios for 2030 and 2050	Urban Basin	Urban and Peri-Urban Basin
Source of input data	Citizens' observation and official data sets	Local Newspaper Articles	Time series measured by governmental agencies
Results or Expected Results	Citizens indicate in what way they believe water consumption, solid waste production and investments on sanitation systems will change	Clarify the interaction between social memory and flood risk and identify non-structural measures that can be taken to reduce their risk	Verify how environmental awareness affects citizens consumption
Site of investigation	São Carlos city - SP	Gregório Creek Basin, São Carlos-SP	São Paulo Metropolitan Area - SP
Related projects	(Hoekstra et al., 2011; Srinivasan et al., 2017)	(Baldassarre et al., 2015)	(Elshafei et al., 2014; M. Garcia et al., 2016; Gonzales & Ajami, 2017)

FINAL REMARKS

The present discussion is a contribution to the *XXIII Simpósio Brasileiro de Recursos Hídricos* on the the-state-of-the-art of socio hydrological research. We aim to raise attention of Brazilian water scientists to the need for better understanding of the two-way coupled feedbacks within human-water systems. We showed that socio-hydrology is an emerging science that has gained worldwide attention, but national scientists still have low participation in socio-hydrology publications in comparison to other countries. Such comprehension on human-water systems can provide good insights and help societies to deal with traditional and interdisciplinary water resources challenges like groundwater, climate change, urban water supply, anthropogenic changes, water allocation and flood dynamics. However, the current national socio-hydrology research is concentrated in very few locations, while a wide variety of regions and problems must be investigated – many parts of Brazil will face complex and interesting water management challenges in the coming decades. For instance, the National Plan for Water Security released this year by the National Agency of Water (ANA, 2019) recognizes the need to integrate human, economic, ecosystem and resilience dimension to tackle water insecurity. The arid and semiarid ecosystems of northeast region comprise very complex dynamics as a consequence of drought propagation. Meanwhile, the increasing number of multiple water uses in the north region is continuously growing. The mid-west region is responsible for exporting a huge volume of virtual water and has a potential and yet under explored human-water system, where the Pantanal region pushes local citizens to immigrate to dry regions every year. In addition, water quality related problems are also challenging within the country, mainly regarding anthropogenic influence. Although the south and south-east regions have been well explored in terms of hydrological monitoring, the imminent effects of climate change and the evolution of local institutions are some fields that will require scientists to provide in depth analysis and, consequently, solutions. Finally, we argue that all these sites are some examples of opportunities for Brazilian scientists to provide local communities better solutions to global challenges, inspired in international experiences and innovative socio-hydrological solutions.

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