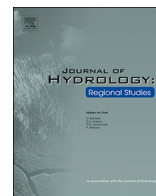


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Editorial for the Special Issue on the International Shared Aquifer Resources Assessment and Management



ABSTRACT

Transboundary water systems, which include interlinked river basins, lakes and aquifers, do not respect jurisdictional boundaries and many of them extend over more than one country. Management of these aquifers in fragmented ways may affect sustainable development within and beyond a country's borders and this requires an integrated water resource management approach. The importance of transboundary water was initially recognized under the 'Convention on the protection and use of transboundary watercourses and international lakes (Helsinki, 1992)', a legal framework for transboundary water cooperation worldwide, globally available since 2003. The global assessment of Transboundary Water Assessment Programme (TWAP) was developed by the UNESCO's International Hydrology Program, and a conceptual framework for transboundary aquifers (TBA) assessment was developed by UNESCO-IHP and the International Association of Hydrogeologists (IAH) in 2002 describing the major issues of concern and the priorities for supporting the conservation of TBA systems. As a result, the International Shared Aquifer Resources Management (ISARM) initiative was launched globally in 2002. Here we summarize key findings from 11 papers, most of which were selected by invitation to prepare this special issue on the International Shared Aquifer Resources Assessment and Management from four continents: Africa, America, Asia and Europe.

Introduction

At present, 592 TBAs of different sizes have been identified in the Americas, Africa, Asia, and Europe. Existing scientific knowledge, water conflicts and level of cooperation, including the role of the different actors involved, varies from region to region. Most regional differences can be related to the relative importance of shared aquifer exploitation within the available water resources together with existing signed bilateral or multilateral agreements among the countries sharing the specific TBA.

The current state of knowledge on transboundary aquifers remains limited in comparison with other water systems (UNESCO-IHP and UNEP, 2016). Among the questions that still need to be addressed we identify the following: characterization/delineation of transboundary aquifers, ecosystems dependency, time-dependent indicators development, data harmonization and information sharing and management, and water use conflicts or impacts of global change in the systems. Answering these questions requires a concerted effort of all partners involved to establish a satisfactory balance between scientific knowledge and efficient management and protection of transboundary waters.

Why this special issue on transboundary aquifers?

This special issue is a global contribution to the development of knowledge on transboundary aquifers over the past fifteen years; it includes 11 contributions covering a broad spectrum of topics from global to local issues focusing in a number of case studies. The papers derive from North and South America, Europe, Asia and Africa, covering:

- Legal aspects, policy, governance and assessment of existing agreements;
- Development and cooperation for sustainable development;
- Science-policy interface for transboundary aquifers assessment and management;
- Importance of social, economic, political responses and environmental aspects for assessments; and
- Emerging and priority issues: drivers, pressures and hotspots.

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Contributions in this Special Issue

Global Issues

The first paper by [Rivera and Candela \(2018\)](#) highlights the main outputs and outcomes of the Internationally Shared Aquifer Resources Management Initiative (ISARM, 2000-2015) of UNESCO/IAH at the global scale. It discusses the lessons learned, what is still relevant in ISARM and what is considered irrelevant and why. A discussion follows on the looming scenarios and next steps following the awareness on transboundary aquifers as identified by ISARM. In short, [Rivera and Candela \(2018\)](#) list a series of outputs and outcomes mostly dealing with regional strategies, alliances and creation of trust among the countries sharing the aquifers. They further describe the value and application of the Draft Articles adopted by UNGA on TBAs and conclude that there is no political will to establish international laws, as well as the concerns of some countries about having to cede riparian rights. The authors summarize the lessons learned and the issues that are still looming in four points: incomplete or contradictory knowledge on TBAs; large number of stakeholders and opinions involved; large economic burden for some countries; and the interconnected nature of these problems with other problems, concluding that groundwater science *alone* cannot solve transboundary groundwater issues.

The second paper, by [Burchi \(2018\)](#), summarizes globally the existing agreements on transboundary aquifers prior to ISARM, as well as those following the ISARM experience. Keeping the international law in perspective, Burchi discusses a few of the TBAs agreements that existed before ISARM, or prepared following the ISARM and/or the UN-A/RES/63/124 in depth. One important aspect covered by Burchi refers to *agreements* on TBAs as a result of ISARM, or existing agreements previous to ISARM, and whether they fit with the ISARM philosophy and the UN Resolution on TBAs, as well as where agreements are missing. Burchi goes on with an open discussion on existing legislation on groundwater and aquifers, whether transboundary or not, suggesting how it may be applicable (or not, and why not) to transboundary aquifers. The author concludes that the link of ISARM to other international aquifer agreements on record is tenuous, and ISARM's influence on their generation speculative; furthermore, he believes that the visibility of ISARM has faded since 2012; however its legacy is lasting.

The African Continent

Papers 3 and 4 discuss TBAs in the African continent. The paper by [Nijsten et al. \(2018\)](#) provides a synthesis of the current state of knowledge and progress towards further development and sustainable management. The authors report seventy-two TBAs identified in Africa, underlying 40% of the continent, where 33% of the population lives often in arid or semi-arid regions. TBA inventories progressed since 2000; today it remains work in progress. Work on the transboundary aquifers of Africa has leveraged cooperation on groundwater more broadly between aquifer-sharing countries and at regional levels, creating incipient frameworks for broader collaboration on aquifer management. The transboundary nature of the shared resources, which receives augmented international attention, potentially increases national emphasis on groundwater resource management, which could improve the overall management of groundwater in Africa.

[Fraser et al., \(2018\)](#) present the Malawi case study. The paper of Fraser et al. presents the current assessment framework, as an example within the Southern African region where important arid and semiarid areas exist and natural recharge may be low. The work emphasizes the critical aspects of defining conceptual models and delineating aquifers at the national and/or regional scales for management purposes, versus the importance of local small transboundary aquifers. Generally, these types of aquifers are not considered in the definition of conceptual models due to their limited thickness and extension, but are of great importance for small communities along the borders of countries sharing the aquifers. Protocols and policy instruments on shared water resources exist in the region, but no legally binding agreements exist between Malawi and its neighboring countries sharing the TBA.

The Americas

Papers 5 to 7 cover case studies in South America and in North America. [Sindico et al. \(2018\)](#) discuss the Guarani Aquifer System and how it became a “question mark” in terms of its management and governance for 15 years, from being a Beacon of hope when the many scientific, social and political activities were first launched in the Guarani Aquifer Agreement (GAA) in 2010. The Guarani Aquifer, shared by Argentina, Brazil, Paraguay and Uruguay, is one of the largest of the world. Most of the pumping in the Guarani is destined for public supply, 96% takes place in Brazil, 80% of which in the State of Sao Paulo alone. The initial GAA established a general framework for the four signatory countries for aquifer preservation cooperation; this paper describes the entry into force of the second cooperation period (2010-2017) with the ratification by member countries (except Paraguay, which was still under negotiation at the time of this publication). One important issue of this work refers to the informal cooperation between bordering cities (Uruguay-Argentina and Uruguay-Brazil) considered of particular relevance. The legal, or under negotiation, transboundary arrangements between municipalities provide support to specific activities, even though there are doubts of whether this cooperation may be considered legally binding under international laws. There are important lessons to learn from this case from the managerial and institutional points of view and for promoting cooperation between border cities. The substantial hydrogeological understanding resulting from numerous scientific studies was not enough to establish collaboration mechanisms. Other issues such as socio-economic pressures and, most importantly, legal and institutional aspects for groundwater management and transboundary cooperation were as important, or even more important, than science alone. Finally, an essential element of the GAS project was the decision to zoom in on specific smaller areas of the aquifer along the international borders. Given the very large size of the GAS, this last outcome is an important lesson for other similar transboundary aquifers where scale matters.

Callegary et al. (2018) present lessons learned in a couple of transboundary aquifers between Mexico and the United States. They describe a very detailed account of a successful social and political collaboration on the assessment of the Sonora (Mexico) and Arizona (USA) transboundary San Pedro and Santa Cruz aquifers, respectively. The authors provide a detailed account of the application of TAAP (The Transboundary Aquifer Assessment Program), as applied to the San Pedro, Santa Cruz, and Nogales aquifers, as an example of a successful collaboration by government and university partners in Mexico and the US. They describe how TAAP was derived from the TAA Act by the US Congress in 2006, and developed within the context of worldwide advances toward transboundary aquifer assessment and governance promulgated by academics, UNESCO and other international bodies beginning in the 1990s. Their study clearly shows how academics, governments and social partners came together in a very successful collaboration between the two countries on the subject of shared groundwater. The method developed in this paper, if used appropriately and flexibly, will help to fill data gaps in those areas in which typical aquifer assessments are weakest and where transboundary aquifer assessments are most in need: socio-political and historical information, governance, legal and institutional frameworks, cultural sensitivity, communication and stakeholder engagement among others.

Sanchez et al. (2018) propose a somehow different approach to identifying and categorizing transboundary aquifers; to illustrate their approach they use the hydrogeological units shared between the states of Chihuahua, Coahuila, Nuevo Leon and Tamaulipas in Mexico and the state of Texas in the U.S. and assess their potential transboundary linkages. Using that particular approach, Sanchez et al. identified potentially 15 transboundary aquifers located between Northeastern Mexico and Texas. Their analysis shows that between 50% and 60% of the total sharable area (of which 60% is in Texas and the rest in Mexico) reports good aquifer potential as well as good water quality conditions. Some 20–25% of the shared land is considered to have poor aquifer conditions and low water quality, with similar areas on the two sides of the border. The authors claim that their efforts could support the development of transboundary management regimes aimed at preventing the degradation of future water supplies along the borderline between Northeastern Mexico and the United States.

ASIA

Paper eight, by Lee et al. (2018) describes the assessment of transboundary aquifer resources in Asia, their status and progress towards sustainable groundwater management. More than 70% of global groundwater consumption takes place in Asia and global estimates suggests that around 38% of irrigated area relies on groundwater; it plays an important role in providing water resources and economic development. This study attempts to provide a comprehensive overview of the status of transboundary groundwater resources in Asia, including TBA inventories, socio-economic implications, and future perspectives. Specifically, the paper focuses on the progress of the assessment and management of TBAs in Asia as a result of the ISARM. The level of understanding transboundary aquifers remains limited; however, reports on the decrease of groundwater levels in many parts of the identified TBAs suggest that groundwater is being depleted over the region. Hydrogeological conditions and social and environmental issues of the shared aquifers in the Greater Mekong sub-region are further elaborated as a case study. A number of initiatives at the legal and institutional levels from different countries have been launched for an effective cooperation; however, ratified agreements exclusively dealing with identification, assessment and governance of TBAs are still limited. Only bilateral agreements exist and most do not explicitly cover groundwater.

Europe

The last three papers, 9, 10 and 11, complete the special issue with cases from Europe. De los Cobos (2018) discusses The Genevese transboundary aquifer (Switzerland-France) and the secret of 40 years of successful management from the financial, technical, political and legal point of views. The Genevese TBA presents results of successful management between France and Switzerland since their initial arrangements dating back from 1978. Extending over 19 km, 90% of aquifer is located in the Canton of Geneva and 10% in France; it constitutes an example of a transboundary agreement between a European Community Member Country (France) and a Swiss Canton (Genovese) providing water supply for around 700,000 inhabitants. This is the only case of a TBA having a legally binding agreement (December 2012) with many good lessons to be learned from the 40 years' experience of that case. The paper also tackles issues referring to the principle of sovereignty, trust and confidence on decisions taken

Szűcs et al. (2018) introduce the Upper Pannonian Thermal Aquifer in Hungary with a discussion of a long-term management of the thermal groundwater system for authorities and policy makers, based in modelling and benchmark indicators. Cooperation in the Pannonian Basin TBA dates back to the 1980s through bilateral commissions established by the countries sharing the aquifer. However, this paper presents a particular view on transboundary aquifer management under the water-energy nexus based in groundwater exploitation for geothermal heat production. A numerical groundwater flow model was implemented following the delineation and review of existing legislation including financial schemes for the Upper Pannonian Thermal Aquifer by Austria, Hungary, Slovakia and Slovenia. Results from modeling scenarios will be used for future aquifer management. A second output from the analysis of that aquifer indicates that sustainable thermal water resources and management require definition of specific benchmark indicators; groundwater monitoring is one of the most important actions agreed upon.

Finally, Lipponen and Chilton (2018) provide a detailed account of the role of international frameworks and joint assessments in the development of cooperation on managing transboundary groundwaters in the pan-European region. Following a detailed analysis of the status of TBAs in Europe, the authors conclude that, although the legal basis for cooperation in managing transboundary waters in the pan-European region is well developed, most existing agreements do not explicitly refer to groundwaters, or their application to groundwaters remains limited. There is a need for comparing and harmonizing approaches across state borders and information on

the extent of aquifer systems is not enough. To understand their vulnerability to the possible impacts of development, the authors suggest building sound conceptual hydrogeological models of TBAs and their groundwater flow regimes. A gradual move from technical monitoring and assessment to legal aspects has occurred in Europe and it is useful to assess the supportiveness and functioning of the legal and regulatory frameworks in relation to the management challenges from a technical perspective

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