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Dialogic science-policy networks for water security governance in the arid Americas

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ABSTRACT

Addressing wicked problems challenging water security requires participation from multiple stakeholders, often with conflicting visions, complicating the attainment of water-security goals and heightening the need for integrative and effective science-policy interfaces. Sustained multi-stakeholder dialogues within science-policy networks can improve adaptive governance and water system resilience. This paper describes what we define as "dialogic science-policy networks," or interactions – both in structural and procedural terms – between scientists and policy-makers that are: 1) interdisciplinary, 2) international (here, inter-American), 3) cross-sectoral, 4) open, 5) continual and iterative in the long-term, and 6) flexible. By fostering these types of interactions, dialogic networks achieve what we call the 4-I criteria for effective science-policy dialogues: inclusivity, involvement, interaction, and influence. Here we present several water-security research and action projects where some of these attributes may be present. Among these, a more comprehensive form of a dialogic network was intentionally created via AQUASEC, a virtual center and network initially fostered by a series of grants from the Inter-American Institute for Global Change Research. Subsequently, AQUASEC has significantly expanded to other regions through direct linkages and additional program support for the International Water Security Network, supported by Lloyd's Register Foundation and other sources. This paper highlights major scientific and policy achievements of a notable suite of science-policy networks, shared practices, methods, and knowledge integrating science and policy, as well as the main

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barriers overcome in network development. An important gap that remains for future research is the assessment and evaluation of dialogic science-policy networks' long-term outcomes.

1. Introduction

In the arid Americas —which in our work comprises arid regions of Argentina, Brazil, Chile, Mexico, and the United States—global environmental change manifests as a number of processes, most of which tend to exacerbate already prevalent water problems. Among these major processes, more frequent and intense drought (Oertel et al., 2018) is notably contributing to shifts in vegetation cover (Bustos and Meza, 2015; Mendez-Estrella et al., 2016), and increasing water scarcity in rural and urban locations (Meza and Scott, 2016; Zuñiga-Teran et al., 2017). Throughout the arid Americas, physically-driven water scarcity intersects with urbanization and farmers' participation in commodity chains. This, in turn, accelerates land-use changes (for example see Díaz-Caravantes et al., 2014), and fosters a vicious cycle in which -land-use change and vegetation shifts affect water resources availability. In places where surface water scarcity becomes the "new normal", users shift to less sustainable groundwater sources (de Chaisemartin et al., 2017; Scott, 2013), addressing a short-term demand, but broadening the gap between demand and supply for both human and ecological uses in the long-term.

The outcomes of these social-ecological dynamics include abandonment of areas where small-scale agriculture was prevalent (Díaz-Caravantes and Wilder, 2014); high environmental and socio-economic costs for already vulnerable livelihoods (Lee et al., 2015; Herwehe and Scott, 2017; Buechler and Lutz-Ley, 2019; Mussetta and Barrientos, 2015); and heightened water-related risks (e.g., mine spills) (Díaz-Caravantes et al., 2016). They are also widening the gap between the people who are the least and most vulnerable (Leichenko and O'Brien, 2008; Wilder et al., 2016), and compromising long-term social-ecological resilience in the arid Americas.

The aforementioned environmental, climatic, and socio-economic manifestations of change in the arid Americas pose wicked problems for policy making because these challenges are often unforeseen and not amenable for governmental action (Head and Alford, 2015; Rittel and Webber, 1973). Wicked problems are those that have higher levels of complexity and uncertainty than "regular" policy problems because they originate in the system's dynamics rather than in single factors or causal relations. They often have no clear boundaries or definitive formulation, and therefore no straightforward solution (Rittel and Webber, 1973). Solutions for wicked problems cannot be characterized as universally and absolutely effective since they depend on multi-dimensional, multi-scalar interacting factors whose behavior and outcomes are often unpredictable or unknown (Balint et al., 2011). Because of this, responses can alter other parameters of the problem, producing unintended consequences. Responses are provisional and deemed "better" or "worse" depending on the valuation of multiple stakeholders[1] involved, whose values and objectives change over time as the problem evolves. Most current global water-resource challenges are wicked problems (IHE Delft Institute for Water Education, 2017).

Addressing wicked problems requires a systems' perspective to understand and improve rather than to solve the situation. Conventional, linear policy-making strategies are not well suited to address the complexity and uncertainty of wicked water problems. Solely bottom-up or locally based solutions also may fail to identify key interconnections with larger scale drivers, impacts and stakeholders (Miller and Erickson, 2006; Chaffin et al., 2014). In addressing wicked water problems, integrative, network- and dialogue-based approaches are alternatives to conventional modes of governance. The objectives of this article are 1) to advance the concept of *dialogic science-policy networks* and their application to address wicked water-security problems (Varady et al., 2020; Albrecht et al., 2018; Scott et al., 2012); and 2) to identify guidelines for action to develop more effective science-policy dialogues. We do this by reviewing several concrete place-based approaches for science-policy interactions aimed at improving water security across the arid Americas. This dialogic approach to water security was initially fostered by a grant from the Collaborative Research Networks 2 (CRN2) program of the Inter-American Institute for Global Change Research (IAI), a western hemisphere treaty organization involving 19 countries' ministries of science and technology and ministries of foreign affairs, financed by numerous national science foundations and other sponsors.

Approaches to wicked water problems need to move from conventional paradigms of science-policy interactions to interdisciplinary, international, cross-sectoral, open, continual and iterative, and flexible approaches. These include *multi-stakeholder dialogues, multi-stakeholder platforms (MSP)*, *science-based stakeholders policy dialogues* (Welp et al., 2006), and *science-policy dialogues* (Scott et al., 2012; Young et al., 2014). We refer to such groupings as *dialogic science-policy networks,* and define them as interactions – both in structural (i.e., networks) and process terms (i.e., dialogic) – among scientists, stakeholders, and policy-makers across multiple governance levels, and usually extending over longer temporal scales than the lifespan of individual water challenges.

Collectively, these approaches are based on knowledge coproduced by multiple participants in the process, instead of unidirectionally transferred from science to policy-making. Often, values can be more important than knowledge in decision-making, and participation of a diversity of stakeholders pertinent to specific water issues can bring legitimacy, democracy and effectiveness to addressing them. Furthermore, the networked nature of these science-policy interfaces can potentially confer flexibility, diversity,

[1] The authors use the term "stakeholder" here to refer to any individual involved in, or affected by, any water issue. However, they recognize this concept does not equally represent all involved parties in water governance (e.g. women, peasants, the poor, Indigenous Peoples, and racial minorities, among others). In particular, many Indigenous Peoples do not feel represented by the term, since it is used in reference to business and government engagement, while their relationships to water and nature in general are qualitatively different from those implied by "stakeholder." See O'Bryan (2019) for more background on this topic.

redundancy and cross-scale learning transferability to the decision-making processes. These are features of adaptive governance increasing the resilience of social-ecological systems (Berkes et al., 2003; Low et al., 2003; Lemos and Morehouse, 2005; Pahl-Wostl et al., 2007).

Scholars consider science-policy dialogues more effective for addressing wicked problems than are conventional modes of resource governance. They allow the integration of multiple narratives, knowledges and values into decision-making processes and have the potential to increase public participation and legitimacy of strategies (Vogel et al., 2007; Welp et al., 2006; Young et al., 2014). Citizens who expect rapid answers and profound changes in their societies also frequently demand these type of approaches (Bridge, 2003; Prno and Slocombe, 2012).

Dialogic approaches are not panaceas, though; they contain their own set of challenges, such as overcoming *communication barriers* from multiple interacting epistemic communities and languages; developing *pertinent bridging processes* between stakeholders, including trust-building and maintenance; and supporting *slow and sometimes cumbersome processes for reaching agreements*, or negotiating commonly accepted positions (Vogel et al., 2007). In addition, perhaps most significantly at a time when questions of social justice arise across the globe, a critical challenge in the formation and development of dialogic networks is dealing with *power imbalances* among stakeholders in a way that does not perpetuate the *status quo* and deepen inequity for disadvantaged groups in favor of the more advantaged (Robbins, 2019).

This paper highlights major achievements of the selected networked collaborations that center on water-security in the arid Americas. We focus on shared practices, methods and knowledge for science-policy integration; the main barriers overcome in network development; and the need for new methods to assess and evaluate dialogic networks' impacts on overall adaptability and social-ecological system resilience to better attain water security. We present concrete cases that offer illustrative lessons that, in principle, may be applicable to similar processes occurring in other areas of the world prone to water insecurity.

2. Water security governance through dialogic science-policy networks

2.1. Conventional approaches for science-based water governance

We define water security as "the sustainable availability of adequate quantities and qualities of water for resilient societies and ecosystems in the face of uncertain global change" (Scott et al., 2012: 281). This concept of water security considers both the productive and destructive nature of water in its interaction with societies and ecosystems. The outcomes of these interactions move in a continuum ranging from adaptability and resilience to irreversible shifts in social-ecological systems (Berkes et al., 2003). An important principle is that different management strategies for water security drive the movements along this continuum. Ideally, such strategies utilize scientific knowledge of water issues with the purpose of increasing policy effectiveness. Other approaches to water security (e.g., Jepson et al., 2017) include relational and political aspects, as well as geographically specific criteria for defining water security at lower scales. This implies that, depending on the scale, water governance would require a diversity of knowledges and values beyond those of the policy or scientific community, or referred only at larger management scales, such as basins, states, or

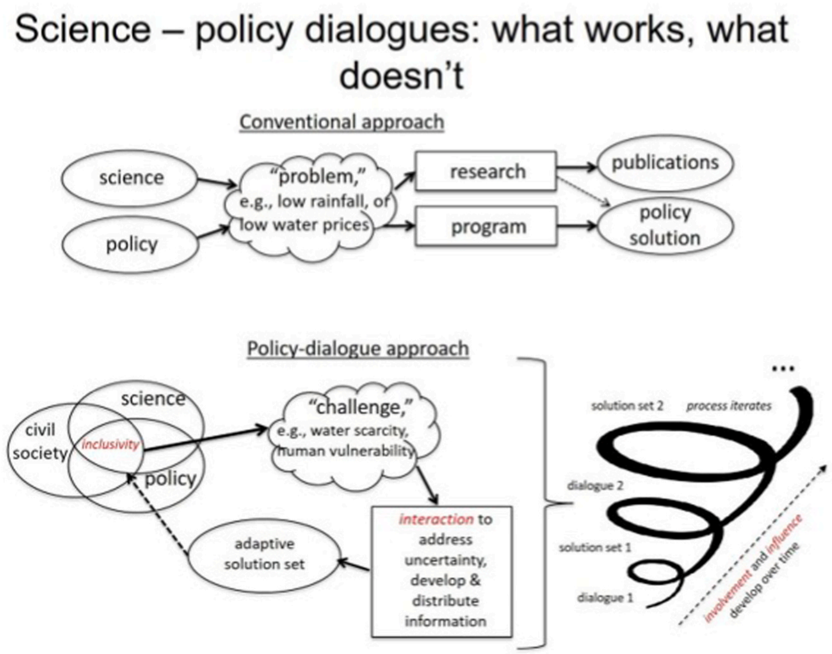

Fig. 1. Conventional and policy-dialogue approaches (Adapted from Scott et al., 2012).

countries.

Linear approaches characterize conventional ways of science-based policy-making for obtaining water scientific knowledge (see upper part of Fig. 1), in which science and policy-making develop separately and join only when the latter requires input from the former. This linear, technocratic-type of model assumes that "… policy-makers pose well-defined questions, scientists provide credible, legitimate, relevant and timely knowledge, and policy-makers will go on to develop solutions based on this knowledge" (Young et al., 2014: 389). There are also many instances of linear-model use where policy-makers do not pose questions, but scientists and others nevertheless suggest questions and provide answers. This fosters uni-dimensional and uni-directional (one-way) interactions from science to policy in which "truth speaks to power" (Beck, 2011: 298). The linear model assumes that 1) there is a separation between science and politics, and science is value-free; 2) more and better research will lead to more certainty; 3) improved scientific knowledge will help in solving political disagreements; and 4) science helps to make policy more "rational" by focusing objectively and systematically on problems. The linear model also accepts that the diversity of stakeholders involved in policy-making is limited (Beck, 2011; Young et al., 2014).

Limitations and simplification of the linear model of the science-policy interface in water governance often include a de-contextualization of water problems and responses and a tendency to develop technical-expert solutions to problems that have a strong socio-economic and political component or that involve equity or justice issues. This sometimes results in the adoption of mainly hard-path solutions (infrastructure or physical solutions) to water problems in situations that would benefit from more integrated multi-scale and multi-dimensional approaches involving both hard- and soft-path interventions (Scott and Lutz-Ley, 2016). Several authors have criticized the linear science-policy model because it fails to represent the complex interactions among scientific knowledge, political judgment and practical considerations underpinning water policy-making (Gluckman, 2016; Head and Alford, 2015).

2.2. Science-policy dialogues for water-security governance

Science-policy dialogues are seen as mechanisms to "increase adaptive capacity of institutions to mitigate potential vulnerabilities via water management and disaster relief and prevention" (Scott et al., 2012: 36) (see bottom of Fig. 1). Science-policy dialogues link different discourses and values to policy through participation of stakeholders otherwise disconnected. They can offer greater accountability of science, as well as increase the legitimacy of the policy process and the acceptability of results and proposed strategies (Welp et al., 2006).

To achieve their full potential, Scott et al. (2012) proposed the "4-I" criteria for science-policy dialogues: 1) inclusivity, 2) involvement, 3) interaction, and 4) influence. *Inclusivity* refers to the degree of diversity of stakeholders engaging in the dialogue in order to represent a pertinent range of perspectives, knowledge sources, and values. *Involvement* indicates how committed or consistent is stakeholders' participation and actions. *Interaction* is the degree to which stakeholders participate in multiple activities involving all the groups and audiences connected to the issue. Finally, *influence* refers to the ability of the science-policy dialogue to affect policy or institutional changes at any scale where an issue develops.

Although science-policy dialogues present advantages in comparison with conventional approaches to science-policy interfaces, they have their own set of challenges and limitations. Maintaining continuity of dialogue efforts, and ensuring the balance in power and diversity of participants to obtain representative inputs, are challenging to sustain. Science-policy dialogues are usually limited by the lifespan and spatial boundaries of the specific issues they deal with, and importantly, by financial constraints. Within those constraints, science-policy dialogues have to find ways to connect long-term uncertain scientific projections with the short-term certainty-based goals demanded by policy, economic and civil sectors (Barton et al., 2014). At the same time, finding the right momentum for collaboration can be tricky, as it can become quicksand when science gets trapped in the middle of contending interests (Budds, 2009; Fuller, 2009; Sarewitz and Pielke, 2007). There are cases in which dialogues get mired in conflicts to a point where they may no longer be useful (Yasmi et al., 2006). In such instances, science can be incapable of providing answers that support pre-existing beliefs and expectations (Bingham, 2003).

2.3. From science-policy dialogues to dialogic science-policy networks

The challenges mentioned above can severely curtail the full potential of science-policy dialogues to serve as an ongoing source of capacity and resilience building, especially when facing water-security problems over longer temporal and wider, often global, spatial scales. To address some of the limitations that science-policy dialogues have, based on our experiences, we use the term dialogic science-policy networks to refer to both the structures and processes involving multiple stakeholders and participants in addressing water issues over different temporal and spatial scales.

Dialogic science-policy networks are built upon science-policy dialogues, but transcend them in cognitive, temporal, and spatial terms through several features: 1) they are interdisciplinary, especially linking social and biophysical sciences; 2) international (here Inter-American), and hence multilingual; 3) cross-sectoral, by recognizing that water security is multi-faceted and requires input and engagement from multiple sectors and interests); 4) open (i.e. transparent) and based on direct communication and interactions to foster trust; 5) continual and iterative, often using virtual platforms to bridge geographical divides; and 6) flexible, which confers adaptive-capacity advantage, by incorporating multiple types of governance arrangements and actors addressing evolving water security issues at different scales.

Networked forms of governance coexist with, or are embedded within, hierarchical state-based and market-based forms of governance. Implementation of dialogic networked approaches cannot ignore prevailing power and governance structures that command resource allocation, define political legitimacy, and dictate accountability and transparency practices (Eberhard et al., 2017). Still, dialogic science-policy networks of the kind we describe represent an evolution in water security governance, as characterized in Table 1.

3. Inter-American experiences in fostering dialogic science-policy networks

3.1. AQUASEC

AQUASEC emerged from an active mix of science-based stakeholder dialogues on adaptive management to address global change. Applied research teams from North America (Mexico and the United States) and South America (Chile, Argentina, Brazil) supported under IAI's Collaborative Research Network CRN2 program had developed expertise in policy engagement in their respective, but still isolated, project sites.

In early 2011, the teams met in Los Cabos, Mexico, along with water-policy decision-makers from several of the countries, basins, or local agencies where projects were developing. An important outcome was the definition of the broad aims and operational structure of what came to be the dialogic network dubbed AQUASEC. The IAI Conference of Parties and its Scientific Advisory Council—IAI's governing and advisory bodies—subsequently endorsed AQUASEC as the first IAI Center of Excellence, an organizational feature that had been written into IAI's founding language in the early 1990s but never actually conferred on any initiative until AQUASEC.

As demonstrated in Fig. 2 below, researchers (in blue) and stakeholders (in green) were brought into dialogue, though initially (in the CRN2 in 2007–11) in their separate spheres and often sequenced in time with research results being delivered to decision-makers after they were developed. With the formation of AQUASEC (IAI-Opportunity grant, 2011–13, as well as several coterminous grants including from NSF's PASI and IAI's training programs), researchers and stakeholders simultaneously developed, or coproduced, usable and policy-relevant research (shown as blue and green spheres aligned in time, also with a widening group of partners). In subsequent steps, the spheres are likened to internally reflecting dialogue (blue-green transitions within an initiative). Although these experiments were replicated, each conforming to local needs and opportunities, in various locations, it was not until 2013 that multiple initiatives in the countries and locations listed were brought into a larger, inter-American dialogic network.

AQUASEC served as the platform to meld parallel efforts in Europe and Africa, with support from Lloyd's Register Foundation to establish the International Water Security Network (IWSN). In the Americas, this network drew on the active participation of many of the same research and stakeholder partners as supported by the IAI grants. Under IWSN, links were established in the United Kingdom, Southern Africa, and South and East Asia. As would be expected, the water-security efforts of AQUASEC drew attention from teams elsewhere grappling with similar challenges, though perhaps less directly aimed at water-scarcity conditions. One example is the SAFER network (Sensing the Americas' Freshwater Ecosystem Risk from Climate Change), also supported by IAI, which addresses

Table 1
Attributes of water security governance approaches.

Governance configuration	Features	Driving actors (goals and strategies pursued)	Applications
Conventional approach (Scott et al., 2012)	Linear, parallel, minimal intermittent communication	Scientists (publications); policy-makers (traditional program planning and expenditures)	Routine, target-driven policy tasks
Multi-stakeholder platforms/ dialogues** (Welp et al., 2006)	Multiple sources of knowledge incorporated, process-oriented	Intergovernmental organizations (partnerships); International nonprofit organizations (lobbying and business practices)	Usually, for legitimacy, participatory dialogue is an end, not necessarily a means. Often lacking clear objectives
Science-based stakeholder dialogues** (Welp et al., 2006; Lemos, 2015)	Combining knowledge bases, checking social relevance	Researchers, scientific institutions or stakeholders' networks thereof (workshops, training, focus groups)	Deepening scientific understanding of a problem's multi-dimensionality
Science-policy dialogues (Scott et al., 2012; Young et al., 2014)	Multiple sources of knowledge incorporated, governance include a wider range of participants from scientific, policy, business, and social sectors	Scientists, policy-makers and civil society co-participate in a range of activities involving immediate network community (co-producing papers or cross-review of policy-science papers; co-development of scenario-planning and other policy tools; scientists' participation in public or private management)	Successful integration of multiple stakeholders' values and knowledge in addressing problems, but cross-scale and temporal continuity is not guaranteed
Dialogic science-policy networks	Interdisciplinary, international, cross-sectoral, open, continual and iterative, and flexible	Scientists, policy-makers and civil society co-participate in a range of activities involving extended network community, including partners in other regions/sectors (enhanced co-development of scenarios, social learning and knowledge transferring across regions through science-policy brokers, and enhanced knowledge uptake by participants)	Addressing holistically multiple dimensions of one selected issue across temporal and spatial scales (e.g., water-security), although it may dissipate over time if focus is not carefully guided; can be adapted to emerging crises such as COVID-19

Source: **modified and expanded from Welp et al. (2006), Table 1, p. 172.

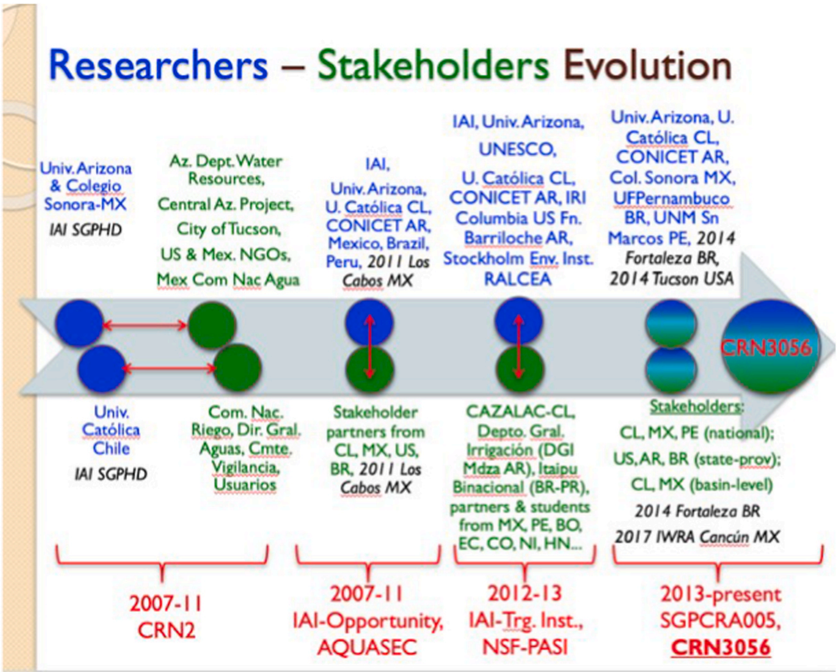

Fig. 2. Evolution and science-policy integration of AQUASEC network.

water quality and ecosystem services in more water-abundant sites of the Americas.[2]

3.2. Networks within regions

3.2.1. North America

3.2.1.1. Northwest Mexico: Sonora River Basin. The Sonora River Basin (SRB) is a water social-ecological system located in arid northwestern Mexico. The basin starts less than 100 km south of the U.S-Mexico border and crosses several municipalities through central Sonora until reaching the Abelardo L. Rodríguez Dam, in Hermosillo, the capital city. On its way downstream, water is used for multiple purposes, ranging from mining to livestock, agriculture and ecosystems (although this use is not legally allocated any water), as well as urban water supply to the city of Hermosillo. As an arid watershed subject to global change processes, the SRB has several urban-rural wicked water problems, such as long-term water scarcity, competition among sectors, lack of systematic monitoring of water quantity and quality, among others. In terms of dialogic networks, this region has been an important focus for researchers and policymakers involved in IAI-CRN2 efforts.

Urban water. – This case shows the importance, and at the same time the difficulties, of sustaining a local network that promotes inclusivity, involvement and interaction of stakeholders (three of the 4-I criteria above). The water issue in this case was the availability of water supply for the growing demand of the state capital, Hermosillo. This city is located 270 km (170 miles) south of the U.S. border with a population close to one million, where assembly plants (*maquiladoras*) and automotive industry are located. As part of the ongoing science-policy dialogue, the local water utility, with the support of the AQUASEC network, launched a long-term scenario-planning effort to devise future alternatives for enhanced water security. The exercise started with an introduction to scenario planning by a former water-planning officer from Tucson, Arizona, a city located approximately at 120 km (75 miles) north of the U.S.-Mexico border. The success of this first encounter fostered further collaborations among the Hermosillo's water utility, IAI's research partners—El Colegio de Sonora (ColSon) and the University of Arizona (UArizona)—and water scholars and practitioners from both sides of the border. This scenario-planning workshop consisted of a series of 12 weekly 3-h meetings attended by the utility officers and scholars. The goal was to identify the driving forces, define strategies and build up institutional capacity to tackle the different scenarios that the city might face by the year 2030 (Agua de Hermosillo, 2017). The new ideas about the future were a breakthrough and a compass for enhancing water security in Hermosillo.

Despite these important collaborative efforts, implementation has been constrained by the frequent turnover of utility officers after the election of new local authorities, which challenges the possibilities of the network to engage in iterative and long-term interactions

[2] The reader is referred to the separate paper, titled "Do ecosystem insecurity and social inequity lead to failure of water security?" also submitted to this special issue.

fostering stakeholder's involvement. During the last 24 years, there have been 14 directors or a new director every 1.7 years (Loera and Salazar, 2017; Haro-Velarde et al., 2016: 211). Patronage and the legal power of every new city mayor (elected every three years) to freely appoint and remove the utility's director causes this frequent turnover. The typically short tenure of office-holders of this strategic position constrains the long-term planning efforts in the city's utility and severely affects the potential for science-policy dialogues. This situation also limits the effectiveness of dialogic networks, which require extended time to consolidate. Another constraint is that the scenario-planning exercise included only water managers and scholars. Clearly, this characteristic enhanced dialogues' potential to influence decision-making. However, the lack of participation by diverse stakeholders from the city and the region narrowed the spatial and temporal scope of the issues under consideration. In summary, this initial dialogic approach started a more comprehensive and flexible planning process by taking into account potential scenarios for water management in Hermosillo. It also fostered the participation of a greater variety of participants not usually involved in the city's water planning. Although it is too early to evaluate the effectiveness of the process, it does indicate some initial features of a functioning dialogic network. In the future, these planning exercises might improve the city's ability to consider social-justice elements of urban water management by comprising a broader scope of stakeholders and citizens.

Rural water. – This example describes interactions that are inclusive, promoting involvement and interaction of multiple stakeholders at the basin scale, while still looking for ways to influence actual decision-making and empower disadvantaged groups at the local level. The wicked water problems taken on by science-policy networks, in this case, were drought and climate-change impacts on water and land resources among farmers and ranchers. A U.S. National Science Foundation (NSF) Coupled Natural Systems (CNH) grant received by the University of Arizona to conduct binational, multi-disciplinary research on riparian communities (in collaboration with researchers from ColSon and Universidad de Sonora, UniSon) facilitated the initiation of science-policy dialogues. This project took place in the San Pedro river basin in Arizona and in the San Miguel river basin, which is part of the larger SRB. Several grassroots organizations such as the Upper San Pedro Partnership, a consortium of local, state and federal agencies and nongovernmental organizations (NGOs) working toward sustainable surface and groundwater management of the San Pedro National Riparian Conservation Area, engaged in dialogues about the future of water security and livelihoods development. Researchers and postgraduate students in the binational team came from multiple social- and natural-science disciplines and learned from each other how to broaden their scope of study to approach issues related to riparian communities.

In the San Miguel river basin, stakeholder meetings enabled the voices of larger as well as smaller-scale ranchers, cheesemakers and other agricultural processors, and crop producers to be heard by regional water managers and agricultural ministry officials in addition to municipal officers. Key shared concerns were drought and climate-change impacts on land and water resources for agricultural production and processing as well as ranching activities. The dialogue focused on how programs and policies could be reoriented to allow producers and processors to confront these challenges. Women's all-too-often ignored voices were heard at these stakeholder meetings including those of the municipal president who was, at that time, a woman (Buechler, 2015). As in the urban case above, obstacles to the continuation of communication between such stakeholders include frequent turnover of government officials from local to federal levels, a phenomenon that can interrupt nascent networks. Obstacles also include the considerable political influence of wealthier actors within the basin and their prioritization of government subsidies for deepening their wells that could ultimately lead to less water for smallholders who have fewer resources to deepen their own wells. These interruptions in networks and the political influence of the wealthier residents can marginalize small-scale farmers and agricultural processors. Thus, as argued by political ecologists, researchers must take care to expose these kinds of power dynamics within networks, rather than portraying all members within networks as participating on an equal footing (Rocheleau, 2015). This initial dialogic approach achieved greater involvement of participants who usually do not participate in water decision-making at the scale of river basins (i.e., women, small-scale ranchers and farmers). It also increased the interaction between several social groups and policy sectors that have a stake in water planning in the SRB. As in the case of Hermosillo's water utility above, this incipient network still needs to foster further interactions and sustain long-term relationships in order to become a dialogic network.

3.2.1.2. U.S.-Mexico: The Colorado Delta. Science-policy collaboration in the Colorado River Delta is an example of an effective dialogic science-policy network fostering the 4-I criteria of inclusivity, involvement, interaction, and influence to address the wicked problem of the need for environmental restoration of endangered wetlands. Furthermore, this collaboration demonstrates how long timeframes and iterative interactions are necessary to expand institutional capacity. The Colorado Delta science-policy networks resulting in binational cooperation on the environment reflect the work of decades of sustained relationships to build trust, develop social learning mechanisms, and reach agreement.

Located in the western portion of the US-Mexico border, the Colorado River (CR) provides water for 45 million users in the U.S. and Mexico, including seven U.S. states and two Mexican states, over 20 Native American tribes (some of which have lands that extend into Mexico), and more than 200 thousand hectares (approximately half a million acres) of irrigated farmland. Due to rapid population growth, which has increased water demand, and climate change that has reduced water flows, the Colorado is one of the most endangered rivers in the U.S. A 1944 treaty allocated ten percent of the CR flows —or 1850 million cubic meters (1.5 million acre-feet) annually—to Mexico. The International Boundary and Water Commission and its Mexican counterpart, the *Comisión Internacional de Límites y Aguas*, known collectively as IBWC/CILA, carry out the treaty provisions.

Critical wetlands (e.g. the Ciénega de Santa Clara) are located at the southern end of the 2334 km (1450-mile) river, which has its headwaters in the high elevations of the Rocky Mountains in the U.S. and drains to the Upper Gulf of California/Sea of Cortez in Mexico. Incidental flows from agricultural drainage had been sustaining critical ecosystems in the area; however, with the implementation of agricultural efficiencies and no dedicated water supply, the ecosystems that provide critical habitat for thousands of migratory and resident birds were in danger of drying up.

To address the need for environmental flows of water to sustain the riparian ecosystems, including wetlands, a binational network of scientists, NGOs, government officials, and the IBWC/CILA collaborated to develop Minute 319 (2012–2017) (Flessa et al., 2016), a treaty amendment, to provide a one-time "pulse flow" release of water to the river bed downstream to the Gulf of California. On March 23, 2014, hundreds of people turned out to watch the pulse-flow released from the Morelos Dam in the U.S.-Mexico border through the riverbed to connect to the sea for the first time in most peoples' living memory. A binational stakeholder process that formed out of Minute 319 helped spawn Minute 323 (2017–2026), which commits both countries to provide water and funding for ecological restoration and scientific monitoring for the next decade. NGOs have developed a water trust as a private funding mechanism to help sustain the flows. Both Minutes also address other shared goals of water-scarcity management in the basin, such as shared reservoir storage and shortage sharing. Minute 319 represents a positive turning point in transboundary Colorado River management and has been called one of the "most significant agreements" to date (Sánchez and Cortez-Lara, 2015: 23). Minutes 319 and 323 are built on foundations laid by Minute 306 (2000) and agreements such as the 1983 La Paz Agreement that committed the two countries to transboundary cooperation; and they are maybe the best indicator of effectiveness for the Colorado Delta dialogic science-policy network.

This network is not supported by IAI, AQUASEC or IWSN. Instead, major impetus for the Colorado Delta network came initially from the "RCN: The Colorado River Delta Research Coordination Network" NSF grant (2005–2012) awarded to K. Flessa at the University of Arizona.[3] However, many of the stakeholders and scientists involved have been long-term partners to several of the AQUASEC projects showcased here. This suggests that governance lessons from successful cases in one place can guide efforts in other parts of the arid Americas through dialogic networks capable of banking and transferring social learning through their brokers and bridging members.

3.2.1.3. U.S.: Cienega Watershed in Southern Arizona. The wicked water issues addressed in this case are reduced water flows and impacts on endangered species in Cienega Creek in southern Arizona. The Cienega Watershed Partnership (CWP) is a citizen-based nonprofit association that works with multiple organizations managing land in the Cienega Watershed—including the U.S. Bureau of Land Management (BLM), Pima County, Pima Association of Governments (PAG), U.S. National Forest Service, and U.S. National Park Service—to protect one of the last perennial creeks of the region (Cienega Watershed Partnership, nd). In addition, CWP partners include environmental NGOs such as The Nature Conservancy and the Sky Island Alliance, and the University of Arizona.

The science-policy network includes and involves a spectrum of stakeholders, such as ranchers, NGOs, federal, state, and local government agencies, and scientists. The network's strategies include the long-term relationship of some key actors who have worked there from the perspective of partner organizations, and became interested in the overall sustainability of the watershed. This long-term relationship has allowed trust to develop, an attribute that is fundamental to the involvement and interactions of the network's members. The group also uses participatory and science-policy co-production processes in their projects. To assess the state of the watershed, for example, the group selected indicators to monitor watershed health. Stakeholders participated in a survey implemented by a researcher from UArizona to narrow down the list of indicators, and through a series of workshops, they further revised and shortened this list. Every year, the research team collects data on these indicators and presents it to the group, who then provide input for the refinement of the assessment process, and collectively agree on the implications of the results on land management (Zuniga-Teran et al., 2017).

Because many CWP members work for the organizations that manage land, this assessment is useful in their own work, increasing the potential of the network to influence decision-making, as it provides a collective vision of sustainability goals for the watershed. This assessment effort has become a model for other community groups interested in protecting neighboring watersheds. A network of communities of concern is developing in Southern Arizona, where groups can exchange lessons and learn from each other's experiences.

One of the main challenges for this network is the lack of steady and sufficient funding. Federal agencies have seen a decline in their budgets and CWP has suffered from this. The CWP has turned to other organizations to fund its work, but the continuity of the assessment effort is threatened. An additional barrier is the low density of population living in the watershed. This makes it difficult to engage many local citizens in conservation efforts. This collaborative assessment of watershed health can be considered a science-policy network because it crosses several sectors and it is interdisciplinary, open, continual and iterative, and flexible. Land managers are key participants of the process and are the ultimate decision-makers. This effort considers multiple dimensions of watershed health, making it a holistic approach to water security. Although the assessment is open to the public, it is through the member's individual networks that meetings are scheduled and convened. This way, networks can both include and exclude people from participating in the assessment effort. Likewise, power differentials between participants can affect deliberations during the workshops, influencing whose perceptions ultimately carry most weight. Nevertheless, because the assessment is data-driven, stakeholders perceive the process as legitimate, and it has been successful in keeping people engaged.

3.2.2. South America

3.2.2.1. Northeast Brazil: the Pernambuco region. Stakeholders in this network have worked together to address wicked water issues

[3] Available at: https://www.nsf.gov/awardsearch/showAward?AWD_ID=0443481 (Access: August 18, 2020).

such as drought and water supply insufficiencies. The Brazilian case displays involvement and interaction of the partners around cooperation in themes of mutual interest. The Water Resources Group of the Federal University of Pernambuco (GRH/UFPE) had the opportunity of expanding links with new partners after the XIV World Water Congress (2011) held in Pernambuco state. In the years following, the GRH/UFPE joined the AQUASEC network, which brought together at least one researcher and one decision-maker from each of the network partners in Fortaleza, Brazil, before the Adaptation Futures Conference (2014). The insertion of GRH/UFPE in AQUASEC was particularly productive for studies involving adaptive water management in watersheds of Pernambuco with a highlight for studies using remote sensing products, drought indices, and climate change scenarios.

Many of the AQUASEC activities used information from and provided policy implications to the Water and Climate Agency of Pernambuco (APAC). This exchange also occurred in terms of personnel, e.g., internships of graduate students as well as an UFPE professor serving as APAC director. The close relationship between GRH/UFPE and APAC greatly facilitated the mutual exchange of information products generated in science-policy research and its access by professionals from the agency. For example, the soil moisture from APAC's stations has been used for validation of remote sensing products, which in turn, is used for agricultural drought indices calculation (Souza et al., 2018). This interaction also allowed participation of students in activities of the river basin committee and evaluation of its role in the process of decision, but without capacity for interfering in the balance power among stakeholders.

Among the achievements of this science-policy network, information co-production and exchange between science and policy participants has allowed more comprehensive and interdisciplinary approaches to water planning and management in this region of Brazil. However, to become a dialogic science-policy network, stakeholders require expanding their reach across sectors to be more inclusive and sustaining interactions in broader temporal and spatial scales.

3.2.2.2. Chile: The Maipo basin. The Maipo basin case, grounded in the importance of inclusivity and involvement of a diversity of stakeholders, shows the development of a decision-analysis approach called Robust Decision Making (RDM) to co-construct and assess uncertainties, policy levers, measures, and relationships (Lempert et al., 2003; Lempert and Groves, 2010). The Maipo Basin Adaptation Plan (MAPA in Spanish) was an initiative led by the interdisciplinary Centre of Global Change and funded by the International Development Research Centre of Canada. The objective of the project was to improve understanding of vulnerability and adaptation opportunities for the 15,300-km^2 Maipo River basin, the most populated region in Chile with seven million people (about 40 percent of Chile's population). The three-year process started in 2012 and followed an iterative science-policy dialogue within a group named the Scenario-Building Team (SBT).

In terms of inclusivity, a central achievement of the collaboration was the beginning of a dialogue with stakeholders who did not usually engage with one another, representing national and regional authorities, private organizations, academia, and civil-society organizations. In the involvement aspect, the processes were able to sustain participation of stakeholders to collect information and co-produce: 1) a land-use-hydrological model (Henríquez-Dole et al., 2018), and 2) the definition of an adaptation measures framework based on the concept of water security (Ocampo-Melgar et al., 2016). This dialogue allowed a diversity of stakeholders to discuss their different development views and aspirations based on water resources for human consumption, production and ecosystems, while minimizing hazards and pollution.

Given the level of unrest and power dynamics among participants, a major challenge of this process was to discuss water-related aspirations and future adaptation without getting into negotiation of trade-offs or compromising changes in value orientations. More importantly, because this was a first attempt to bring together these stakeholders, collective discussion was possible by not including in the conversation the largest source of disagreement in water management: the market-based Chilean water legislation (Water Code) and its emphasis on water as a mean for economic development (Bauer, 2015, 2004; Oyarzún and Oyarzún, 2011).

In summary, this science-policy network successfully brought together participants that do not interact on a regular basis, improving inclusiveness and interaction of a variety of visions regarding water planning and management in the Maipo River basin. Today, there exists a more complex context in Chile fostered by the impacts of a 10-year drought; nevertheless, this nascent network can open the opportunity for deeper conversations on the legal framework if it grows more integrated and inclusive in the long term, with enough capacity to address this essential but conflictive issue.

3.2.2.3. Argentina: Mendoza. This network exemplifies the importance of inclusive and iterative interactions in trying to address wicked problems of long-term water security in a wine-producing county in Argentina. In 2012, the General Irrigation Department (DGI in Spanish) of Mendoza Province implemented a basin-water-balance program at a time that coincided with science-policy dialogue initiatives between DGI and the AQUASEC network fostered by IAI. A diversity of approaches to stakeholder engagement helped in designing more robust water balances. In particular, the incorporation of medium and long-term scenarios into decision-making using scenario-planning methods was especially important to overcome the usual short-term vision in water planning.

Users have challenged the DGI in Mendoza to offer effective responses to drought management during and after more than a decade with river flows lower than 50% of their historical average. In this context, stakeholders used the water balance and scenario planning initiatives effectively as a policy tool to prioritize specific and flexible policies. These also required overcoming a strict single-sector approach focused solely on water, by recognizing the interdependence of hydro-climatic, energy, food and social systems.

AQUASEC, with resources from the International Water Security Network, played a crucial role in DGI's institutional advancement by articulating and offering specific mechanisms to address challenges through dialogue with high-level research, management and policy partnerships. For five years, DGI's staff has actively participated in meetings, workshops, conferences, field trips and trainings organized by AQUASEC in the United States, Chile, Brazil, Colombia, Peru, and Mexico. On numerous occasions, DGI invested its own and complementary funds to enhance participation in these activities. This allowed DGI to incorporate science-policy dialogues as part of its own agenda, evidencing the capacity of this dialogic approach to influence policy-making. In the following years, DGI has co-ordinated its own conferences and workshops that explicitly incorporate dialogic network agendas and has invited all AQUASEC members to participate (i.e., the 2019 Conference "Agua para el Futuro" hosted by DGI and other partner organizations in Mendoza). This demonstrates not only a successful ongoing dialogue process but also its viability in the medium and long term. This network has strengthen the institutional capacity for water planning and management in Mendoza, by integrating multiple types of knowledges and expertise and connecting DGI with a broader range of stakeholders and specialists beyond the boundaries of its region.

3.2.3. Development of dialogic science-policy networks in the arid Americas: a summary

Table 2 below summarizes the cases presented here in terms of their level of development (e.g., high, medium, low) of features defining a dialogic science-policy network. Two of the cases exhibit a fully-constituted dialogic network according to the features presented (AQUASEC and the binational U.S.-Mexico network of the Colorado Delta). But several of the local or regional cases face important challenges in terms of a) representativeness and inclusiveness of a broad range of participant sectors, values and knowledges (i.e., low or medium development of international, interdisciplinary, open, cross-sectoral features); and b) difficulties to sustain iterative interactions in the long-term, mostly related to lack of time and financial resources. The flexibility of each network depends, in part, on how much it is constrained by predetermined institutional legal arrangements that limit the strategies that participants can pursue. For example, the Hermosillo's municipal legal framework bounds its water utility; therefore, the scenario planning activities described here for that network should integrate within the mandated guidelines, requiring more time and political effort to transform.

4. Contributions and challenges of dialogic network approaches to address wicked water security problems in the arid Americas

As evidenced by the increasing integration of science and policy stakeholders depicted in Fig. 2, AQUASEC has made palpable progress in establishing robust working communication between researchers and policy-makers. The network is interdisciplinary (it builds on numerous natural and social sciences), international (at least six countries of the Americas plus numerous others via IWSN), open (although some hierarchy persists), continual and iterative (based on ongoing support from a diverse set of sponsors). Greater challenges have been faced in ensuring its capacity to cross sectors (i.e., AQUASEC remains primarily water-security focused) and to be flexible (adaptation is often subsumed to growth targets and certainty that are still embedded in existing or even emerging water security governance approaches).

With the exception of AQUASEC and the Colorado Delta, not all the cases presented under the umbrella of IAI-supported efforts can be identified as cohesive, successful, and sustainable dialogic networks. Nevertheless, the beginning of a dialogue among different stakeholders across the arid Americas basins set a new way of framing, planning and responding to water wicked problems, which in many cases was a turning point in "business as usual" water resources governance. By and large, the dialogic network approach described above has produced useful, usable, and integrative science in policy-making, chiefly because of open communication and continual and iterative interactions. These processes have meant that in research design, scientists actively involve decision-makers' views and priorities, and with them data, human, and other resources. We refer to this as "in-reach" (establishing applied-research objectives through science-policy and public engagement). Below we develop several aspects that require further attention and represent contributions of and challenges to these networks.

Coordinating multiple governance levels or sectors and filling or correcting institutional mismatches. - Dialogic networks offer a platform for long-term engagement of stakeholders at multiple levels of water governance systems that would not be able to interact under conventional or more hierarchical arrangements. This is an advantageous opportunity, especially in systems characterized by centralization of power in government-led decision-making (e.g., Mexico, Chile). In natural resources governance, when multiple actors interact, interplay issues emerge both in horizontal (within level) and in vertical (across levels) interactions (Young, 2002, 2008). In vertical interplay, it is common that decision-making happens at an upper-management level, while implementation occurs in more localized settings. This can foster a lack of attention to contextual factors unique to each specific case, hindering successful policy implementation that is appropriate to local realities. In horizontal interplay, the different objectives, capacities, resources, and power of actors can generate asymmetries that benefit those with dominant discourses or agendas (e.g., in negotiations between state-level water and agricultural agencies). In both vertical and horizontal interplay, institutional mismatches can emerge and risk the achievement of long-term resilience. By establishing a dialogic network where participants can voice their concerns, knowledge and

Table 2
Degree of development of dialogic network features observed in cases.

Science-policy network	Interdisciplinary	International	Cross-sectoral	Open	Continual and Iterative	Flexible
AQUASEC	HIGH	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM
Mexico: Sonora River Basin - Urban Water	MEDIUM	LOW	LOW	MEDIUM	LOW	LOW
Mexico: Sonora River Basin - Rural Water	HIGH	MEDIUM	LOW	MEDIUM	LOW	MEDIUM
U.S.-Mexico: The Colorado Delta	HIGH	HIGH	HIGH	MEDIUM	HIGH	MEDIUM
U.S. Cienega Watershed in Southern Arizona	HIGH	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM
Brazil: Pernambuco	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM
Chile: The Maipo Basin	HIGH	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM
Argentina: Mendoza Province	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM

Source: elaborated by authors.

values, stakeholders establish a communication channel to integrate multiple backgrounds into decision-making.

Balancing power relationships and addressing political-ecology concerns. - Hierarchies and power asymmetries still coexist with and within dialogic networks. The diversity of examples presented here does not necessarily level the field for all disempowered actors. In developing dialogic networks, stakeholders need to distinguish between: 1) being aware of the fact that power relations unavoidably cross water security issues; and 2) actually incorporating subordinate actors "into the dialogue."

Some scientists have claimed both of these objectives as political-ecology concerns; however, achieving the latter is much more complex. First, the science-policy dialogues approach has an original bias on big "decision makers," due to their possession of resources and their capacity to make change happen. Second, funding conditions in fact guide and limit research agendas. In relation to this and attentive to the interaction with grassroots voices, it is common that dialogue results in a "fight for words" (e.g., water security/water sovereignty). Finally, the matter of reconciling contrasting temporalities and interests of the different actors in a mainstream and international project (academics, technicians, politicians) is extremely complicated. Resolving this problem is even more difficult when some members seek to give voice and visibility to historically marginalized actors and groups. Such a resolution would require developing links of trust and co-construction, which demand extra time and resources that are rarely foreseen in project timelines and budgets. Nonetheless, in several of the cases presented here, the nascent networks initiated discussions for the first time with those able to make policy changes, while still dealing with lobbies, powerful economic groups, and politics. Inclusiveness and iterative involvement are critical to ensure that networks' influence on policy-making avoid perpetuating power imbalances and environmental injustice.

Improving accountability and participatory processes. - Recent theoretical and empirical research shows that both accountability and participatory processes are central for realizing effective water governance and subsequently, effective integrated water management (Lane, 2014). On the one hand, accountability stimulates and consolidates good management practices and trust among stakeholders from different sectors and organizations in water-governance networks, and therefore leads to stable and long-lasting partnerships (Simon and Schiemer, 2015). On the other hand, broad stakeholder participation, although difficult to achieve in real-world settings, is critical for the effective representation of a variety of interests and values involved in water management and the pooling of resources and capacities needed to solve existing and emerging problems (e.g., the Cienega Watershed and the Colorado Delta cases). Accountability and stakeholder participation act within a continuous loop because transparency and openness of water interventions engender certainty about the responsible, equitable, and ethical setting of objectives and intended impacts. That, in turn, tends to foster the willingness of stakeholders to engage in water policy-making and implementation.

Balancing multiple demands on partners to foster resilient water systems. - This sort of constant balancing requires the continuous participation of stakeholders and a sustained funding mechanism. Trusted partnerships necessarily require time to develop. These characteristics are very difficult to obtain, unless stakeholders' jobs relate to a common effort, as the Cienega Watershed in Arizona illustrates. In that case, stakeholders collect the data needed to monitor the state of the watershed, each one looking at their own piece of land. The collective assessment effort consists of compiling data together from different stakeholders, and presenting it to the group every year. The Cienega case suggests that adaptive governance is likely to be a collaboration between organizations whose employees stay in their jobs for enough time, or move to other jobs in collaborating organizations (this contrasts with the Sonora River Basin cases for both urban and rural water, where public officials have a rapid turnover). In addition, continued engagement trough stable positions in organizations can foster stakeholders' connections to the land and their commitment to enhancing resilience in water systems.

Working with government agencies where the partnering staff changes frequently. - Networks are fundamentally about relationships among individuals and groups of people. To the extent that networks function effectively, they do so due to the sustenance of relationships over the long-term that promotes the sharing and co-production of knowledge, the creation of collaborative goals, and trust building. Given that personal relationships are at the root of high-functioning networks, they are also subject to change as individuals shift jobs and move out of the network, and new actors come in. Such movement often reflects changing power relations, especially if new leadership moves in new directions. Thus, the essential relational nature of networks is at once a strength and a potential liability. Collaborations involving Hermosillo's water utility and scientists demonstrate these effects. As Loera and Salazar (2017) have pointed out, the utility faces several management challenges, such as constant changes in its directive. In part, this is due to the director's appointment by the municipal mayor, who changes every three years. The short duration of this strategic position tends to limit long-term planning and consolidation of dialogic science-policy networks. To be effective, therefore, networks must find ways to withstand institutional change to retain strength and relevance within preexisting political frameworks.

Balancing stakeholders needs with financial sponsor ***requirements. -*** Collaboration networks are usually made possible due to external investment or grants from organizations whose objectives may not always be aligned with scientists' main research interests, nor with participants' diverse expectations of what they require to resolve their problems. Balancing these different expected outcomes is not simple. Financing organizations generally set project outcomes from the beginning, while scientific interests evolve with processes, and participants' demands increase and diversify. Then, the different stages of the process should receive enough time, so the stakeholders do not feel they are merely information sources while researchers and financiers get the results they need. This process becomes even more complex when collaboration also is necessary to develop decision tools such as models or maps. Our observations suggest that enhancement of dialogic networks will require flexibility in all involved organizations, particularly academic and financial, for an iterative and non-constrained process where information is coproduced, sufficient, and useful for everyone involved.

5. Conclusions and recommendations

We have portrayed dialogic science-policy networks as a governance approach to address water security wicked problems in arid and semi-arid regions. This approach incorporates both the structure ("network" of diverse partners) and process ("dialogic" or dialogue-based) of science-policy interactions that build upon science-policy dialogues; but the approach also transcends the structure and process by widening their temporal and spatial scales, and by addressing the multiple dimensions and sectors challenged by wicked water problems. Dialogic networks cross sectors, are interdisciplinary, international, open, continual, and iterative over the long term, and flexible, to accommodate the complexity and evolving nature characterizing wicked water problems. In building dialogic networks, there are both multiple advantages and pressing challenges that we illustrated through several cases in the arid Americas that reflect some or all the listed properties.

Maybe one of the most difficult questions regarding dialogic science-policy networks, as well as for other types of dialogic approaches, is their capacity to influence (4-I) actual shifts in water security governance (Scott et al., 2012). What we can derive from our cases is that dialogic efforts supported by IAI and other sources are indeed promoting water security by means of increased collaborations, improved knowledge and legitimacy of that knowledge, and better representations of the constantly changing reality. These shifts, however, are incremental and progressive and require constant effort to maintain momentum in policy framing, strategy design, implementation, and evaluation and assessment of outcomes. There are important challenges in assessing and evaluating results and impacts of science-policy dialogues in networks. We anticipate that novel methods that capture the adaptive capacity and resilience of social-ecological systems will become more important as the global waterscape is increasingly human-driven.

Another challenge in implementing successful dialogic science-policy networks is addressing the issue of replicability and generalizability. How can these putative models of effective networks be shared and exported across different contexts and yet remain suitable to address problems that are multi-scalar spatially and temporally? Our work on the role of networks is in large part an attempt to develop more holistic understandings of governance and the contribution of networks to make the process more effective, with water security in arid lands as our common challenge. However, since networks form in specific contexts and are fundamentally about relationships, generalizability to other contexts can never be assured.

For dialogic science-policy networks to become effective and sustainable there exist several pathways for improving accountability and engagement. Each of these pathways requires enhancing science-water governance integration (by involving a maximally diverse range of stakeholders), appreciating the impact of knowledge production, and recognizing the multi-factorial process of decision-making.

First, to some scholars, committed involvement of the full spectrum of stakeholders in the research process—including setting scientific goals and framing research questions—is key for accountability and sustained participation in water management (Simon and Schiemer, 2015), even if full inclusion of *all* pertinent stakeholders is in practice very difficult, if not impossible. The primacy often granted to scientific and 'expert' knowledge over practitioner-generated knowledge may not only alienate a critical resource for science-based solutions, but it can generate mistrust and limit the ability of networks to engage in the co-production of usable science.

Second, research has also suggested that scientists should be not only proactive in understanding power dynamics of the parties involved in water management, but also in mitigating the impact of knowledge production in exacerbating existing disparities (Lemos, 2015; Simon and Schiemer, 2015). Awareness of conflictual positions and power disparities is crucial to maintain the interest and participation of less-informed or less-influential stakeholders (e.g., the poor, women, youth, indigenous communities, racial minorities, and those geographically more isolated, etc.), whose participation is more likely to be sidelined by conventional decision-making and who are the most affected by its negative consequences. As observed by Lemos (2015) the success of a project directly correlates with facilitating stakeholders' interaction and the management of power differentials. In this interaction lies the potential to close cognitive gaps between scientists, policy-makers, and community groups as well as the establishment of a solid foundation for collaborative water management.

Third, a major challenge in the integration of science and water management is the fact that water policy-making and practice are not unidimensional nor driven by a rational imperative. Rather, pre-cognitive experiences, value judgments, language, and other cultural factors influencing those involved in decision systems shape the acceptance and use of knowledge in decision-making. For example, one recent study demonstrated that the fit of scientific evidence and stakeholders' prior values and perceptions influenced the uptake of climate information by local water managers, and that enhancing the effectiveness of collaborative research depended partially on increasing public education and outreach (Kirchhoff, 2013). Importantly, cognitive openness and bridging of new ideas among stakeholders also depends on building and maintaining trust. This is possible to achieve if the dialogic network is able to persist in the long term; to broaden its temporal, spatial, and sectoral scope of action; and to be sustainable in financial, political and academic terms.

Declaration of competing interest

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

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