Environment, Development and Sustainability (2021) 23:2337–2357
https://doi.org/10.1007/s10668-020-00677-2

A state-of-the-art review of water diplomacy

Soheila Zareie[1] · Omid Bozorg-Haddad[1] · Hugo A. Loáiciga[2]

Received: 5 June 2019 / Accepted: 9 March 2020 / Published online: 14 March 2020

Abstract
Diplomacy is the art and skill of managing international relations through negotiations between representatives of states or agencies. Water diplomacy is an innovative approach and strategic tool to resolve water issues at local and trans-boundary scales when water conflicts rise in sharing water resources. Complex water supply and sharing issues arise from the existence of multiple stakeholders such as agriculture, industry, urban and domestic users, environmental use, and others competing for scarce water. Water diplomacy may contribute to solving a variety of water conflicts and in this sense is a tool for sustainable water resources management. This paper presents a review of water diplomacy focusing on various themes such as the vitality of water as a resource, virtual water, water conflicts, international water law, and management of trans-boundary waters that are reviewed in this paper in the context of searching for cogent water diplomacy strategies. This work's findings show that conflicts about trans-boundary waters are more common in developing countries than in developed countries. The latter countries have developed trans-boundary agreements, which may serve as guidelines to developing countries in some cases. Virtual water may prevent future water conflicts by reducing water demand and water stresses and providing suitable conditions for negotiation between countries. Capacity building, training in cooperation, and negotiation are means of averting water conflicts.

Keywords International water law · Trans-boundary waters · Virtual water · Water conflicts · Management

✉ Omid Bozorg-Haddad
OBHaddad@ut.ac.ir

Soheila Zareie
Soheila.Zareie@ut.ac.ir

Hugo A. Loáiciga
Hugo.Loaiciga@geog.ucsb.edu

[1] Department of Irrigation and Reclamation Engineering, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, University of Tehran, Karaj, Tehran, Iran

[2] Department of Geography, University of California, Santa Barbara, CA 93016-4060, USA

1 Introduction

Today's world faces a complex web of interconnected water issues such as managing water allocation to meet multiple functions in the natural, societal, and political domains (Bozorg-Haddad et al. 2009; Soltanjalili et al. 2011; Sabbaghpour et al. 2012; Fallah-Mehdipour et al. 2014; Islam and Repella 2015). There are 13 river basins shared between five and eight countries, and five basins are shared between nine and 11 countries (Choudhury and Islam 2015). Allocation of these trans-boundary waters is uniquely difficult because of insufficient water and the involvement of several countries which may have divergent strategic visions of national development (Fu et al. 2018). Competition for shared water resources transcends trans-boundary rivers. Also, it involves trans-boundary lakes and aquifers.

Besides trans-boundary issues, water scarcity caused by climatic patterns and increasing water demand by growing population in arid and semiarid regions of the world, such as the Middle East, cause competition for water between regions and countries. Such competition calls for cooperative agreements concerning shared water resources (FAO 2011). Water issues are complex because they involve natural, societal, disciplinary, political, and jurisdictional boundaries (Islam and Repella 2015) at times when competing demands for scarce water are increasing.

Water diplomacy is an innovative and integrative approach to resolve complex water issues (Islam 2010), and environmental policy, water management strategies, and technical solutions are available tools to water diplomats (Islam et al. 2009; Islam 2010). Harold Nicholson (1939) presented a definition for diplomacy as: "the art of conducting dialogue between and among states." It is a tool that is strategic for sustainable water resources management and for enhancing cooperation between nations with negotiation. Hefny (2011) proposed water diplomacy is not a theory but an action. Islam and Repella (2015) defined the water diplomacy framework (WDF) as a technique or value-focused approach to management water allocation issues. The latter authors believe tools such as optimization, cost–benefit analyses, and scenario analysis may assist with decision making concerning complex problems, but do not commonly provide sustainable solutions. Honkonen and Lipponen (2018) stated that water diplomacy is intention for resolving conflicts related to water availability, allocation, and shared use between and within states.

Grech-Madin et al. (2018) reported a review of policy procedures that develop water diplomacy and then broaden water diplomacy from points of peace and conflict research. The latter authors identified political, multilevel, and normative properties tools for water diplomacy property. Within the political domain, the main subjects are politically operational and effective codes of nation-states and "norm inventory" for water governance at the interstate level of water diplomacy. The multilevel tool concerns ethnography and field data of sub-state water users. Finally, the normative properties tool is used within countries and relies on disaggregated and geo-referenced data to illustrate the alteration of water and conflict risk (Grech-Madin et al. 2018).

Gleick (1993) warned that policymakers must be aware of potential conflicts arising over water issues and cognizant of the procedures by which international bodies may reduce or avoid possible conflicts. Awareness and proficiency on water concepts in the practice of water diplomacy have resulted in cooperative agreements between states. Literature reviews indicate these concepts constitute practical and theoretical principles that must be considered in water diplomacy. Yet, there are no comprehensive studies available on this subject matter, and there is a need for a deeper understanding of such principles.

This work presents a comprehensive review of water diplomacy, addressing its most important practical and theoretical concepts, and outlines common water-sharing issues arising between countries. Figure 1 presents selected concepts pertinent to water diplomacy. This figure places selected concepts (water resources, water conflicts, virtual water, international water law, and management of trans-boundary waters) in three boxes; the concepts are closely related to water diplomacy and are reviewed in this study. The first box in Fig. 1 depicts water resources at three scales and related concepts that affect water resources, such as climate change and increasing population that tend to heighten water scarcity and conflicts. Water diplomacy and its relevance to issues related to shared waters, and common waters (trans-boundary waters) are reviewed in this work. Virtual water is mostly a concept and practice involving several countries. The second box depicts problems concerning international waters which lead to water conflicts. The third box depicts solutions to water problems achievable through negotiation and cooperation in the international arena. This paper covers the following topics: (1) water as a vital and critical resource, (2) water conflicts, (3) virtual water, (4) international water law, and (5) management of trans-boundary waters. Water diplomacy attempts to find effective ways to link science and practice, facts and narratives, and quantitative and qualitative information considering the cited five topics as exposed in this paper.

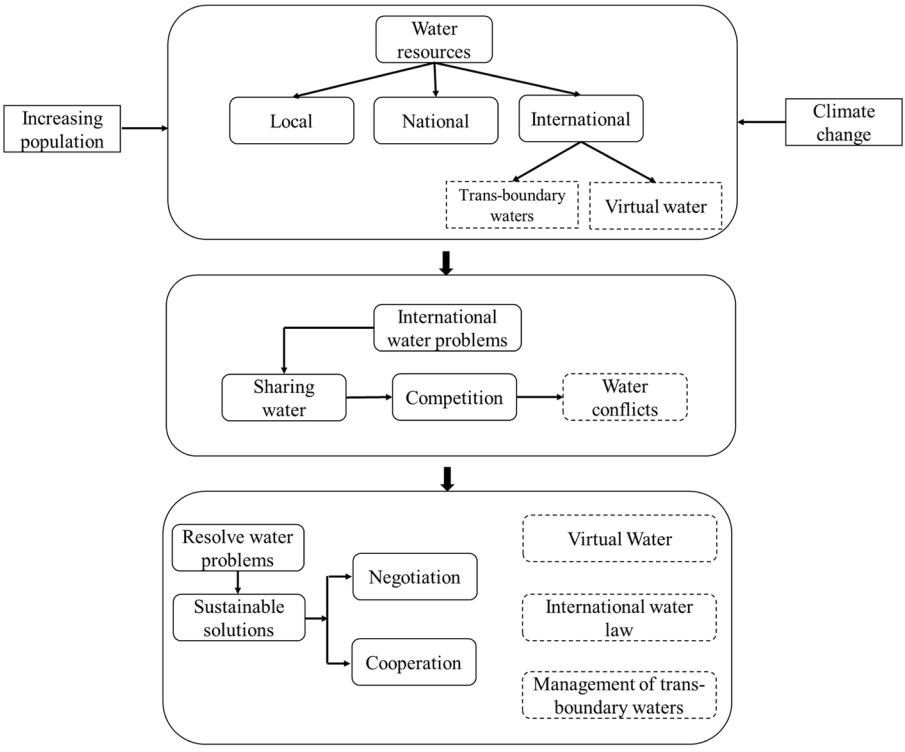

Fig. 1 Selected concepts related to water diplomacy

2 Methodology

Key concepts of water diplomacy are herein reviewed. Water as a vital resource is discussed in Sect. 2.1. Section 2.2 describes water conflicts. Sections 2.3, 2.4, 2.5 review the roles of virtual water, international water law, and trans-boundary water management in propose means of resolving and preventing conflicts.

International water law and management of trans-boundary waters are regarded as separate concepts, because the former contains agreements (in the form of doctrines, rules, treaties, principles) that were created to replace conflicts with compromise between countries through negotiation and cooperation, while water diplomacy (and its international laws) is a strategic tool for the latter.

2.1 Water as a vital and critical resource

Water concerns about water resources security are common in many countries (Foster and Ait-Kadi 2012). Water is a renewable resource replenished by rainfall, but it is scarce in many regions to meet human needs. One of the matters that influence water crises is climate change through its potential impacts on precipitation and increased water demand (Evans and Sadler 2008).

A United Nations report (UNW-DPAC 2015) highlighted the vitality of water in social, economic, and environmental systems undergoing rapid and uncertain changes. More than half of all animals and plants live in water, and water is necessary for most of the biochemical reactions that occur in all living beings. Human health depends on the availability of clean water. Approximately half the world population lacks adequate sanitation, and 20% of the world population suffering from lack of safe water for drinking (UNESCO 2002; Archer 2002). 80% of the earth is covered with water, while only 1% is freshwater and it is estimated that nearly 60% of the world's population may suffer from water scarcity by 2025 (Qadir et al. 2007) under current schemes of water supply. Increasing water demand in growing economies threatens biodiversity (Pimentel et al. 2004). Therefore, a review of the water supply to meet the human needs of the future is appropriate (Pimentel et al. 2004; Herrero et al. 2010; Tilman et al. 2011).

Water supply to urban, industry/commerce, and agriculture is inadequate in many parts of the world primarily because of management practices (Klimes et al. 2019). Evans and Sadler (2008) argued that agricultural and nonagricultural water-user groups such as sanitation, drinking water, industry, and energy must cooperate as they practice more water-efficient approaches to freshwater consumption. This is true because most of freshwater in aquifer systems, rivers, and lakes which serve multiple functions and users do not follow state borders, rendering water diplomacy a useful tool to promote collaborative regional and international cooperation through agreements and treaties (Council of the European Union 2013). Therefore, different major water uses, i.e., urban (domestic), industry/commerce, and agriculture, are discussed in the following sections emphasizing water management practices.

2.1.1 Urban (domestic) water use

Approximately 8% of freshwater globally is for domestic use and drinking (Vetter 2016). Life in cities has different demands for water such as drinking, cooking, washing, and

health. Fan et al. (2017) studied urban water use and its impacts on cities in China. They showed that water consumption in cities affected by various factors (e.g., meteorological factors, water supply, and socioeconomic condition) that vary across cities.

Domestic water use is a national concern (Vetter 2016), and water diplomacy studies may be required to design water policies for this use. Also, domestic water use can be the cause of conflicts between different water-user sectors because of their interactions and the dichotomy of water demand and supply (Tribaldos 2013). Vetter (2016) in a report on water diplomacy estimated that efficiency gains in water use in the domestic sector could lower consumption by about 2 billion m^3 of water annually.

2.1.2 Industrial water use

The industrial sector consumes water for cooling, heating, washing, fabricating, and processing of products. Globally 59% of the water used in high-income countries and 8% in low-income countries serves the industrial sector (Commission for Environmental Cooperation http://nationalatlas.gov/articles/water/a_wateruse.html#five). Industrial sector water allocations generate conflicts not unlike those arising in the urban sector.

2.1.3 Agricultural water sue

The agricultural sector consists of two major water users, i.e., irrigation and livestock. Irrigated lands produce 40% of today's world's food (FAO 2011). Water security affects food security, which remains a challenge in many countries. It is estimated that 260 million hectares worldwide are irrigated presently while it was less than 100 million hectares in 1950 (Evans and Sadler 2008). About 75% of the total freshwater in the world is currently used for irrigation (Qadir et al. 2007). In some countries nearly 90% of the total water resources are devoted to irrigation (FAO 2003). Pimentel et al. (2004) estimated that agriculture consumes about 70% of freshwater worldwide. The latter authors estimated that 1000 L of water may be required to produce 1 kg of cereal grain and 43,000 L to produce 1 kg of beef. Ran et al. (2016) assessed the effect of water in supplying the global food and livestock production systems. He contended that there is no obvious or consistent method for assessing the amount of water input to livestock production. The production of more food may be achieved without depleting additional natural resources by using various methods to reduce water use in agriculture. Those include installing high water-efficiency irrigation methods, planting drought-resistant varieties, and scheduling the planting times to match occurrence of rainfall. Evans and Sadler (2008) argued that agriculture, in particular, must improve its flexibility in managing the rate, duration, and frequency of water supplies to successfully allocate limited water.

The water intensities in agricultural and livestock production vary considerably among countries due to variations in the quantity of water resources, local climate conditions, soil types, agricultural practices, and cultural traits. Demand for food and water is increasing in developing countries with growing populations and economies such as Brazil and China (Bruinsma 2003; WEO 2010; Gerbens-Leenes et al. 2013).

Food security looms uncertain in many developing countries, and it is related to water scarcity, social dysfunctions caused by war, and political and economic instabilities (Smith 1998). It has been estimated that one billion people are afflicted by hunger in the developing world (Barrett 2010). The United Nations Educational, Scientific, and Cultural Organization (UNESCO 2006) estimated the cropping intensity for meeting world demands must

rise by 40% by 2030, and the amount of water allocated to irrigation must increase correspondingly by 14%. Feeding a growing world population would require larger production of nutritious vegetable foods while facing scarce natural freshwater and arable land.

Water crises cause numerous national and international conflicts. The next section addresses the topic of water conflicts.

2.2 Water conflicts

Gleick (2014) quotes from Jacobsen (1969) and Cooper (1983) that the earliest water-related conflict ever recorded occurred over 4500 years ago over access to irrigation water, whereby Urlama, king of the city state of Lagash in ancient Mesopotamia, cut off water to deprive neighboring Umma. His son, II, also diverted water from irrigation systems feeding Umma.

Population growth, pervasive pollution, and weak institutions worsen water scarcity and raise the threat of conflict between states (De Angelis et al. 2017). North African regions were the first to suffer from severe water scarcity (Allan 2000), followed by southern Africa (Allan 2002). About 25% of the African population experiences water stress, while 69% of that continent's inhabitants live under conditions of relative water abundance (Vörösmarty et al. 2000; Algamal 2011).

Water conflicts are caused by issues involving quantity, quality, and timing of water use (Kramer 2004; Wolf et al. 2005). Competition over a limited quantity of water is the primary reason for water-related conflicts. Degradation of water quality is another cause of contention between those who cause it and those affected by it. Degraded water quality may affect humans or the environment. The timing of water use is the third cause of water conflicts. Consider for instance the operation of dams, where water storage can be dedicated to supply irrigation water during the summer, while releasing water during the winter to generate electric power (Kramer 2004; Wolf et al. 2005).

There is another type of conflict afflicting trans-boundary waters. Petersen-Perlman et al. (2017) defined "trans-boundary water conflict" as verbal, economic, or militarily hostile actions between stakeholders over internationally shared water resources, and "violent trans-boundary water conflict" as militarily hostile actions involving trans-boundary water stakeholders. Access to water becomes the source of potential conflict between countries sharing trans-boundary rivers, lakes, and aquifers (Priscoli 1996; Wolf 1996; Pallett et al. 1997). In a progressively water-stressed world shared water resources are becoming an implement of power, fostering competition within and between countries (Rivera 2015). Changes in the alignment of a boundary river may lead to disputes over ownership wherever specific activities are associated with the original river channel (Ashton 2007).

Among the issues underlying water conflicts are the spatial and temporal scales. The first step in promoting the understanding of human societies in relation to water has been the creation of appropriate platforms providing general information on water issues at national, regional, and international levels. Water conflicts can be internal to a country or international. Wolf et al. (2005) defined several geographical scales in relation to water conflicts. The international scale concerns political boundaries of two or more countries. The national scale involves tribes, water-use sectors, rural and urban populations, and states or provinces, and the local scale involving people in special communities, such as farmers, or fishermen depending on riverine fisheries. Local-scale water conflicts tend to escalate rapidly and require prompt responses. In contrast, trans-boundary water conflicts

tend to develop gradually, and responses to these situations must be appropriate to the scale of the problem confronted (Wolf 1996; Turton 1999; Ashton 2007).

Ashton (2000) recognized four separate groups of water conflicts concerning spatial scales:

- Within communities (conflicts take place over a relatively small area: between members of the same community);
- Between communities (conflicts take place over a relatively larger scale: between individuals within each community or with a neighboring community);
- National (conflicts take place among groups of communities within a country: these conflicts are over the rights of communities located in the same country to use water that is not located within their geographical areas of jurisdiction). Inter-basin water transfers raise this type of conflicts. A well-known example of water conflicts at this scale can be found in California (a state of the USA), where there is tension over the transfer of water between water-rich regions (northern California) to water-poor regions (southern California); and
- International (conflicts between countries: water resources are shared by several countries which contest each other's right to use the common waters). Riparian rights are one of the most common examples of these conflicts to rivers which flow through international boundaries, triggering disputes rise between "upstream" and "downstream" countries.

Ashton (2000) described another spatial scale, whereby two countries dispute the precise location of the international boundary that separates them.

Among examples of national conflict are the violence along the Cauvery River in India and Owens Valley residents (California) blowing up a pipeline conveying water to the City of Los Angeles from a distant region (Bernabé-Crespo and Loáiciga 2019). Many of the conflicts about territory and resources control in the USA have pitted indigenous peoples and European settlers (Yoffe et al. 2004). There are examples of international conflicts. A long-standing theme of contention is the border along the shifting San Juan River between Costa Rica and Nicaragua. It is a periodical conflict because of the naturally shifting location of the river channel and the interpretation of the navigation rights written in the Cañas–Jerez Treaty of 1858 that gives the river to Nicaragua by putting the border on the right bank of the river, but gives navigation rights to Costa Rica (O'Brien 2013). Karaev (2005) studied conflicts involving the sharing of water between several countries, and border conflicts that have arisen in central Asia since the collapse of the USSR's (Union of Soviet Socialist Republics) over water resources control. These resources were domestic before the collapse of the Soviet Union and became international after its collapse. In 1976 the Six-Day War involved the issue of water resources of the Jordan River between Israel and Arab states. Israel diverted the Upper Jordan River to the National Water Carrier with a pipeline that connects the Sea of Galilee to the Negev desert (Cohen 1998; De Angelis et al. 2017).

Lazerwitz (1993) stated that according to the United States Department of State conflicts over trans-boundary water resources could occur in at least ten regions in the world. Most of them are in the Middle East, where water conflicts date back 5000 years (Gleick 1993), and the water deficit has been worsening since the 1970s (Allan 1997, 2000). This region is beset by decreasing water resources due to climate change (Topcu et al. 2010; Amini et al. 2016). There are several cases of contested trans-boundary waters in the Middle East and Asia (Detges et al. 2017). A few are cited next.

- The Euphrates and Tigris are rivers that harbored early Middle Eastern civilizations in a region beset by water scarcity (Daoudy 2004). The Euphrates–Tigris rivers lie mostly within Turkey, Syria, and Iraq, with Iran containing parts of the Tigris basin. Turkey contributes 90% to the Euphrates' stream flow, while Syria contributes just 10% of the stream flow (HARC research, Reports1-EuphratesTigris). Unilateral irrigation plans altering the Euphrates–Tigris Basin (ETB) flows of the rivers have been implemented since the 1960s, and this is coupled with political tensions between the cited ETB countries, causing strained relations in the ETB. In spite of cooperation efforts renewed in the 2000s, these have yet to produce a formal agreement on managing the ETB waters (Kibaroglu, and Maden 2014). Drought in the ETB endangers food and water security in the tributary countries. Drought may become more frequent and intense in the future exacerbating vulnerabilities to water scarcity in the ETB (Amini et al. 2016).
- The Nile River basin in the Middle East has faced many conflicts due to the common water resources shared by 11 countries. The Nile Basin Initiative (NBI), an intergovernmental technical partnership of 10 Nile basin countries (Eritrea acts as an observer), was established in 1999 to manage and develop shared water of Nile Basin water through building capacity, the generation and sharing of knowledge, and support for project preparation and continued monitoring (The world Bank 2019). The NBI was successful in its attempts to strengthen cooperation by increasing trust among riparian countries via negotiation. However, since 2007, different interests between upstream and downstream countries have brought negotiations to a standstill, pitting Egypt (and, to a lesser extent, Sudan) against upstream riparian countries, especially Ethiopia. In 2015, negotiations between Egypt, Sudan, and Ethiopia over a major dam under construction in Ethiopia led to a framework agreement (ECC Platform website).
- Another trans-boundary water dispute in the Middle East is between Afghanistan and Iran that date to the 1870s. The waters of the Helmand and Harirud rivers flow from Afghanistan to Iran. Afghanistan's agricultural expansion and construction of dams in the two rivers pose a threat to water security in Iran, especially in the eastern and northeastern provinces. Although there were different negotiations between the two countries (from 1930 to 1969), in 1973 they agreed to flow 22 m^3/s of water to Iran, and Iran allowed Afghanistan to access the ports of Bandar Abbas and Chabahar. Also, this agreement was not completely implemented due to different reasons in both countries such as political developments in Iran and Afghanistan (Amen 2016). Therefore, cooperative initiatives have not yet achieved a breakthrough between these two countries concerning this matter (Amen 2016).
- Conflicts over the construction and operation of Syrian dams on the Yarmouk River since 1990s, between Jordan and Syria (Gleick 2014).
- Severe mismanagement of water resources led to declining Yemen's water availability. Water scarcity plays a role in fueling the political and security crisis in Yemen (Suter 2017, 2018).
- The Arpacay River forms the border between Turkey and Armenia, two co-riparian countries that have put their tensions aside and cooperate in their mutual aims sharing trans-boundary waters equitably even though they do not have formal diplomatic relations (ECC Platform website).

There are other situations involving water tensions occurring in many other regions, such as Bolivia, India, Somalia, the Mekong River pitting China and Laos, the Colorado and the Rio Grande rivers shared by the USA and Mexico, and the Parana River in South America.

From another perspective, water has potential for creating cooperation between nations and communities rather than being a cause for conflict. In this respect, Barnaby (2009) argued that "small-scale water disputes can lead to the development of diplomacy and help to prevent bigger water wars." Yet, water conflict is on the rise spearheaded by improving living standards and the concomitant increase in water demand.

Xie and Jia (2017) argued that water disputes between two countries are strongly affected by domestic water politics and bilateral relations. The latter authors analyzed water cooperation with respect to the water conflict between China and India and proposed a resolution mechanism that aims to benefit the management of shared rivers. Their results showed that international water management in this case is complex to the extent that China and India have only reached preliminary agreements managing common rivers.

Information sharing functions as a diplomatic channel to promote trust-building between riparian states sharing rivers, lakes, and aquifers (Conca 2006; Karkkainen 2006; Zawahri 2008, 2009). Cordial relations between states and provinces of countries, and between countries who share water resources, facilitate the achievement of shared water resources management that can be effectively enforced without involving third parties or arbitrators to settle down their water conflicts (Ashton 2000).

Turton et al. (2006) assessed internationally shared water resources and potential conflict by examining trans-boundary water resource management in southern Africa. The latter authors concluded that water conflicts exhibit several levels of geographical scale ranging from regional authorities to community pressure groups. Their study demonstrated the importance of geographical scale in the analysis of potential for conflict or cooperation. The latter authors demonstrated that demand-side drivers, such as population growth, agricultural productivity, and economic development, are likely to have a stronger impact on water-conflict risk than supply-side factors, represented by climate variability. The same authors found that violent water conflicts are rare, and that factors conductive to restraint, such as a stable political regime, may lead to cooperation. Overall, their analysis suggested the combined study of demand, supply, and restraint is suitable to explain domestic water-related conflict and cooperation.

Hefny (2009) proposed that approaches such as system analysis and system thinking may be helpful in handling water conflicts and water management negotiations. Gizelis and Wooden (2010) reported that political and institutional responses can intercede between resource scarcity and the risk of intrastate conflict. The latter authors argued that political institutions and democratic governance have a fundamental role in preventing and reducing water conflicts. Hefny (2011) proposed capacity building and training in negotiation theory as prerequisites to resolve water conflicts. The latter author cited multiple reasons for water conflict. Those are the interdependence of people and responsibilities, jurisdictional ambiguities, functional overlap, competition for scarce resources, differences in organizational status and influence, incompatible objectives and methods, differences in behavioral styles, differences in access to information, distortions in communications, unmet expectations, unmet needs or interests, unequal power or authority, misperceptions, and others. Susskind and Islam (2012) stated that countries sharing trans-boundary water must build and enhance trust in the search for sustainable solutions that are acceptable to all sides. Failing this, water conflicts cause degradation and destruction of water resources affecting all stakeholders.

Much progress remains to be done to resolve these water conflicts cooperatively and equitably. Sustainable solutions to water conflicts can be obtained through negotiation and cooperation, i.e., resorting to virtual water, international water law, and management of trans-boundary waters. The unequal distribution of water and land resources begets

for inter-regional trade that takes advantage of the geographical characteristics of water and land resources (Ali et al. 2017). Trading water through goods, especially agricultural goods, is named virtual water holds potential in the realm of water conflicts solving. Virtual water is a concept that may help prevent conflicts and substantially reduces the water demand in domestic food production and compensating for a lack of water (Yang and Zehnder 2007). The next section ponders this topic.

2.3 Virtual water

Following studies in the arid and semiarid regions of the Middle East and Northern Africa (MENA), the concept of virtual water was introduced by Allan (1993, see also Hoekstra and Hung 2005). For example, Antonelli and Tamea (2015) studied political economy in the MENA region through virtual water trade to investigate the effects of the region's economies on water and food needs; Sakhel et al. (2017) quantified virtual water export by presenting useful methods in the MENA region; Bacon (2017) studied virtual water trade in agriculture to realize this trade in the MENA region. The international trade of agricultural goods transfers water "virtually" that input as a factor of production in the country of origin to the country of consumption. The volume of water transferred in this manner is known as "virtual water" (Allan 2000; Antonelli and Sartori 2014), and the transfer is called virtual water trade (Tuninetti et al. 2017). Also, virtual water is defined as the amount of water that is necessary to produce goods, including food, furniture, clothes, and so on. The term "water footprint" is sometimes used synonymously with "virtual water," even though "virtual water" concerns water used in the production of consumer products, while, strictly, "water footprint" concerns water human consumption, say, expressed in liters per day per capita.

Barnaby (2009) proposed that countries solve their water shortages through trade and international agreements (see also, Tamea et al. 2014; Fracasso 2014). Several countries in the Middle East afflicted by water scarcity successfully compensated their freshwater shortages through importation of virtual water contained in food products such as rice, maize, and wheat. For instance, one thousand cubic meters of water is required to produce one cubic meter of wheat. Therefore, by importing a cubic meter of wheat a water-poor economy avoids all the economic costs and environmental stresses of mobilizing that volume of water. Virtual water trade, therefore, creates an opportunity to minimize consumption of local water by increasing the import of water-intensive goods (De Angelis et al. 2017). Europe accounted for slightly more than 50% of global virtual water imports in 1960, percentage that has dropped to about 36% in 2015–2016, Asian Pacific countries have been virtual water importers and that trend has been accentuated in recent years, and Africa was a net virtual water exporter until 1980. Thereafter, it became a net importer (Duarte et al. 2016). China has 6% of global freshwater resources and possesses about 8% of global cultivated land to provide food for a population equivalent to 20% of the world's population. It constitutes a remarkable example for virtual water accounting (Ali et al. 2017). Since the 1990s China has increasingly relied on virtual water (Ali et al. 2017). This has materialized by importing land- and water-intensive crops (e.g., cereal, soybean, edible oils, and sugar) and the export of labor-intensive products (vegetables, fruits, and processed foods) (Huang et al. 2010; Ali et al. 2017). The USA is the largest exporter of virtual water. Irrigated lands in the USA rose from 7.7 million acres in 1900 to 49.4 million acres in 1992 (Carter et al. 2006), 56.6 million acres in 2007, 55.8 million acres in 2012 (USDA 2019), and 58 million acres in 2017 (Walton 2019). The USA is a prolific exporter of agricultural products

because of its large-scale and efficient agriculture linked to the world's food market (Olmstead and Rhode 2000; Duarte et al. 2016).

Effective food trade between nations constitutes a means to feed disadvantaged populations in the twenty-first century (Hanjra and Qureshi 2010). The associated volume of traded virtual water rose from 403 km^3 in 1965 to 1415 km^3 in 2010. Duarte et al. (2016) studied agricultural virtual water flows and assessed the progress of virtual water flows over the long term and as an indicator of water stress. The latter authors demonstrated that the international virtual water trade has risen at an average annual rate equal to 2.7% from 1965 to 2010. Reimer (2012) researched the economics of virtual water trade and developed theoretical results showing the virtual water concept has an economic basis (see also, Merrett 1997, 2003), and that profit is another reason behind the rise of increasing virtual water trade (beside solving water shortage issue).

Benefits from virtual water trade and reach to food security consistent with ecologic conservation require political stability and security, as well as affordability of traded products by domestic consumers (Hanjra and Qureshi 2010). It can be postulated that "virtual water diplomacy" is a necessary aspect of water diplomacy given that virtual water trade can affect conflicts over water under scarcity conditions (De Angelis et al. 2017). Water diplomacy may create opportunities among different countries through negotiation by considering virtual water in the management of regional and international water resources and water demands.

Rosa et al. (2019) described that globalization of water through trade results in the drying up of rivers and highlighted the need for policies to achieve sustainable water and food security. Therefore, there must be other factors besides the virtual water trade that must be employed in the solution of water conflicts.

2.4 International water law

About 90% of the world's population has common water resources with neighboring countries (Sadoff and Grey 2005; FAO 2011). The achievement of sustainable development and avoidance of water conflicts arising from the use of common water resources requires a legal framework, in which international and national water laws are essential for the "equitable" and "reasonable" uses of all freshwaters without causing harm their users (E-Learning Capacity Development Project in International Water Law). Agreements and treaties have been created to replace conflicts between countries. Lazerwitz (1993) proposed that irrespective of political boundaries treaties governing trans-boundary water resources must consider public resources and protect ecosystems.

There are two historical doctrines about trans-boundary waters. First, the Harmon doctrine dictates an upstream country may freely utilize the portions of the water within its territory regardless of impacts to downstream countries. Secondly, the territorial integrity doctrine proposes that none of the activities of a riparian state in a river, aquifer, or lake should lead to harm to other riparian states (Lazerwitz 1993). Evidently, the latter doctrine is consequential with water diplomacy and efforts to develop cooperative agreements leading to sustainably use of shared water resources.

Rules associated with water resources are substantially important procedural elements of any governance system. Legal rules have often failed to protect environments well or promote sustainable development in shifting contexts (Ostrom 2005; Ebbesson 2010). The "Helsinki Rules" adopted by the International Law Association (ILA) in Helsinki, Finland, in 1996 including six chapters and 37 articles about rights of bordering nations prescribing

how to share water resources equitability. These rules concern the uses of international rivers considering ground waters hydraulically connected to these rivers. The International Law Committee (ILC) was established to provide a treaty governing the uses of international water resources through cooperation in developing and protecting international rivers (Lazerwitz 1993). Such text was presented to the United Nations General Assembly 1997 Water Convention (Hefny 2011).

Possible changes in international water law and regional water treaties could be implemented to minimize conflicts (Gleick 1993). Narasimhan (2008) analyzed water, law, and science, borrowing for his analysis from the Roman law of antiquity, which touched on surface water and groundwater and on the relation between science and water law according to the ideology of two millennia ago. Albrecht (2013) had a discussion on the European Water Framework Directive (WFD), a legislative instrument in water policy which focuses on international river basin management. The goal of WFD for managing river basin is to obtain suitable conditions in all the water resources, including surface and ground waters, in the European Union. Water planning under WFD was successful in planning regulated by the Federal Water Act (FWA) in Germany. The success is due to WFD planning tools addressing entire river basins, concentrating on water quality rather than on its quantity and paying attention to detail. The WFD is a far-reaching concept in the water field (Chase 2001; Lawrence et al. 2004; Hering et al. 2010; Liefferink et al. 2011). It gave impetus to water planning in Europe (FWA, ELAW 2002). Clarvis et al. (2014) reviewed studies about water resources management law and feasible examples of "legal mechanisms" and demonstrated "adaptive governance and integrated water resources management" provide sound management principles for policymakers that consider uncertainty into legislation and policy making. Gupta et al. (2014) reviewed international law and analyzed its standing with respect to "the traditional rights of indigenous people to water and how states deal with those rights." The rights of native people have received irregular recognition over time. Formalization and institutionalizing of these rights have in some cases protected the claims of indigenous people to their ancestral lands, and the waters, ecosystems, and minerals in these peoples' lands. Roa-García et al. (2015) analyzed the advances of, and hindrances to, attempts at modifying the balance of power over water through the use of the law as an instrument for social transformation, and to characterize the alternatives in some ways that challenge neoliberal principles. The latter authors assessed the major legal tensions in Bolivia, Colombia, and Peru. These cases showed that the law is a field in which prior debates, consultations, approvals, implementations, applications, and reforms produce tensions and struggles in the search for a balance between social regulation and freedom to act in a modern society.

Properly applied water diplomacy and implementation of the rule of international law can alleviate and prevent conflicts and enhance cooperation. Water diplomacy is conducive to reaching consensus among countries guided by international law. Hence, the resolution of water conflicts should include capacity building and training in negotiation theory and related skills; water diplomats must be proficient in the skills of mediation, litigation, arbitration, and negotiation, to be able to write water agreements for managing international waters cordially and effectively.

2.5 Management of trans-boundary waters

About 40% of the world's population, 50% of the earth's surface area, and 60% of the global freshwater flow are located in 145 riparian countries and 263 international basins (Wolf

et al. 1999). Water diplomacy seeks to reach agreements about internationally shared water resources (Hefny 2009). Misunderstanding, mistrust, incorrect or insufficient information cause mismanagement in the administrative and conceptual realms (Petersen-Perlman et al. 2017). On the contrary, water diplomacy is a strategic tool for integrated water resources management (IWRM). The latter authors described "boundaries" in various ways including "the actual or conceptual spaces, economic sectors, sovereign nation-states, contested areas, ethnic or language regions, other legal jurisdictions, climate zones, mountain ranges, infrastructure, or socially constructed concepts of the environment, space or history." IWRM was introduced to improve the management of the world's limited water resources and avoid related conflict of this scarce resource. Gao et al. (2014) investigated water savings identified by IWRM and demonstrated that by applying IWRM the local freshwater use decreased by 21.5%. Access, demand, usage, and management of trans-boundary water are complex due to multiplicity of political, social, and jurisdictional institutions involved, as well as the existence of various physical, ecological, and biogeochemical scales (Choudhury and Islam 2015; Petersen-Perlman et al. 2017).

Swain (2001) argued that reaching successful agreements on trans-boundary water is an elusive task. Giordano and Wolf (2003) reported on the past decade's developments on international trans-boundary water management at the regional and basin scales. The latter authors assessed continuing weaknesses in the management of internationally shared river basins and suggested policy options to the international community supporting integrated management of international waters. Significant improvement in international trans-boundary water management has been made, yet essential vulnerabilities remain and many water basins lack cooperative management frameworks (Giordano and Wolf 2003). Böhmelt et al. (2014) focused on water resources demand and supply in the analysis of water management within a theoretical framework while considering factors that lead to restrain the actors involved. They demonstrated that considering demand, supply, and restraint enhances cooperation and the ability to solve domestic water conflicts.

Gleditsch et al. (2004) studied water wars and fuzzy borders conflicts with an emphasis on the linkage between trans-boundary waters and interstate conflict. Competition for limited supplies can induce violent conflicts between nations as water scarcity worsens (Gleick 1993). Risk of international conflicts exists between upstream and downstream countries, especially in the Middle East and Africa (Gleditsch et al. 2004). Swain (2001) reported that most trans-boundary water agreements have been reached in developed countries of Europe and North America. On the other hand, developing countries, prominently in Africa, have not enjoyed the same success. The developed countries harbored four river basins regulated by 175 treaties and shared by four or more countries. The developing countries encompassed 12 river basins regulated by 34 treaties and shared among four or more countries. Five river basins regulated by 31 treaties are shared by four or more countries in Asia. An example of successful trans-boundary water management is the agreement reached between Canada and the USA called the Great Lakes Water Quality Agreement (GLWQA) to commit the USA and Canada to restore and protect the waters of the Great Lakes in perpetuity (Botts and Muldoon 2005; EPA). The United Nations' Department of Economic and Social Affairs (UN-DESA) supports international cooperation for developing and developed countries and provides technical support for developing countries on trans-boundary waters. The Global Environment Facility (GEF), an international financing mechanism established in 1991, supports developing countries in improving cross-sectoral management of trans-boundary basins and aquifers (UNW 2008).

Governmental action is necessary to involve stakeholders in water management that would restore the health of streams, lakes, and aquifers depleted by water withdrawals and

diversions (Huang et al. 2010; Fulazzaky 2014). Successful implementation of IWRM relies on the sound management, integrated planning, "water pays for water" principles, coordination of stakeholders' interactions on the basis of seller–buyer approach (Fulazzaky 2014). Petersen-Perlman et al. (2017) concluded that parties involved in water-conflict resolution must become effective practitioners of water diplomacy and must invest in institutional capacity building.

3 Conclusion

We summarized previous research in this section to provide visions and directions for future studies. This paper makes an attempt at linking water diplomacy with the tenets of water as a vital resource, water conflicts, virtual water, international water law, and management of trans-boundary waters, which are practical and theoretical aspects of water diplomacy.

Tensions and conflicts that take place in many regions over access to water threaten national and international peace and security, especially in developing countries that cope with multiple issues such as rising population, water shortage, climate change, lack of international agreements, which are conductive to social and political instability, migration, and violence. Figure 2 summarizes the reasons underlying conflicts over water.

Water diplomacy is a useful tool for avoiding or reducing conflicts arising from using shared water resources. A collaboration between decision makers and the scientific community through water diplomacy can lead to successful resolution of many water problems. Figure 3 shows some solutions to control and resolve water conflicts, although providing management principles to policymakers is a complex process.

Development in a trans-boundary basin must consider the complex interactions between participating stakeholders. Based on the portions of water use by the agricultural sector (almost 75%) and the urban sector (almost 8%) the agricultural sector could achieve the largest share of water savings among several water-using sectors, and the urban sector could achieve a smaller share of the water reduction. Also, downstream reaches of river are directly affected by their upstream riverine environment, and reverse feedbacks, i.e., from downstream to upstream regions may also occur. Generally, downstream countries are more vulnerable than upstream countries concerning the use of stream flow, creating an asymmetric relation between trans-boundary countries that calls for water diplomacy to resolve issues in a durable manner. Water diplomacy may help settle water problems and provides a foundation for sustainable development through negotiation.

Water as a vital resource is essential for socioeconomic developments. In some instances, water scarcity can be alleviated through the consideration of virtual water involving the international trade of goods. Water diplomacy provides a useful framework to enhance cooperation between countries by trading water through the exchange of products. Virtual water provides many possibilities to enhance food security by encouraging trade between water-rich and water-poor countries and regions.

Agreements and treaties have been created to replace grievances existing from past conflicts between countries. Moreover, another key matter in the resolution of water problems is international water law. International water law and regional water treaties offer immense possibilities to minimize conflicts. Policymakers must develop and implement programs to assure the conservation of water, control water pollution to protect public health, agriculture, and preserve environmental well-being. A promising

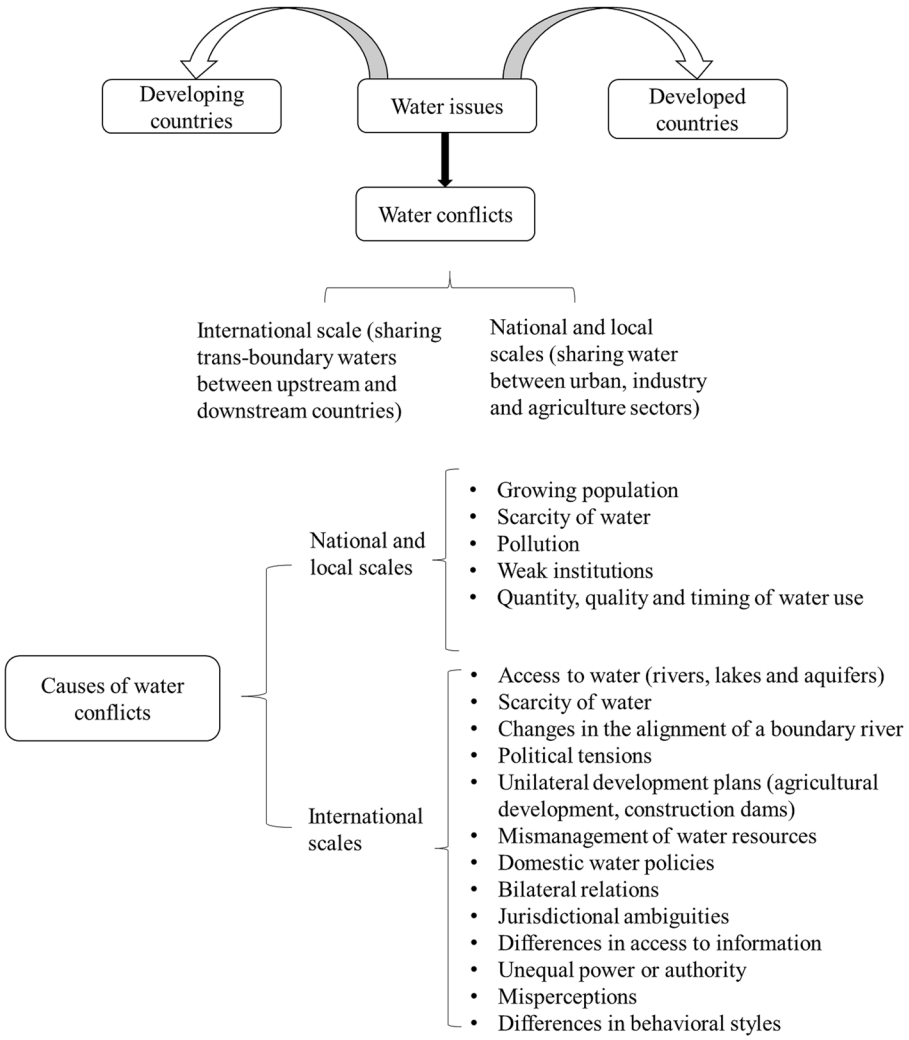

Fig. 2 Reasons for water conflicts

foundation for such planning was advanced by the ILC, which proposed rules for water use that were accepted at the 1997 Water Convention. Water diplomacy may achieve No-Harm Rules and create benefits for all water users through implementation of water laws.

The benefits of water diplomacy are measured by the resolution of water conflicts and the creation of opportunities for rewarding and peaceful coexistence. Water diplomacy provides the tools to pursue negotiations and encourage and engage stakeholder to achieve lasting, mutually beneficial agreements despite the elaboration of water conflicts. Preventing water conflicts benefits from concentrating on new, longer-term solutions, which are more effective than focusing on short-term fixes that do not achieve lasting beneficial outcomes for all the parties involved. Evidently, all stakeholders must participate in the resolution of common water problems, paying attention to water use,

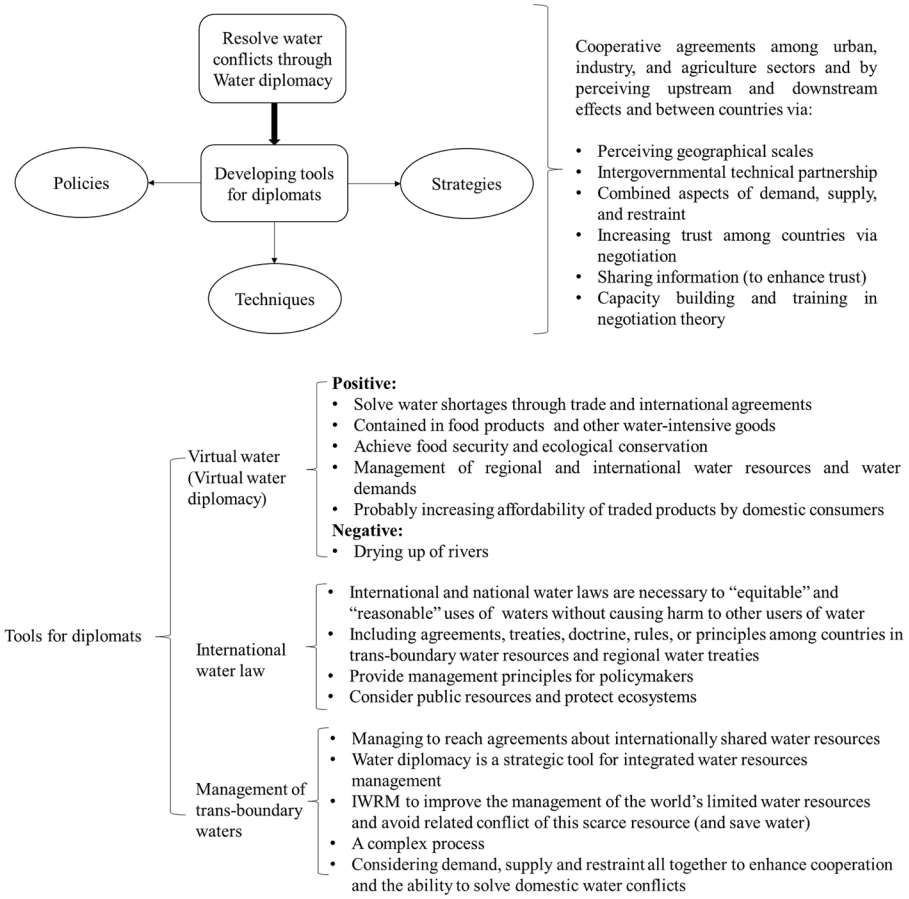

Fig. 3 Available solutions to prevent and reduce water conflicts through water diplomacy

economic development, rules of engagement, and other water-related issues that affect the achievement of sustainable water resources utilization.

It is recommended that, in addition to the concepts presented in this paper, water diplomacy focuses on multiple factors affecting stakeholders, including environmental quality and preservation of water resources, quality of life and food security, climate change and water security, and the nexus between water and energy resources. We must highlight that water diplomacy may not lead to entirely peaceful coexistence of trans-boundary countries; yet, it may diffuse and contain violence between countries sharing common waters.

Acknowledgement The authors thank Iran's National Science Foundation (INSF) for its financial support of this research.

Compliance with ethical standards

Conflict of interest The authors declared that they have no conflict of interest.

References

Albrecht, J. (2013). The Europeanization of water law by the water framework directive: A second chance for water planning in Germany. *Land Use Policy, 30*(1), 381–391.

Algamal, S. A. (2011). An assessment of climate-induced conflict risks over shared water resources in Africa. In W. L. Filho (Ed.), *The economic, social and political elements of climate change, climate change management*. Berlin: Springer. https://doi.org/10.1007/978-3-642-14776-0_2.

Ali, T., Huang, J., Wang, J., & Xie, W. (2017). Global footprints of water and land resources through China's food trade. *Global Food Security, 12,* 139–145.

Allan, J. A. (1993). Fortunately there are substitutes for water otherwise our hydro-political futures would be impossible. In *ODA, priorities for water resources allocation and management* (pp. 13–26). London: ODA.

Allan, J. A. (1997). *Virtual water: A long term solution for water short middle eastern economies?*. London: University of London.

Allan, J. A. (2000). *The middle east water question: Hydropolitics and the global economy*. London: IB Tauris.

Allan, J. A. (2002). Water resources in semi-arid regions: Real deficits and economically invisible and politically silent solutions. In *Hydropolitics in the developing world: A Southern African perspective*. African Water Issues Research Unit, University of Pretoria, South Africa.

Amen, F. (2016). Water dispute escalating between Iran and Afghanistan. Atlantic Council, South Asia Center.

Amini, A., Zareie, S., Taherei, P., Yusof, K. B. W., & ul Mustafa, M. R. (2016). *Drought analysis and water resources management in Euphrates-Tigris Basin* (pp. 97–112). INTEC: River Basin Management.

Antonelli, M., & Sartori, M. (2014). Unfolding the potential of the virtual water concept. What is still under debate? *Environmental Science & Policy, 50,* 240–251.

Antonelli, M., & Tamea, S. (2015). Food-water security and virtual water trade in the Middle East and North Africa. *International Journal of Water Resources Development*. https://doi.org/10.1080/07900627.2015.1030496.

Archer, H. (2002). *The challenge of sustainability, an action agenda for the global environment*. Washington, DC: Global Environment Facility (GEF). ISBN 1-884122-79-5.

Ashton, P. J. (2000). Southern African water conflicts: Are they inevitable or preventable? In *The African dialogue lecture series. Pretoria University, South Africa*.

Ashton, P. J. (2007). Disputes and conflicts over water in Africa. In N. Mlambo (Ed.), *Violent conflicts, fragile peace: Perspectives on Africa's security*. London: Adonis and Abbey.

Bacon, D. (2017). The MENA region, the virtual water trade, and the opportunity cost of agriculture. Masters' thesis at the University of Leiden, Netherlands.

Barnaby, W. (2009). These letters respond to the essay 'Do nations go to war over water?'. *Nature, 459,* 282–283.

Barrett, C. B. (2010). Measuring food insecurity. *Science, 327*(5967), 825–828.

Bernabé Crespo, M. B., & Loáiciga, H. A. (2019). Water supply in Los Angeles metropolitan region (USA). *Agua y Territorio, 13*(1), 35–42. https://doi.org/10.17561/at.13.

Böhmelt, T., Bernauer, T., Buhaug, H., Gleditsch, N. P., Tribaldos, T., & Wischnath, G. (2014). Demand, supply, and restraint: Determinants of domestic water conflict and cooperation. *Global Environmental Change Part A: Human & Policy Dimensions, 29,* 337–348.

Botts, L., & Muldoon, P. (2005). *Evolutionof the great lakes water quality agreement*. East Lansing, Michigan: Michigan State University Press.

Bozorg-Haddad, O., Afshar, A., & Mariño, M. A. (2009). Optimization of non-convex water resource problems by honey-bee mating optimization (HBMO) algorithm. *Engineering Computations (Swansea, Wales), 26*(3), 267–280. https://doi.org/10.1108/02644400910943617.

Bruinsma, J. (Ed.). (2003). Earthscan, London.

Carter, S. B., Gartner, S. S., Michael, H. R., Olmstead, A. L., Sutch, R., & Wright, G. (2006). *The historical statistics of the United States millennium edition*. Cambridge: Cambridge University Press.

Chase, P. (2001). *The EU water framework directive. An introduction*. London: IWA Publishing.

Choudhury, E., & Islam, S. (2015). The complex problem of addressing transboundary water disputes. *Journal of Contemporary Water Research and Education, 155,* 43–52.

Clarvis, M. H., Allan, A., & Hannah, D. M. (2014). Water, resilience and the law: From general concepts and governance design principles to actionable mechanisms. *Environmental Science & Policy, 43,* 98–110.

Cohen, S. (1998). Rivers of discord: International water disputes in the Middle East. *The Middle East Journal, 52*(4), 626.

Commission for Environmental Cooperation. North American environmental atlas: Water use in the U.S. http://nationalatlas.gov/articles/water/a_wateruse.html#five.
Conca, K. (2006). Governing water: Review 2. *International Environmental Agreements: Politics, Law and Economics, 6*(3), 317–320.
Cooper, J. S. (1983). *Reconstructing history from ancient inscriptions: The Lagash-Umma border conflict* (p. 61). Malibu: Undena Publications.
Council of the European Union, Council conclusions on EU water diplomacy, Brussels, 22 July 2013.
Daoudy, M. (2004). Syria and Turkey in water diplomacy (1962–2003). In F. Zereini & W. Jaeschke (Eds.), *Water in the middle east and in north Africa*. Heidelberg: Springer.
De Angelis, E., Metulini, R., Bove, V., & Riccaboni, M. (2017). Virtual water trade and bilateral conflicts. *Advances in Water Resources, 110,* 549–561.
Detges, A., Pohl, B., & Schaller, S. A. (2017). A new climate for peace-10 violent water conflicts. https://www.newclimateforpeace.org/blog/editor's-pick-10-violent-water-conflicts. Retrieved June 8, 2018.
Duarte, R., Pinilla, V., & Serrano, A. (2016). Understanding agricultural virtual water flows in the world from an economic perspective: A long term study. *Ecological Indicators, 61,* 980–990.
Ebbesson, J. (2010). The rule of law in governance of complex socio-ecological changes. *Global Environmental Change, 20,* 414–422.
ECC Platform website, "Dispute over water in the Nile Basin." https://library.ecc-platform.org/conflicts/dispute-over-water-nile-basin.
ECC Platform website, "Turkey-Armenia: Water cooperation despite tensions. https://library.ecc-platform.org/conflicts/turkey-armenia-water-cooperation-despite-tensions.
E-learning capacity development project in international water law, implementation report.
EPA, United States Environmental Protection Agency. https://www.epa.gov/glwqa/what-glwqa.
Evans, R. G., & Sadler, E. J. (2008). Methods and technologies to improve efficiency of water use. *Water Resources Research, 44*(7), 1–15.
Fallah-Mehdipour, E., Bozorg-Haddad, O., & Mariño, M. A. (2014). Genetic programming in groundwater modeling. *Journal of Hydrologic Engineering, 19*(12), 04014031. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000987.
Fan, L., Gai, L., Tong, Y., & Lia, R. (2017). Urban water consumption and its influencing factors in China: Evidence from 286 cities. *Journal of Cleaner Production, 166,* 124–133.
Federal Water Act (19 August 2002)|ELAW. (2002). https://www.elaw.org/content/germany-federal-water-act-19-august-2002.
Food and Agriculture Organization of the United Nations (FAO). (2011). The state of the world's land and water resources for food and agriculture, managing systems at risk.
Food and Agriculture Organization of the United Nations (FAO). Land and Water Development Division. (2003). Review of world water resources by country. Water Reports 23 (p. 110). Rome: FAO.
Foster, S., & Ait-Kadi, M. (2012). Integrated water resources management (IWRM): How does groundwater fit in? *Hydrogeology Journal, 20*(3), 415–418.
Fracasso, A. (2014). A gravity model of virtual water trade. *Ecological Economics, 108*(54124), 215–228.
Fu, J., Zhong, P. A., Zhu, F., Chen, J., Wu, Y., & Xu, B. (2018). Water resources allocation in transboundary river based on asymmetric Nash–Harsanyi leader–follower game model. *Water, 10*(3), 270. https://doi.org/10.3390/w10030270.
Fulazzaky, M. (2014). Review, challenges of integrated water resources management in Indonesia. *Water, 6*(7), 2000–2020.
Gao, H., Wei, T., Lou, I., Yang, Z., Shen, Z., & Li, y. (2014). Water saving effect on integrated water resource management. *Resources, Conservation and Recycling, 93,* 50–58.
Gerbens-Leenes, P. W., Mekonnen, M. M., & Hoekstra, A. Y. (2013). The water footprint of poultry, pork and beef: A comparative study in different countries and production systems. *Water Resources and Industry, 1–2,* 25–36.
Giordano, M. A., & Wolf, A. T. (2003). Sharing waters: Post-Rio international water management. *Natural Resources Forum, 27*(2), 163–171.
Gizelis, T. I., & Wooden, A. E. (2010). Water resources, institutions, & intrastate conflict. *Political Geography, 29*(8), 444–453.
Gleditsch, N. P., Owen, T., Furlong, K., & Lacina, B. (2004). Conflicts over shared rivers: Resource wars or fuzzy boundaries? 45th Annual Convention of the International Studies Association, Montreal, 17–20, WD06, Wednesday 17 March, 1545–1730, Panel on 'conflict and cooperation over international rivers'.
Gleick, P. H. (1993). Water and conflict. Fresh water resources and international security. *International Security, 18*(1), 79–112.

Gleick, P. H. (2014). Water, drought, climate change, and conflict in Syria. *Weather, Climate and Society, 6*(3), 331–340.
Grech-Madin, C., Döring, S., Kim, K., & Swain, A. (2018). Negotiating water across levels: A peace and conflict ''Toolbox" for water diplomacy. *Journal of Hydrology, 559,* 100–109.
Gupta, J., Hildering, A., & Misiedjan, D. (2014). Indigenous people's right to water under international law: A legal pluralism perspective. *Current Opinion in Environmental Sustainability, 11,* 26–33.
Hanjra, M. A., & Qureshi, M. E. (2010). Global water crisis and future food security in an era of climate change. *Food Policy, 35*(5), 365–377.
HARC research, Reports1-EuphratesTigris. https://www.harcresearch.org/sites/default/files/Project_Documents/Reports1-EuphratesTigris.pdf.
Hefny, M. A. (2009). *Water diplomacy in a changing world: Adapting to new paradigm shifts, and the need for new innovative tools*. Mediterranean Academy of Diplomatic Studies.
Hefny, M. A. (2011). Water diplomacy: A tool for enhancing water peace and sustainability in the Arab region. Technical document, presented in preparation for the second Arab water forum. Theme 3: Sustainable and fair solutions for the transboundary rivers and groundwater aquifers Cairo, 20–23rd November 2011.
Hering, D., Borja, A., Carstensen, J., Carvalho, L., Elliott, M., Feld, C. K., et al. (2010). The European water framework directive at the age of 10: A critical review of the achievements with recommendations for the future. *Science of the Total Environment, 408*(19), 4007–4019.
Herrero, M., Thornton, P. K., Notenbaert, A. M., Wood, S., Msangi, S., Freeman, H. A., et al. (2010). Smart investments in sustainable food production: Revisiting mixed crop-livestock systems. *Science (New York), 327*(5967), 822–825.
Hoekstra, A. Y., & Hung, P. Q. (2005). Globalisation of water resources: International virtual water flows in relation to crop trade. *Global Environmental Change, 15*(1), 45–56.
Honkonen, T., & Lipponen, A. (2018). Principles for effective joint bodies: Value for water diplomacy? Author links open overlay panel. *Journal of Hydrology, 567,* 320–331.
Huang, J., Yang, J., & Rozelle, S. (2010). China's agriculture: Drivers of change and implications for china and the rest of world. *Agricultural Economics, 41*(11), 47–55.
IMF. (2010). World Economic Outlook (WEO), Rebalancing Growth, World Economic and Financial Surveys, International Monetary Fund. Washington, D.C., USA.
Islam, S. (2010). *Water diplomacy welcome*. Water Diplomacy @ Tufts University. http://ase.tufts.edu/igert/waterdiplomacy/.
Islam, S., & Repella, A. C. (2015). Water diplomacy: A negotiated approach to manage complex water problems. *Journal of Contemporary Water Research & Education, 155,* 1–10.
Islam, S., Moomaw, W., Akanda, A. S., Jutla, A. S., Schulz, A., Lin, C., & Grogan, D. (2009). AquaPedia: Building capacity to resolve water conflicts. In *'Education, knowledge and capacity development strategies' session. World Water Forum 5, Istanbul, Turkey*. Retrieved February 1, 2011.
Jacobsen, T. (1969). A survey of the Girsu (Tello) region. *Sumer, 25,* 103–108.
Karaev, B. Z. (2005). Water diplomacy in Central Asia. *Middle East Review of International Affairs, 9*(1), 63–69.
Karkkainen, B. C. (2006). Managing transboundary aquatic ecosystems: Lessons from the great lakes. *Pacific McGeorge Global Business and Development Law Journal, 19*(1), 209–240.
Kibaroglu, A., & Maden, T. E. (2014). An analysis of the causes of water crisis in the Euphrates-Tigris river basin. *Journal of Environmental Studies and Sciences, 4,* 347–353. https://doi.org/10.1007/s13412-014-0185-9.
Klimes, M., Michel, D., Yaari, E., & Restiani, P. (2019). Water diplomacy: The intersect of science, policy and practice. *Journal of Hydrology, 575,* 1362–1370.
Kramer, A. (2004). *Water and conflict* (*Policy briefing for USAID*). Berlin, Bogor, Washington, DC: Adelphi Research, Center for International Forestry Research, Woodrow Wilson International Center for Scholars.
Lawrence, D., Kaminskaite-Salters, G., & Mueller, H. (2004). A challenging road: Implementing the water framework directive in the UK. *JEEPL, 31,* 179–193.
Lazerwitz, D. J. (1993). The flow of international water law: The international law commission's law of the non-navigational uses of international watercourses. *Indiana Journal of Global Legal Studies, 1*(1), 12.
Liefferink, D., Wiering, M., & Uitenboogaart, Y. (2011). The EU water framework directive: A multi-dimensional analysis of implementation and domestic impact. *Land Use Policy, 28*(4), 712–722.
Merrett, S. (1997). *Introduction to the economics of water resources: An international perspective*. London: UCL Press.

Merrett, S. (2003). Virtual water and Occam's razor. Occasional paper no 62. SOAS Water Issues Study Group (Vol. 62, pp. 1–5).
Narasimhan, T. N. (2008). Water, law, science. *Journal of Hydrology, 349*(1–2), 125–138.
Nicholson, H. G. (1939). *Diplomacy*. Institute for the Study of Diplomacy Edition with Foreword by Nigel Nicolson.
O'Brien, W. (2013). Transforming the riparian border disputes between Nicaragua and Costa Rica through environmental peace-building: A vision for trans-boundary collaboration in Central America. Bachelor of Science degree, School of Environment and Natural Resources and the Honors College at the University of Vermont.
Olmstead, A. L., & Rhode, P. (2000). The transformation of northern agriculture, 1910–1990. *The Cambridge Economic History of the United States, 3,* 693–742.
Ostrom, E. (2005). *Understanding institutional diversity*. Princeton, NJ: Princeton University Press.
Pallett, J., Heyns, P., Falkenmark, M., Lundqvist, J., & Seely, M. (1997). *Sharing water in Southern Africa* (p. 121). Windhoek: Desert Research Foundation of Namibia.
Petersen-Perlman, J. D., Veilleux, J. C., & Wolf, A. T. (2017). International water conflict and cooperation: Challenges and opportunities. *Water International, 42*(2), 105–120.
Pimentel, D., Berger, B., Filiberto, D., Newton, M., Wolfe, B., Karabinakis, E., et al. (2004). Water resources: Agricultural and the environmental issues. *Bio Science, 54*(10), 909–918.
Priscoli, D. J. (1996). *Conflict resolution, collaboration and management in international water resource issues. Alternative dispute resolution series*, Working Paper #6 (p. 48). Institute for Water Resources, U.S. Army Corps of Engineers, Washington DC.
Qadir, M., Sharma, B. R., Bruggeman, A., Choukr-Allah, R., & Karajeh, F. (2007). Non-conventional water resources and opportunities for water augmentation to achieve food security in water scarce countries. *Agricultural Water Management, 87*(1), 2–22.
Ran, Y., Lannerstad, M., Herrero, M., Middelaar, C. E. V., & De Boer, I. J. M. (2016). Assessing water resource use in livestock production: A review of methods. *Livestock Science, 187,* 68–79.
Reimer, J. J. (2012). On the economics of virtual water trade. *Ecological Economics, 75,* 135–139.
Rivera, A. (2015). Transboundary aquifers along the Canada-USA border: Science, policy and social issues. *Journal of Hydrology: Regional Studies, 4,* 623–643.
Roa-García, M. C., Urteaga- Crovetto, P., & Bustamante- Zenteno, R. (2015). Water laws in the Andes: A promising precedent for challenging neoliberalism. *Geoforum, 64,* 270–280.
Rosa, L., Chiarelli, D. D., Tu, Ch., Rulli, M. C., & D'Odorico, P. (2019). Global unsustainable virtual water flows in agricultural trade. *Environmental Research Letters, 14*(11), 114001.
Sabbaghpour, S., Naghashzadehgan, M., Javaherdeh, K., & Bozorg-Haddad, O. (2012). HBMO algorithm for calibrating water distribution network of Langarud city. *Water Science and Technology, 65*(9), 1564–1569. https://doi.org/10.2166/wst.2012.045.
Sadoff, C., & Grey, D. (2005). Cooperation on international rivers: A continuum for securing and sharing benefits. *Water International, 30*(4), 420–427.
Sakhel, S. R., Geissen, S., & Vogelpohl, A. (2017). Virtual industrial water usage and wastewater generation in the Middle East and North Africa. *Euro-Mediterranean Journal for Environmental Integration.*. https://doi.org/10.1007/s41207-017-0018-9.
Smith, P. J. (1998). Food security and political stability in the asia-pacific region asia-pacific center for security studies. Report food security, Honolulu, Hawaii.
Soltanjalili, M., Bozorg-Haddad, O., & Mariño, M. A. (2011). Effect of breakage level one in design of water distribution networks. *Water Resources Management, 25*(1), 311–337. https://doi.org/10.1007/s11269-010-9701-1.
Susskind, L., & Islam, S. (2012). Water diplomacy: Creating value and building trust in transboundary water negotiations. *Science & Diplomacy, 1*(3), 1–7.
Suter, M. (2017). Running out of water: Conflict and water scarcity in Yemen and Syria. Atlantic Council, South Asia Center
Suter, M. (2018). An update on Yemen's water crisis and the weaponization of water. Atlantic Council. South Asia Center.
Swain, A. (2001). Water wars: Fact or fiction. *Futures, 33,* 769–781.
Tamea, S., Carr, J., Laio, F., & Ridolfi, L. (2014). Drivers of the virtual water trade. *Water Resources Reaserch, 50*(1), 17–28.
The World Bank, IBRD. (2019). IDA, stronger together: 20 Years of cooperation around the Nile. https://www.worldbank.org/en/news/feature/2019/02/22/stronger-together-20-years-of-cooperation-around-the-nile.

Tilman, D., Balzer, C., Hill, J., & Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences of the United States of America, 108*(50), 20260–20264.
Topcu, S., Sen, B., Odemis, B., & Sen, B. (2010). Vulnerability of water resources under changing climate conditions in Upper Mesopotamia. In *BHS 3rd international conference*. https://doi.org/10.7558/bhs.2010.ic21.
Tribaldos, T. M. (2013). Conflict and cooperation over domestic water resources in the mediterranean, the Sahel area, and the middle east: Drivers and structural alternatives for conflict-reducing management. Ph.D thesis, ETH Zurich.
Tuninetti, M., Tamea, S., Laio, F., & Ridolfi, L. (2017). Advances in water resources to trade or not to trade: Link prediction in the virtual water network. *Advances in Water Resources, 110,* 528–537.
Turton, A. R. (1999). Water and conflict in an African context. *Conflict Trends, 5,* 24–27.
Turton, A. R., Patrick, M. J., & Julien, F. (2006). Transboundary water resources in Southern Africa: Conflict or cooperation? *Development, 49*(3), 22–31.
UN Water (UNW). (2008). Trans-boundary waters: Sharing benefits, sharing responsibilities. Thematic paper.
United Nations Educational, Scientific and Cultural Organization (UNESCO). (2002). Meeting basic needs. UNESCO world water assessment programme. www.unesco.org/water/wwap/facts_figures/basic_needs.shtml. 3 September 2004.
United Nations Educational, Scientific, and Cultural Organization (UNESCO). (2006).
United States Department of Agriculture (USDA), Economic Research Service. (2019). https://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use.
UN-Water Decade Programme on Advocacy and Communication (UNW-DPAC). (2015).
Vetter, T. (2016). *Water connects. A short guide to preventive water diplomacy*. Berlin: University of Greifswald.
Vörösmarty, C. J., Green, P., Salisbury, J., & Lammers, R. B. (2000). Global water resources: Vulnerability from climate change and population growth. *Science, 289*(5477), 284–288.
Walton, B. 2019. U.S. irrigation continues steady eastward expansion. In *Water & food, water news*. WEF. https://www.circleofblue.org/2019/world/u-s-irrigation-continues-steady-eastward-expansion.
Wolf, A. T. 1996. Middle east water conflicts and directions for conflict resolution. 2020 Brief No. 31 (p. 4). http://www.cgiar.org/ifpri/2020/briefs/number31.htm.
Wolf, A. T. (1999). Criteria for equitable allocations: The heart of international water conflict. *Natural Resources Forum, 23,* 3–30.
Wolf, A. T., Kramer, A., Carius, A., & Dabelko, D. G. (2005). State of the world. Chapter 5: Managing of water conflict and cooperation. State of the World 2005 redefining global security (pp. 80–99).
Xie, L., & Jia, S. (2017). Diplomatic water cooperation: The case of Sino-India dispute over Brahmaputra. *International Environmental Agreements: Politics, Law and Economics, 17*(5), 677–694.
Yang, H., & Zehnder, A. (2007). Virtual water: An unfolding concept in integrated water resources management. *Water Resources Research, 43*(2), 1–10.
Yoffe, S., Fiske, G., Giordano, M., Giordano, M., Larson, K., Stahl, K. T., & Wolf, A. (2004). Geography of international water conflict and cooperation: Data sets and applications. *Water Resources Research, Water Policy: Economics, and Systems Analysis*. https://doi.org/10.1029/2003WR002530.
Zawahri, N. (2008). Designing river commissions to implement treaties and manage water disputs: The story of the Joint Water Committee and Permanent Indus Commission. *Water International, 33*(4), 464–474.
Zawahri, N. (2009). Third party mediation of international river disputes. *International Negotiation, 14*(2), 281–310.