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transboundary freshwater treaties*

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A review of the evolution and state of transboundary freshwater treaties

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Abstract Internationally shared basins supply 60 % of global freshwater supply, are home to about 1/3 of the world's population, and are focal points for interstate conflict and, as importantly, cooperation. To manage these waters, states have developed a large set of formal treaties, but until now these treaties have been difficult to access and systematically assess. This paper presents and makes publicly available the assembly and organization of the largest known collection of transboundary water agreements in existence. We apply for the first time a “lineage” concept to differentiate between independent agreements and groups of legally related texts, spatially reference the texts to a global basin database, and identify agreement

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purposes, goals and a variety of content areas. The 688 agreements identified were signed between 1820 and 2007 and constitute 250 independent treaties which apply to 113 basins. While the scope and content varies widely, these treaties nominally govern almost 70 % of the world's transboundary basin area. In terms of content, treaties have shifted from an earlier focus on regulation and development of water resources to the management of resources and the setting of frameworks for that management. While "traditional" issues such as hydro-power, water allocation and irrigation are still important, the environment is now the most commonly mentioned issue in treaty texts. Treaties are also increasingly likely to include data and information sharing provisions, have conflict resolution mechanisms, and include mechanisms for participation beyond traditional nation-state actors. Generalizing, treaties have become more comprehensive over time, both in the issues they address and the tools they use to manage those issues cooperatively.

Keywords Transboundary river basins · Water resources · International water treaties · Environmental agreements · Transboundary water cooperation

1 Introduction

Transboundary waters and their management have formed an increasing corpus of practice and scholarship in international resource management in general and water management in particular. Transboundary waters are ubiquitous (276 basins overlaying 148 countries), important in the global water system (60 % of global flows) and of increasing management concern in the face of growing water scarcity, especially as a potential flash point for conflict. While more recent scholarship has argued against the likelihood of conflict (Pacific Institute 2005; Wolf 1998; Wolf et al. 2005), there is no question that the management of transboundary waters can be a significant issue in international relations even between friendly states and therefore requires careful attention.

To support the productive and peaceful use of transboundary waters, a long history of scholarship has evolved to examine the nature of international relations over water and the nature and efficacy of institutional tools for transboundary water management. Case studies have provided insights into how transboundary water law has developed and functioned in specific, usually conflict prone, basins (e.g. the Jordan, Nile and Tigris–Euphrates), while large-N studies have used transboundary water agreements as dependent or explanatory variables to provide insights into regional and global patterns of transboundary governance, such as the role of water in international conflict (e.g. Gleditsch et al. 2006; Toset et al. 2000; Wolf et al. 2003) or the uptake of international legal norms (e.g. Conca et al. 2006).

However, a key challenge for scholarship has been that the full body of transboundary water agreements to which case studies can be compared or on which large-N studies can be based has not been readily available. Furthermore, those agreements which have been available have not always been systematically and consistently compiled. As a result, the extent and nature of transboundary water law and basic patterns in the governance of transboundary waters has not been available to inform scholars or practitioners.

This paper attempts to partially fill this gap by presenting the assembly and organization of the largest known collection of basin-specific transboundary water agreements in existence. The collection, freely available, is a quantitative expansion of the well-known Transboundary Freshwater Dispute Database (TFDD)¹ and a qualitative deepening in its

¹ <http://www.transboundarywaters.orst.edu/database/interfreshtreatdata.html>.

categorization. In particular, we introduce the use of a “lineage” concept to differentiate between independent agreements and groups of legally related texts, spatially reference the texts to a global basin database, and identify agreement purposes, goals and a variety of content areas. While the primary goal of the paper is to describe and present the collection, we also use the results of our organization to provide a picture of the extent and nature of transboundary water law and its change over time, provide insights into a number of current issues in the field of transboundary water law and highlight how our findings change the body of knowledge of transboundary water governance.

2 Background

Water scholars have tried to overcome the incomplete catalogue of historic and current transboundary water agreements in a variety of ways. One has been to make inferences based on a limited number of agreements combined with knowledge of the broader social and political context. Dellapenna (1994) described the evolution of water-related treaties using a select number of agreements spanning from the mid-1800s to the end of the 1950s, and McCaffrey (1993) developed theories on trends in treaty making, specifically the shift towards integrated management from unilateral development, the move away from navigation as the primary use and the trend towards “equitable utilization” based on a substantial but incomplete reading of agreements.

Another approach has been to limit the domain of agreements examined to a specific recompilation of treaties. Westcoat and James (1996) review of multilateral water treaties from 1648 to 1948, covering all aspects of water including navigation and border demarcation, limited itself to the U.N. Food and Agriculture Organization’s agreement indices.² Hamner and Wolf (1998) limited the scope of their study to the same source but considered only the 145 post-1870 agreements “which deal with water per se, and excluding those which deal only with boundaries, navigation or fishing rights” (158). The agreements in that study became the foundation for the Transboundary Freshwater Dispute Database. Because of its size (over 400 documents before the update presented in this paper) and separation of “water” agreements from those involving water in other issues (e.g. navigation or fishing), the TFDD was later used to define the scope of other studies on particular aspects of transboundary water law including groundwater (Matsumoto 2002), water quality (Giordano 2003) and treaty formation (Espey and Towfique 2004). Other studies have expanded on the TFDD collection, but limited themselves in terms of spatial (e.g. Lautze and Giordano (2005) for Africa) or temporal (e.g. Conca et al. (2006) analysis from 1980 to 2000) scope or focused on particular issues (e.g. Dinar (2006) on the role and meaning of side payments in bilateral agreements).

A difficulty in some of these studies is that the collections on which they have been based have tended to treat individual documents as independent observations rather than part of a lineage of connected agreements. Thus, a protocol to a treaty signed the day after the signing of the original agreement has sometimes been considered as a second, new agreement. This can be problematic, because the number of agreements for a given basin has been used as dependent and independent variables in a number of studies relating

² U.N. Food and Agriculture Organization, 1 Systematic Index of International Water Resources Treaties, Declarations, Acts and Cases, by Basin, Legislative Study No. 15 (1978) and U.N. Food and Agriculture Organization, 2 Systematic Index of International Water Resources Treaties, Declarations, Acts and Cases, by Basin, Legislative Study No. 34 (1984).

institutional development with conflict (e.g. Yoffe et al. (2003); UNEP (2006)). To provide an indication of the nature of the problem, about 1/3 of agreements incorporate conflict resolution mechanisms, but when viewed as treaties, the figure rises to 2/3. This is because an agreement does not need to include a conflict resolution mechanism if the treaty to which it applies already has one in place.

Furthermore, once determined to be water related, agreements have not been catalogued and analysed according to goal or purpose. There is a growing body of literature, backed by international law including the 1997 UN non-navigational water law and now popular principals of Integrated Water Resources Management, which has tried to highlight attributes necessary for institutional robustness. However, blanket application of robustness concepts to agreements with very different underlying goals can lead to misleading conclusions. For example, a treaty leading to the establishment of a hydropower plant in a water-rich region could be criticized for not incorporating allocation mechanisms. Similarly, an agreement laying down the institutional framework within which parties will cooperate could be criticized for not providing any clear commitments from the parties with regard to the management of the water resource.

The discussion of these problems is not intended as a criticism of earlier efforts to understand trends and drivers of transboundary water law. Rather, it is meant to highlight the difficulties in analysing and evaluating past and present transboundary water treaties given previously available data. The aggregation and organization of agreements presented here and the subsequent description aim to address some of these difficulties. The next section outlines the methodology used to collect, organize and describe the body of international water treaties. We then highlight some of the most interesting trends in those agreements from 1870 up to the present. Finally, we place the description of the agreements into the perspective of current debates within the transboundary water literature.

3 Methodology

We took seven steps to improve the scope and conceptual organization of the body of transboundary water agreements to address the issues just described and provide new insights into their nature. We first performed a systematic search of possible agreement sources to expand the known body of transboundary water agreements (step 1 below) and to ensure that those agreements identified contributed to the body of transboundary water law (steps 3 and 4). We organized those agreements according to a lineage concept following accepted legal norms (step 2) and provided a new geographic referencing so that treaty coverage could be examined with greater nuance (step 5). Finally, we classified agreements according to both purpose and content (steps 6 and 7). We now describe in more detail how each step was pursued.

To expand the availability of international water treaties, we first conducted manual and electronic searches of primary document collections including The League of Nations Treaty Series, The United Nations Treaty Series, FAOLEX, the French register, the British register and the FAO Legislative Series on non-navigational uses of water (FAO 1995). In addition, published papers related to time series or cross-sectional analyses of existing transboundary law were examined for references not found through documentary sources. Key articles included Lautze and Giordano (2005), Ashton et al. (2005) and Dinar (2006). Finally, the general literature on transboundary waters was surveyed for additional references.

Building on the earlier Hamner and Wolf (1998) distinction, only agreements which included provisions related to water as a scarce or consumable resource, a quantity to be managed, or an ecosystem to be improved or maintained are included. Most importantly, this meant agreements focused on navigation, border delineation and fishing rights (as distinct from water as a provider of habitat for fish) and which did not also have an element related to water as a scarce or consumable resource were excluded. Further, agreements that dealt exclusively with financial aspects of water-related projects were excluded.

The majority of agreements identified are in English, but documents in French, Spanish, German, Polish and Portuguese are also included and have been used in the analysis presented below.³ Despite our efforts, not all agreements could be found—in some cases, references to an agreement were located but the actual document was not or was available only in synopsis form. In these cases, the agreement is not included in the analysis which follows. From contextual information, we believe that the vast majority of missing documents would have only minor reference to water-related issues. Most were related to colonial Africa.

Second, we grouped agreements according to “lineage.” A treaty is defined as a “an international agreement concluded between States in written form and governed by international law, whether embodied in a single instrument or in two or more related instruments and whatever its particular designation.”⁴ This definition highlights the need to consider texts not individually but rather in terms of related groups. Identified texts were categorized as primary agreements, protocols to primary agreements, amendments to primary agreements or replacements of primary agreements. Texts defined as amendments and protocols—either through their own language or our reading—were combined with their primary agreement to define a single unit for analysis⁵ (Fig. 1a).

Third, we excluded agreements in which water was an inconsequential issue in terms of international water law. For example, the Boundary Agreement between Iran and Pakistan of 6 February 1958 includes provisions for water from one side of the border being used to meet the drinking needs of border guards on the other side. While arguably important at the local level, in the context of the whole basin, the water issues these agreements cover are inconsequential. More importantly, they do not draw from or contribute to precedence in international water law or management, because their primary goals tend to be related to issues other than water.

Fourth, we differentiated between global agreements, regional agreements, agreements dealing with all the transboundary waters crossing at least one international boundary, agreements dealing with entire specific basins and agreements dealing with specific sections of a basin. Because global and regional agreements can provide only general concepts for management of shared water resources rather than specific rules for action, they are not included in the content analysis.

Fifth, we improved the geographic presentation of treaties in the TFDD. To accomplish this, all agreements were linked to explicit basin-country units (BCUs). BCUs are defined as the portion of a transboundary basin that is congruent with a single country (see Fig. 1b). For example, the Juba-Shibeli basin in East Africa overlaps three states, generating three

³ Due to translation limitations, agreements available only in Russian, Ukrainian or Arabic are excluded from our analysis. However, these documents are available in the TFDD collection.

⁴ Vienna Convention of the Law of Treaties, Article 2 (1), United Nations, Treaty Series, vol. 1155 (1969), p. 331.

⁵ In some cases, a protocol to an agreement is the only portion related to water. For the purposes of this work, those protocols were considered to be the primary agreement.

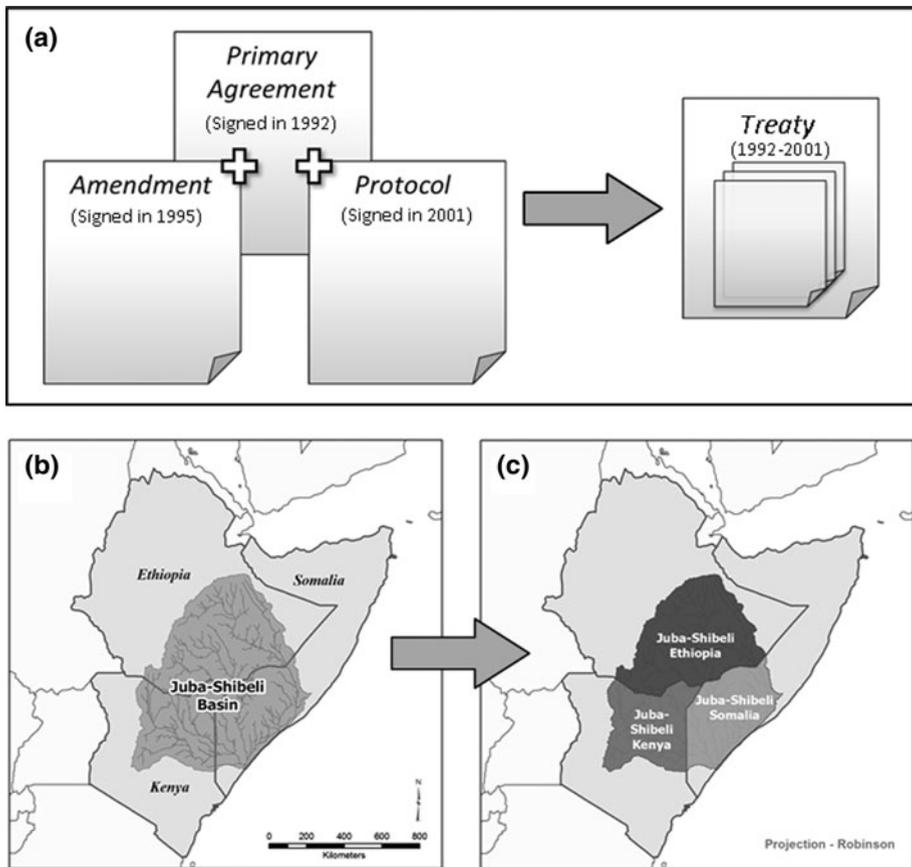


Fig. 1 Conceptual diagrams showing how **a** separate agreement texts are grouped into a single treaty and how **b** basins and countries are intersected to form **c** basin-country units for the example of the Juba-Shibeli basin in East Africa

BCUs (Fig. 1c). A “Treaty Application Area” (TAA) was also determined for each agreement. The TAA is defined as the set of present-day BCUs to which an agreement applies. According to the 1969 Vienna Convention on the Law of Treaties, successor states automatically assume the rights and obligations stemming from international treaties that were binding for the predecessor, unless they explicitly decide otherwise. This is of particular importance in cases where colonial powers signed treaties on behalf of the colonized territories and in cases of secession or state separation. To determine the TTA, treaties referencing countries that have ceased to exist were examined using boundary delineations (Anderson 2003) and political history (Tir et al. 1998) as well as internet searches to determine which present-day countries best represented the area intended for management by the agreement. Note that more than one treaty can still apply to a single BCU.

Sixth, we classified treaties according to their goals using Young’s framework of analysis (1999) as applied to transboundary waters (Drieschova et al. 2008). We classified each of the sampled agreements according to whether its function was regulatory, procedural, programmatic or generative. Regulatory agreements proscribe or prescribe action

(e.g. water allocation or control of pollution). Procedural agreements provide frameworks for regular, collective decision-making (e.g. joint water management committees). Programmatic agreements provide rules for generating resources for project development (e.g. construction and operation of dams). Generative agreements develop new social practices and norms (e.g. establishing principles such as “no significant harm”). An agreement can have more than one assigned purpose.

Finally, all the agreements were coded for content pertinent to transboundary water law. The categorization for coding was generally consistent with the literature already cited and efforts such as the International Law Association framework (Wouters et al. 2005; Delapenna 2001), but was also further developed based on analysis of the texts themselves. Overall, agreements were categorized for three areas of content. The first we term “focus” which denotes the goals to which the treaty is intended to contribute. These include water allocation, joint management, hydropower, irrigation, groundwater and environmental issues. The second are procedural mechanisms for treaty implementation including information exchange and conflict resolution. Finally, we coded for the emerging area of non-state actors in transboundary water affairs by examining treaties for consideration of local needs and stakeholder participation.⁶

4 Results

We provide here a description of how the collection and categorization process just described changes the picture of the known volume of transboundary water law and how the results are used in the remaining analyses of the paper. In these analyses, we describe how the volume of treaties has changed over time, examining the degree and meaning of global coverage including differences between bilateral and multilateral basins. We examine changes in the purpose and substantive focus of treaties and agreements, showing a shift towards management and rule making and a growth in focus on the environment. We then show how implementation mechanisms, in particular information sharing and conflict resolution, have evolved, before finally examining how the discourse on non-state actors is reflected in treaty reality.

4.1 Changes in the known body of transboundary water treaties

The original TFDD collection published by Hamner and Wolf (1998) contained 145 agreements and had grown to 448 by the time of the present update. By systematically broadening the search as described in step 1 above, we were able to identify an additional 240 agreements, bringing the total number of known transboundary water agreements to 688 (see Table 1). Of these, 403 were amendments to or protocols or replacements of primary agreements. By lineage (step 2) then, there are a total of 285 independent treaties. Of these, 21 were classified as “minor” with respect to water (step 3), and 14 were focused on global or regional issues or had no text available for analysis, bringing the total number of basin or sub-basin focused treaties to 250.

To describe the content of these treaties and their component agreements in the remainder of this paper, we developed two different data subsets, one for geographic coverage and one for the analysis of time trends. For each dataset, we had to first remove

⁶ Definitions from our coding manual are included as an online supplement. Coding was done for more variables than are described here. All data and results are available at TFDD.

16 treaties for which insufficient text was available for consistent coding, bringing the potential number of treaties for analysis down to 234. For analyses considering geographic content and coverage, we excluded the 17 treaties that were later replaced by other treaties, as defined in step two above, giving 217 observations. For analyses of time trends, we considered the signature dates of the 322 individual agreements (primary agreements, replacement agreements, amendments and protocols) to determine when a particular mechanism was “added” to the body of transboundary law. For example, an amendment from 1973 adds a joint management provision to a treaty signed in 1950 that initially had no such provision. With respect to geographic coverage and content, these two contributing agreements are counted as one treaty containing joint management, but with respect to evolution over time, they form two different observations, one in 1950 without joint management, and one in 1973 with joint management. In other words, we report time trends in *contributing agreements* rather than *treaties*, and as such, the sample sizes in time trends differ. We use the words “treaties” and “agreements” to signal which set of data we refer to in the descriptions that follow.

4.2 Geography and trends

By 2007, 323 (43 %) of the 747 basin-country units had at least one treaty (Fig. 2). Since basin-country units with treaties tend to be both larger and more populous than average, about 68 % of the earth’s total transboundary area, 42 million km², is at least nominally governed by at least one treaty as are 79 % of the 2.8 billion inhabitants.

Trends in both the rate of transboundary treaty formation and the cumulative geographic area covered by water treaties are shown in Fig. 3. One striking shift has been the increase in the number of treaties signed per year in the post-war period to more than 3 per year, up from less than 1. Even more striking is the difference between growth in treaties applying to multilateral basins (basins shared by more than 2 countries) and bilateral basins. Rather than revealing a geopolitical trend, this is explained largely by the facts that, first, 6 of the 7 largest bilateral basins, accounting for 49 % of all bilateral basin area, were in North

Table 1 Number and type of transboundary agreements

Step	Categories	#	% Breakdown of treaties in each step
1. Agreements	Documents	688	–
2. Lineage	Treaties	285	100
3. Water focus	Minor	21	7
	Substantive or not determined	264	93
4. Geographic Scope	Not available	1	0
	Global	5	2
	Regional	8	3
	All shared waters	27	10
	Entire basin	65	25
	Sub-basin or specific portion of a basin	158	60
5. Text availability	Insufficient	16	6
	Sufficient for analysis	234	94

Bolded variables form the basis for filtering in the following step

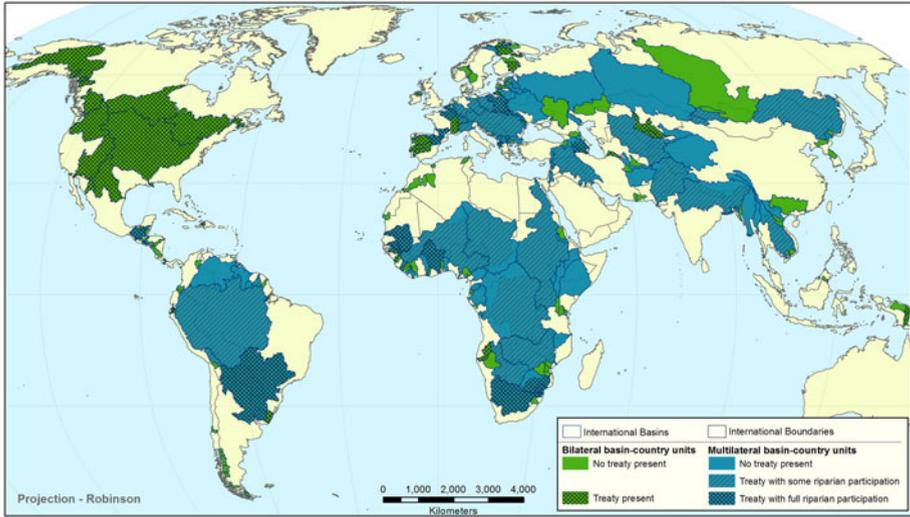


Fig. 2 Treaty coverage (at least one treaty present) and riparian participation at the basin-country level for bilateral basins (*shades of green*) and multilateral basins (*shades of blue*)

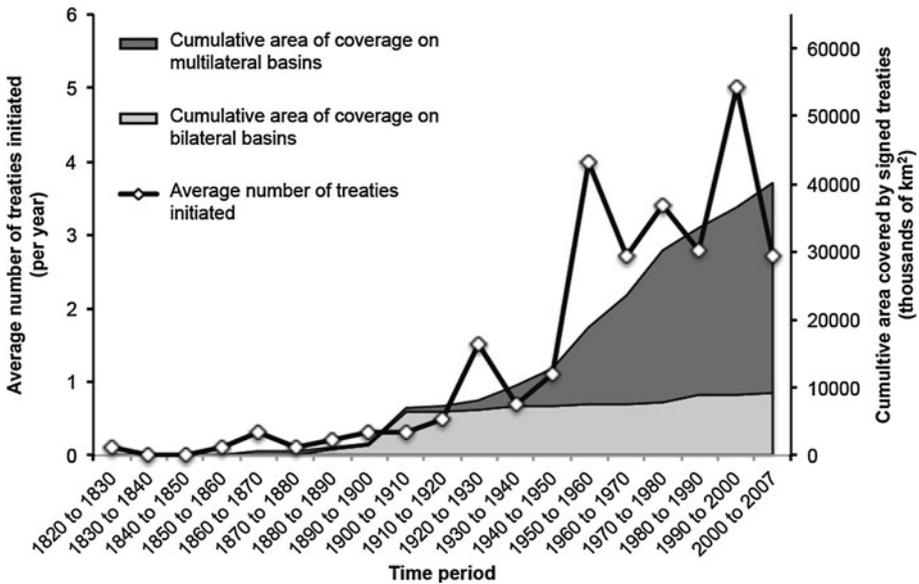


Fig. 3 Average number of transboundary water treaties signed per year and cumulative area covered. The total areal coverage of transboundary basins is 62 million hectares

America and had treaties by 1910 and, second, multilateral basins cover three times the area of bilateral basins. After 1910, almost all growth in covered area had by definition to come from multilateral basins.

While there may be a tendency to use overall coverage or treaty existence/non-existence as an indicator of the adequacy of transboundary water governance mechanisms, a number

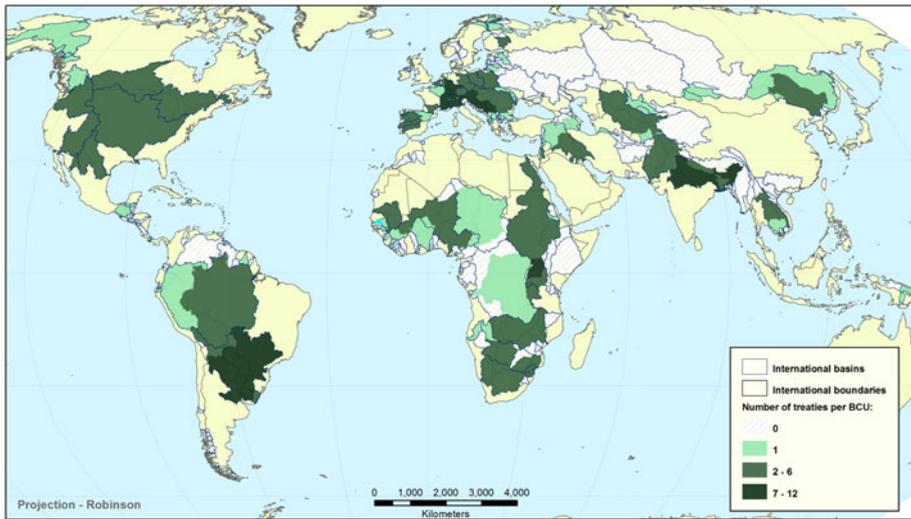


Fig. 4 Number of treaties applying to each basin-country unit

of considerations should be kept in mind. First, not all riparians in a basin are necessarily parties to the treaties which apply to a particular basin as highlighted in Fig. 4 and by the basin-country unit concept. There are 86 multilateral basins which together are home to 85 % of the “transboundary” population mentioned above. Only around one-third of multilateral basins have treaties signed by three or more states. Only 11 (13 %) have a treaty that includes all riparians. This may be because multilateral treaties are more complex to negotiate. It may also be because hegemonic states in multilateral basins push for sets of bilateral agreements to avoid diluting their power (Nader 1995). Alternatively, when a hegemonic state is an upper riparians, it might refuse to bind its hands with a multilateral agreement, while less powerful lower riparians decide to proceed with cooperation.

Second, and related, only about a quarter of all treaties cover the entire basin to which they apply. For example, while Fig. 4 shows that there is at least one treaty in place for the Nile (and in fact there are 13), none apply to the entire basin. Instead, they are focused on particular issues such as the management of Lake Victoria or the flows between Egypt and Sudan. Third, many treaties (23) have been technically designed to cover all waters shared between two or more states (e.g. the U.S.–Canada Boundary Water treaty mentioned above). However, these treaties are rarely if ever focused on specific basin scale issues and instead provide only a framework for cooperation if issues in a particular basin later arise.

Fourth, and importantly, while there is clear evidence that having any water treaty in place increases cooperation and reduces conflict (e.g. Wolf et al. 2003), the actual content of treaties can vary from a comprehensive framework for management with clear governance procedures in place to simple rules for data sharing or dam operations. In short, treaties are far from equal, and thus, the mere presence of an agreement does not mean that there are reasonable mechanisms in place to cope with any water issues which arise.

Finally, while the lineage concept groups’ agreements related to a single treaty, it does not preclude the possibility that more than one treaty can exist for a single basin or even basin-country unit. The case of the Nile was just mentioned, but as shown in Fig. 4, it is the

norm rather than the exception for overlapping treaties to exist for one geographic area. In some cases, this may be the result of legal gradualism as described by Abbott and Snidal (2002, 2004) in which later, more complex agreements are built on the confidence emerging from earlier, low-cost agreements. In other cases, it may simply be the case that issues or even governments have changed, requiring new rule making.

4.3 Evolving purpose

Using Young's (1999) categorization of international environmental treaty purpose as regulatory, procedural, programmatic and generative, we found almost half of all treaties have regulatory components and another third have procedural components. Less common are treaties whose purpose is programmatic (29 %) or generative (21 %). Each treaty can of course have more than one purpose, and in fact, we found approximately 1.3 "purposes" per treaty.

From the perspective of transboundary water law development, the changing focus of purpose over time shows interesting trends (Fig. 5). In particular, the share of agreements with procedural and especially generative purposes has increased, primarily at the expense of regulatory agreements and to a lesser extent programmatic agreements. In essence, this is a shift towards cooperative management of water and principles for that management rather than the division of water and specific water uses that had prevailed in the first half of the century. This is a trend previously identified by Mostert (2003) and consistent with other observations of changing water paradigms (Gleick 2003; Pahl-Wostl et al. 2006).

4.4 Evolving focus

While purpose has varied, so has focus. Allocation may at one time have been at the heart of international water agreements (Wolf 1999), but our analysis shows that this is no longer the case, at least in the traditional sense of the concept. Water quality and the environment are now the most common foci (Fig. 6). We discuss here how trends in these and other important areas have evolved, what provisions relating to these focal areas look like and what the changes mean.

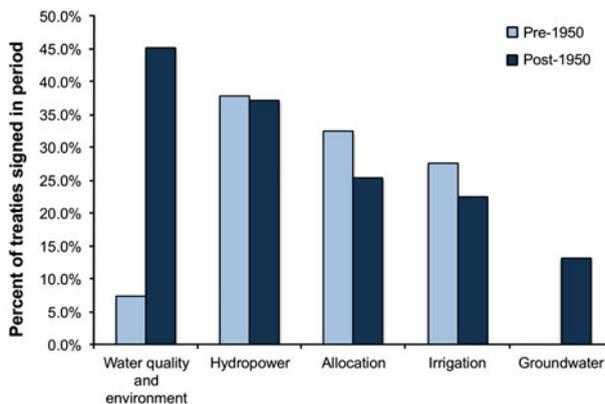


Fig. 5 Differences in the purpose of transboundary water agreements, pre- and post-1950

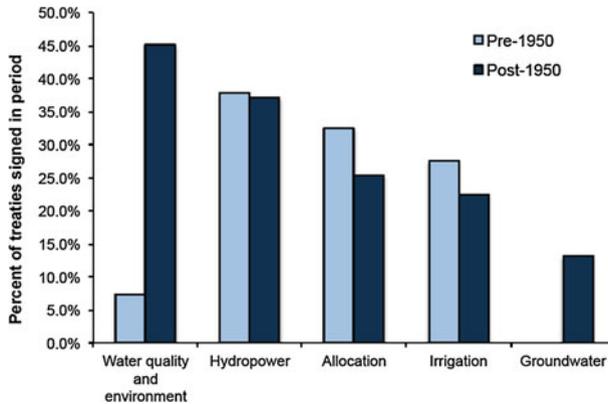


Fig. 6 Focus of transboundary water agreements, pre- and post-1950

4.4.1 Allocation

While less dominant than earlier, water allocation remains a key topic in transboundary water management and how it is codified can have significant implications for the resilience of agreements to changing resource conditions (Fig. 6). Allocation in agreements is addressed in three basic ways. The first is direct codification in which flows, measured in volume, percentage terms, time or some combination are divided between signatory states. The second is the use of indirect mechanisms, which determine the processes for establishing allocations (e.g. consultations, prioritization of uses and prior approval) without codifying the specific quantities or proportions to be shared. The third is the establishment of principles for allocation which outline the broader concepts for determining how water should be allocated now or in the future without defining specific formulae or processes (e.g. equitable and reasonable use, rational use, sustainable use and protection of existing uses) (see Drieschova et al. 2008).

Of the 217 treaties, 37 % incorporated some kind of water allocation mechanism. While allocation is commonly thought of in terms of fixed volumes, the increasing focus on climate-induced uncertainties also brings up the question of how transboundary water law addresses variability management (De Stefano et al. 2012). Negotiators have recognized the importance of uncertainty, and about one-third of all treaties incorporate mechanisms addressing flow variability. While many of these (58 %) address unexpected high flows (floods), the focus on low flows is increasing (now 15 %) as is, in particular, the incorporation of both dry season and flood control (27 %).

As already discussed and shown in Fig. 6, the direct focus on allocation has declined. This appears consistent with the evolving nature of treaty purpose towards management and principles of management rather than specific regulations. However, this does not mean that water allocation is not or cannot be dealt with within the broader framework of agreements with other explicit foci. For example, procedural agreements can provide the structure within which allocation will later be discussed and negotiated, even without specific mention of allocation in an agreement. Fischhendler (2008) has highlighted how these non-explicit arrangements provide alternative avenues for managing issues such as uncertainties in transboundary waters.

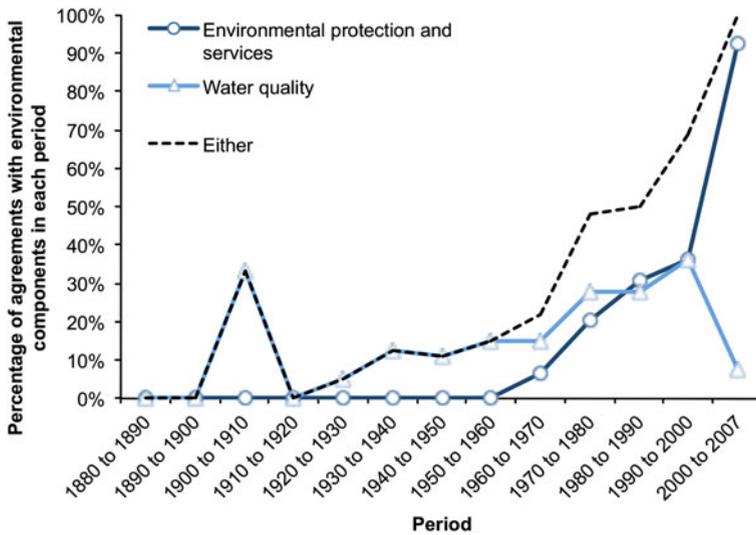


Fig. 7 Growing focus on water quality and the environment in transboundary water agreements

4.4.2 Water quality and environmental issues

While explicit consideration of water quantity is becoming less prominent in transboundary water law, water quality and the environment have risen to dominance (Fig. 6). Over 160 agreements (97 treaties) include at least some language on one or both of these issues. Almost every agreement signed in the last decade at least mentions the environment or water quality (Fig. 7).

Within the general realm of the environment, water quality has the longest history in agreement texts. However, as also noted by Giordano (2003), the actual content addressing water quality issues varies widely. About half of the treaties mentioning water quality include only vague references to riparian obligations and primarily express a desire to improve the water quality conditions of shared basins with some incorporating pledges for future action. A smaller share requires signatory states to assume some defined responsibility, such as independently monitoring water quality or cooperatively instituting regulatory measures. An even smaller group includes explicit water quality standards and mechanisms for their enforcement. Although the more detailed agreements have increased proportionately over time, agreements with only vague references to water quality still dominate.

Agreements considering the broader topic of environmental services (e.g. preservation of flora and fauna, maintenance of ecosystems and consideration of environmental flows) have grown even faster. This increase has occurred entirely after the 1960s, before which not a single agreement mentioned the environment. Since 1990, three quarters of all agreements have made at least some mention of the environment, perhaps in response to the language and influence of the 1991 Rio summit, though the related Agenda 21 did not mention transboundary aspects of freshwater resource management. However, it is equally possible that with or without the conference, values and conditions had changed and treaty language would have increasingly changed anyway. In other words, it is possible that Rio was in part a reflection of ongoing trends rather than a setter of trends. This appears likely to be the case, since environmental language in treaties began appearing before the

conference took place, though it accelerated afterwards. As with agreements referring to water quality, the actual content of these agreements is typically weak, usually including only reference to the idea that the environment should be included in decision-making.

4.4.3 Hydropower

While hydropower still forms a major focus of transboundary water law, its path through transboundary water law history has not been as linear as many of those discussed so far. With relatively little focus on hydropower in the pre-war years, it became a dominant theme by the end of the 1950s before falling back again. This pattern seems consistent with a similar, more general pattern in global hydropower development (Lautze and Giordano 2007) in which dam construction was spurred by the desire to use water to increase economic development and improve human well-being and was supported by increasing technical and financing abilities (Allan 1999). The fall after the 1970s may be attributed to the exhaustion of the most suitable dam sites, increasing recognition and criticism of the social and environmental externalities attached to dams, and the growing value attached to environmental goods (Conca 2006; Gleick et al. 2004; WCD 2000). The changing focus of treaty content towards the environment as already discussed is also consistent with these changes.

4.4.4 Groundwater

The fact that groundwater in general is a “hidden” resource has been cited as one of the reasons it is so difficult to manage (e.g. Chapelle 1997). The issue of groundwater in transboundary water management first received significant attention in the early 1980s (Hayton 1982; Utton 1982 and Barberis 1991). However, most of this attention was focused on what has become known as the Bellagio Draft Agreement (Hayton and Utton 1989).

Groundwater is in fact still largely hidden in transboundary water law (Eckstein 2005). But while it has only been mentioned in 14 % of all agreements, a sharp increase in focus in recent decades merits attention (Fig. 6). Between 2000 and 2007, for example, more than half of all agreements had some provision for considering groundwater. While the majority of agreements including groundwater only deal with it indirectly as some extension of surface water and often only through mentioning the terms groundwater or aquifer, a small number deals more directly with the regulation of groundwater quantity or quality. Given the recent changes, we can expect that groundwater will continue to receive increasing attention in the future.

4.5 Implementation mechanisms

In this section, we examine two main topics in treaty implementation, the sharing of data and information which provides a basis for the enforceability of agreements and the mechanisms for resolving conflicts when they occur.

4.5.1 Information exchange

Agreements including provisions for information exchange were rare before the 1920s but became a common feature from the 1950s. More than 40 % of all agreements have some mechanism for information exchange with the percentage continuing to increase.

About half (47 %) of all treaties include provisions for direct data exchange, and most of these are in fact related to hydrologic information, but there is large variation in how that information is shared. For example, about one-third of the agreements making up these treaties call for regular exchange, 16 % are on request or as needed and 9 % are event triggered. The other half of the treaties with data and information exchange provisions are unclear about when the provision is to occur.

A slightly larger (54 %) group of treaties calls for information exchange through technical cooperation (note that these treaties may also call for direct data exchange). This may include joint research, investigation and assessments that suppose some aspects of data and information exchange. Another large set of agreements includes more indirect methods for sharing data and information, for example, through prior notification provisions or formalized communication procedures.

The important point is that information sharing in transboundary water law involves a wide variety of issues and wide variety of methods (Gerlak et al. 2011). As in many other aspects of treaty construction, a careful reading is required to interpret if and how data sharing is incorporated. Even though data sharing may not be explicitly mentioned, treaties may still have mechanisms to facilitate exchange, such as consultation procedures, when the issue arises.

4.5.2 Conflict resolution

Conflict resolution procedures may be among the most important institutional mechanisms incorporated in treaties (Wouters et al. 2005). As with data and information exchange, mechanisms for conflict resolution have also become increasingly common, rising from 31 % of agreements signed before 1950 to 44 % of agreements signed after 1950. Since 1990, 61 % of agreements have incorporated some sort of conflict resolution mechanism. We were able to identify five different methods for conflict resolution. These are the use of diplomatic channels (39 %), arbitration (32 %), the creation of special commissions for conflict resolution (28 %), the agreement to submit a dispute to an existing permanent judicial organ (8 %), such as the International Court of Justice, and third-party involvement (6 %). We are not aware of previous literature which has examined the content or impact of these conflict resolution mechanisms in the context of transboundary water management.

4.6 Local needs and stakeholder participation

A major trend in the literature on transboundary waters has been the role of non-state actors (e.g. Swyngedouw 2000; Sneddon; Glassman 2001; Miller; Hirsch 2003, 2008; Dore and Lebel 2010), both in terms of how (intranational) community interests are considered and in the negotiating and implementation process. We find that local needs are at least mentioned in 14 % of all treaties. Perhaps surprisingly, the proportion of agreements referring to local needs has fluctuated over the 20th century, peaking at 33 % of agreements signed in the 1900s before declining to zero by 1960. Since then, the share has been increasing, but only in the 2000s did it again exceed 30 %.

Stakeholder participation, on the other hand, has been a more recent phenomenon. Prior to 1980, only one agreement—between the United States of America and Canada regarding the level of Lake Memphremagog of 6 November 1935—referred to stakeholder participation in decision-making. By contrast, in the period from 2000 to 2007, more than 45 % of treaties signed referred to stakeholder participation as an important element of governance.

Interestingly, the largest number of treaties (22) referring to stakeholder participation is found in Africa, followed by Europe (18), while Asia, North America and South America have few treaties incorporating such provisions. The high propensity for inclusion of stakeholder participation in Africa may be more due to donor involvement and the push for the “ideal” than real belief in the value of such approaches (Lautze and Giordano 2007).

5 Discussion

The analysis presented here brings out four major insights that inform our knowledge of the state and direction of transboundary water law. First, while less than half the world's transboundary basins have any formal agreement in place for their management, there has been a steady increase in the number of agreements over the last century and especially over the last 50 years. Perhaps as importantly, those agreements that have been formed apply to the most significant basins. Thus, almost 70 % of the world's transboundary areas and 80 % of the people living in those areas are at least nominally covered by an agreement. Having said this, it is also clear that the existence of an agreement that applies to a basin is not equivalent to having a basin scale agreement. For example, some $\frac{3}{4}$ of agreements apply only to specific portions of basins, and most agreements pertaining to multilateral basins do not include all basin riparians.

Second, agreements have shifted from an earlier focus on regulation and development of water resources to the management of existing resources and the setting of frameworks for that management. Third, and consistent with the last finding, the days when allocation can be said to be the heart of the transboundary water governance problem appear to be over. Whereas Hamner and Wolf (1998) observed that the majority of water treaties focused on hydropower and water allocation, that is, regulation and development of water resources, we found that water quality and the environment now form the single largest content areas of existing and new transboundary water agreements, a trend also observed by McCaffrey (1993) and Conca et al. (2006). Thus, even though many of the substantial problems with regard to transboundary water quality management might persist (Giordano 2003), the current study demonstrates at least a heightened awareness of water quality considerations. While still not substantial within the overall body of law, considerations of groundwater are now commonly included in instruments. We can thus conclude that a significant change in awareness and weighting of issues has been made since Hamner and Wolf (1998) examined the issue almost 15 years ago.

Finally, while not discussed in great detail here, treaties have become more comprehensive over time, both in the issues they address and the tools they use, a finding that expands upon McCaffrey's (1993) observation of multiple purposes included in water treaties and Conca et al.'s (2006) observation of enhanced procedural mechanisms. Likewise, the procedural mechanisms incorporated in treaties are increasingly more complex, with joint management institutions, data exchange and monitoring more frequent, and stakeholder participation and conflict resolution mechanisms more commonly incorporated and sophisticated.

6 Conclusion

This paper presents an expanded version of the well-used Transboundary Freshwater Dispute Database's (TFDD) collection of transboundary freshwater agreements. The

refined collection provides a new picture of the volume and geography of freshwater law by employing more precise agreement definitions, organizing the agreements according to lineage and spatially locating the resulting treaties using the concept of basin-country units. Analysis of the treaties and their component agreements was made possible by new classification according to purpose, focus and other criteria. Original agreements and all coded variables are available online and should serve as a resource for both case study and large-N research on transboundary water law.

Recent publications estimate the existence of 300–400 freshwater agreements. These estimates are usually directly or indirectly based on the number of *documents* previously available in TFDD. Our work expanded the number of these documents to 688 from 448, an increase of some 50 %. However, more careful classification and application of the lineage concept shows that the actual number of independent freshwater *treaties* was only 250 by 2007. Thus, while the most frequently cited numbers in the literature were not necessarily far from the currently known number, they were in some senses correct for the wrong reasons—an underestimate of the number of agreements and an overestimate of independent treaties.

There has been a fairly consistent expansion in the number of transboundary freshwater treaties, with more than 30 new treaties signed each decade for the past half century. As a result, most of the world's transboundary area and the population living within transboundary basins are now formally governed by at least one treaty. If the trends we identified have continued, an additional 15–20 agreements have likely been signed since we stopped our exploration.

Our analysis of the identified treaties and their component agreements shows both differences and similarities with the somewhat fragmentary evidence of their content which has been published in the past. For example, evidence based on the much cited analysis of Hamner and Wolf (1998) showing that treaties in multilateral basins were less common than those in bilateral basins turns out to be incorrect. We show here that multilateral basins are much more likely to have a treaty in place than bilateral (51 vs. 30 %). This divergence in findings from early work can be attributed to a more complete collection of treaties for analysis and the continued dominance in the proportion of multilateral agreements since the original analysis took place. In fact, an overwhelming majority of the growth in treaty coverage over the last century has been from agreements in multilateral basins, a previously undocumented phenomenon.

We find that explicit consideration of allocation, while still a major element of freshwater treaties, is a less dominant issue in freshwater cooperation than previously thought and that there has been a rise in the focus on water quality even greater than that previously documented (Giordano 2003). We documented a clear growth in focus on environmental issues beyond just water quality that has hitherto been speculated but not established as well as increasing consideration of groundwater. While the literature has been aware of the growth of non-state actors in international affairs in general and in transboundary waters in particular, we were able to document the formalized reflection of this growth in treaty texts, even if the practical implications are still unclear.

An overall observation from the analysis that treaties have shifted towards paradigms for management rather than strict rules and are more comprehensive and complex further supports McCaffrey's (1993) early finding of a trend from piecemeal to integrated approaches. This highlights the important point that any agreement is more than the sum of its individual parts. Other published analyses on issues such as variability management (Drieschova et al. 2008; Fischhendler 2004; Fischhendler and Zilberman 2005; Kistin and Ashton 2008) and information sharing (Gerlak et al. 2011) have made clear that it is the

combined content of a treaty that provides the flexibility to find solutions to problems that may not exist at the time of treaty signature. Fischhendler (2008) has highlighted the positive and negative roles of ambiguity in treaty design. If we are to appreciate how transboundary water treaties function and contribute to the generally peaceful state of transboundary water sharing, we must understand how these portfolios of approaches spread the dangers of uncertainty, physical and political, by simultaneously including multiple management strategies.

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