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Governance mechanisms to address flow variability in water treaties

Alena Drieschova[a,*], Mark Giordano[a,1], Itay Fischhendler[b,2]

[a]International Water Management Institute, P.O. Box 2075, Colombo, Sri Lanka
[b]Department of Geography, The Hebrew University of Jerusalem, Mount Scopus, Jerusalem 91905, Israel

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Abstract

While the importance of flow variability in water treaties is acknowledged, little work has been done to identify those mechanisms that have actually been employed. The present study uses a content analysis of a large number of water treaties in order to identify approaches used in practice. It was found that flow variability has been governed using a variety of mechanisms. While some mechanisms explicitly address variability, the majority use more subtle, open-ended approaches. Most of the mechanisms adopted deviate from an "ideal" state of being both flexible in the face of change but binding in enforcement. Instead, they reflect trade-offs between flexibility and enforcement. These results are used to discuss the advantages and disadvantages of particular variability management strategies.

Keywords: Flow variability; Water treaties; International water law

1. Introduction

Many countries are dependent upon water that originates outside their borders. In fact, international basins shared by more than one country cover almost half of the Earth's land surface (UNEP, 2002). Thus, the predictions of available climate change scenarios that the frequency of extreme weather events, such as draughts or floods, will increase on a global scale (IPCC, 2001, pp. 572–573) requires adaptable water management mechanisms not only within states, but also between them. Downstream riparian states, often already stressed by uncontrolled land and water development occurring in upper basins (UNEP, 2006), may be particularly at risk to rising intra- and inter-annual flow variability. Examples where this is already an issue include the Nile Basin and the concerns of Sudan and Egypt related to upstream precipitation patterns and changing water uses by upper riparians (Conway, 2005) or the Rio Grande basin and the dependency of Mexico on the water and land use in the US states of New Mexico and Texas (Fischhendler, 2004).

These concerns about variability in the flow of transboundary waters, and the development of institutional mechanisms to ensure that variability is cooperatively managed, are not new. As early as 1863, the Netherlands and Belgium made allocation of the Meuse's water conditional on annual availability (Transboundary Freshwater Dispute Database (TFDD)). More recently diplomats, lawyers and hydrologists have focused on generalized guidelines and principles for governing flow variability in internationally shared waters. For example, the 1997 UN Convention on the Law of the Non-navigational Uses of International Watercourses, although only a framework agreement, still includes reference to unexpected changes in water availability (McIntyre, 1998). The inclusion of guidelines to respond to extreme conditions and the recognition of ecological flow in the latest Berlin Rules on Water Resources, initiated by the International Law Association in 2004 (Berlin Rules, 2004), is another example. The expectation of increasing flow variability due to climate change has furthered calls by many experts to include flexible mechanisms into treaties in order to further the efficient management of transboundary waters (Goldenman, 1990).

*Corresponding author. Tel.: +94 11 2787404; fax: +94 11 2786854.
E-mail addresses: drieschova@seznam.cz (A. Drieschova), Mark.Giordano@cgiar.org (M. Giordano), fishi30@hotmail.com (I. Fischhendler).
[1]Tel.: +94 11 2787404; fax: +94 11 2786854.
[2]Tel.: +972 2 5883346; fax: +972 2 5883347.

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Research on conflict related to transboundary waters has suggested that one cause of escalated tensions can be a change in resource environments which outpaces the capacity of existing institutions to deal with that change (Yoffe et al., 2003). Mechanisms that allow flexibility in treaty implementation, it is thus argued, have the capacity to defuse the potential conflict between states when resource availability changes. Indeed, history has already provided examples in which the absence of such mechanisms in transboundary water resource treaties led to conflict. The 1944 treaty between USA and Mexico over three shared rivers is one such example. Despite the inclusion of several mechanisms to address flow variability, the agreement could not cope with 10 consecutive years of low flows in the 1990s. The result was a growing water debt for Mexico and calls on both sides to renegotiate the treaty (Fischhendler et al., 2004). Similarly, low water levels on the Ganges in 1997 combined with political mistrust threatened the continuation of the Treaty between India and Bangladesh on Sharing of the Ganges Waters at Farakka, signed just one year earlier (Salman and Uprety, 2002). While both treaties remain legally binding for the parties involved, controversies about treaty implementation have lead to a general atmosphere of mistrust and probably missed opportunities to improve water management practices.

While the importance of considering flow variability in shared-water agreements is acknowledged, numerous in-depth case studies have revealed that many agreements still lack mechanisms to handle changes in resource availability (Fischhendler, 2004; Goldenman, 1990). Indeed, only half of the agreements surveyed by Hamner and Wolf (1998) were identified as containing monitoring provisions and a conflict resolution mechanism, both of which are essential for adaptation. This implies that there are barriers impeding organizational adaptation; some of which may be inherent to the difficulties of building cooperative institutions while others may be political or technical.

Despite the need to address variability and overcome these impediments, little work has been done to identify those variability management mechanisms that have been employed in environmental agreements, water treaties in particular and the frequency of their use (Boockmann and Thurner, 2006). A few have conceptualized the role of climate uncertainty in the development of treaty regimes and tested their hypothesis on case studies (Fischhendler, 2004), but to our knowledge no large N-studies have been undertaken to conceptualize the issues raised by flow variability. Even the many studies that have examined the content of transboundary water treaties in general (Conca et al., 2006) or their specific attributes (Giordano, 2003; Matsumoto, 2002; Wolf, 1999) did not explore how variability is incorporated.

The present study aims to partially fill this gap by examining the use and potential use of variability management mechanisms in transboundary water treaties. It does this by first reviewing how adaptive governance can be achieved through the incorporation of flow variability mechanisms in international water agreements. It then uses the resulting typology to frame an analysis of the commonality of mechanisms, and their variation, to address flow variability in 50 treaties signed between 1980 and 2002. Finally, it presents a rudimentary model for the choice of governance mechanisms to address variability, discussing the likely advantages and disadvantages of each. The predications of climate change and associated extreme weather events, among them droughts and floods, has added a new dimension and urgency to the topic. It is in particular in the light of existing climate change scenarios that the findings of this study can be used to inform policy on how flow variability in transboundary waters might be better managed in the future.

2. Adaptive water governance and variability

It is widely recognized that sustainable ecosystem management requires institutional regimes, which can adapt to necessarily variable and often unpredictable conditions (Walker et al., 2002). In other words, ecosystem management requires an adaptive approach that, instead of aiming to maintain a fixed management regime, includes management rules, which are sufficiently flexible to meet unexpected conditions. Dietz et al. (2003) introduced the concept of adaptive governance to expand adaptive ecosystem management to broader social contexts including human and ecological uncertainties. To achieve its goals, adaptive governance must be institutionally embedded in society (Scholz and Stiftel, 2005) through horizontal and vertical ties (Dietz et al., 2003).

The growing focus on adaptive governance has resulted in studies seeking to identify why some communities and their institutions exhibit adaptability, and thus resiliency to change, while others become vulnerable in the face of change. These studies often stress physical, economic, social and physiological conditions for adaptation in the face of climate change (Adger and Kelly, 1999; Cutter et al., 2003). For example, in South Asia the ability to diversify income sources was found as a factor affecting communities' vulnerability to water variability (Moench and Dixit, 2004). Some studies have even suggested frameworks for adaptability/vulnerability analysis, which help to explain the behavior of states and stakeholders in face of new background conditions. These frameworks often introduce a host of contextual key drivers, and the relationships between them, that can affect the ability of a governance system to adapt (Pahl-Wostl et al., 2006).

One of the variables often stressed as a factor in the capacity to adapt to variability is the degree of flexibility incorporated in governance systems. Flexibility can mean either the ability to change the rules of the game, for example in order to allow for the incorporation of new scientific knowledge (Boockmann and Thurner, 2006), or the option to apply a variety of policies in the face of changing conditions (Arvai et al., 2006). The latter often

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results in a portfolio of policies enacted together, some of which address several objectives or risk diversification in case one policy fails (Fischhendler and Zilberman, 2005) while others compensate parts of the population adversely affected by those very same policies (Feitelson, 2003).

Since transboundary environmental agreements are typically rigid instruments that are modified only under exceptional circumstances, the need for some degree of flexibility in their design is clear (McCaffrey, 2003). In addition to playing a direct role in resource management, flexibility in treaty content can also reduce the sovereignty costs of negotiations and allow regime creation to move forward, even if issues of uncertainty about the future state of the world are not fully resolved (Mitchell and Keilbach, 2001). It was in this context that flexible criteria were used to overcome political obstacles in the formation of the Kyoto Protocol (Thompson, 2005). Once agreements are in place, flexibility can also allow countries to deviate from a treaty when unexpected change occurs while still maintaining the overall benefits of the agreement (Fischhendler, 2004; Koremenos, 2001). Climate change, which may lead to long-term increases or decreases in mean flows (Dai et al., 1998) or affect the variability of those flows (Jury and Vaux, 2004), adds a degree of urgency to the imperative of flexibility in treaty structure in order to cope with changes in resource conditions (Gleick, 1993; McCaffrey, 2003).

Variability first and foremost impacts the available amount of water to be allocated between riparians. Allocation of shared waters is a widely discussed topic in international water management and represents one of the most controversial aspects of treaty negotiations (Wolf, 1999), in large part because it appears to be a zero-sum game of resource division. In fact, codified inflexibility in allocation has been cited as one factor behind the failure of agreements to withstand variability shocks. Other allocation mechanisms, such as flow percentages, have been advocated as an alternative (Wolf, 1998).

Moving beyond direct allocation, variability in transboundary water resources can also be addressed through mechanisms to change the levels of resource availability. Mechanisms to jointly develop infrastructure or transfer technology to either increase supply (in the case of shortage) or decrease it (in the case of flooding) can mitigate changing supply or demand conditions. Furthermore, in some cases manufacturing water through these supply oriented solutions can be easier than negotiating it. Alternatively, in particular in order to mitigate flow variability, it can be helpful to develop infrastructure allowing for more equally distributed water availability through time, without changing the overall amount of water available for human use. The construction of barrages, for instance, can fulfil this function. According to functional theories of international relations, such technical cooperation, as a form of "low politics" is especially useful as a starting point for more comprehensive cooperation (Haas, 1961; Weinthal and Marei, 2002).

While allocation rules and mechanisms to change absolute supply may be most obviously connected to variability management, there are a variety of less obvious means available to states to address resource variability within water agreements. For example, developing formalized communication between parties through the establishment of joint management institutions can overcome the rigidity of water treaties and serve as a venue for solving water conflicts (Feitelson and Haddad, 1999). Such institutions can remove the need to codify rules on current and future resource sharing, thereby reducing the transaction costs of agreement formation. Establishing conflict resolution mechanisms and encouraging data exchange are two other means through which communication channels can be established. Conflict resolution mechanisms provide an agreed forum for the discussion of changes in resource conditions not envisioned within initial agreements. Data exchange can reduce the potential impacts of flow variability by facilitating early identification of future trends, and offseting the problem of asymmetrical information between riparians.

At times asymmetry in information can hinder cooperation and lead to sub-optimal outcomes, because the less informed party might expect the worst scenario (Akerlof and Maun, 1970). In general, channels of communication increase the contact between riparians which can help in reducing threat perceptions and in creating epistemic communities across borders able to address difficulties related to variability, and other contentious issues, in a cooperative and technical manner (Adler, 1991; Haas, 1992).

Finally, since states give different weight to different problems (Sebenius, 1983), broadening the scope of cooperation to go beyond water or to include other elements of the water cycle allows concessions to be made by each party on some issues in exchange for gains on matters they perceive of greater importance. For example, concurrent discussion on several elements of a treaty or of several treaties can allow side payments and trade-offs as one possible mechanism for solving conflicts, for instance, over how to divide unexpectedly low or high flows in the implementation phase of the regime. Broader linkages can also strengthen an agreement, as stakeholders will think twice before denouncing or defecting from a treaty when conditions change, since they now have more to lose. Indeed, the success of scope broadening as a means to enhance cooperation has motivated scholars to advocate its use to settle conflicts concerning natural resources variability (e.g. Susskind, 1994; Weinthal, 2001). In fact, Dinar (2006), in his study on the effect of the border configuration on the nature of water regimes, found that in treaties characterized by upstream–downstream relations, side payments often take place from downstream to upstream riparians.

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3. The state of variability management

In order to ascertain if and how transboundary water treaties address resource variability, a content analysis of available agreements signed since 1980 was undertaken and placed within the framework presented above. For the analysis, a treaty is considered to be "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" (Vienna Convention of the Law of Treaties, 1969, Article 2). To limit the analysis to those of primary relevance to flow variability, only treaties concerning "water as a scarce or consumable resource, a quantity to be managed, or an ecosystem to be improved or maintained" are included in the analysis, while those dealing "only with boundaries, navigation or fishing rights" were excluded (Hamner and Wolf, 1998, p. 158).

The TFDD is the most comprehensive source of agreements related to these definitions and criteria. Of the more than 400 agreements included in the TFDD, 118 were signed between 1980 and 2002, the last year the database was updated. The full-text of 99 of these agreements is available for analysis. Of those, 21 did not satisfy the criteria outlined above and are therefore not considered.

The remaining 78 documents were categorized as primary agreements, protocols to primary agreements, or amendments to primary agreements. If an amendment or protocol was related to or replaced a primary agreement included in the sample, it was considered jointly with the primary agreement. Amendments and protocols related to primary agreements signed prior to 1980 were excluded. In addition, two primary agreements, which were replaced by later agreements, were excluded. In this way we reduced the analytical redundancy of documents in the collection and limited the analysis to agreements actually in force. Of the remaining 52 agreements, two were broad conventions rather than basin specific treaties. While conventions can set basic norms and principles on handling flow variability, they do not directly solve concrete issues between states. Their basic purpose thus differs from the other agreements considered here, and they are therefore excluded. In total then there were 50 basin specific agreements for analysis.

Flow variability is explicitly mentioned in the text of 34 of the 50 treaties. For instance, article 40 (3(d)) of Annex III to the Israeli-Palestinian interim agreement on the West Bank and the Gaza Strip provides for "adjusting the utilization of the resources according to variable climatological and hydrological conditions". Similarly the Agreement between the government of the Republic of Namibia and the government of the Republic of South Africa on the establishment of a permanent water commission states in Article 3 (1(f)) that it is one of the functions of the Commission to advise the parties on "measures that can be implemented by either or both Parties to alleviate short-term problems resulting from water shortages in any river of common interest to the Parties during periods of drought …" The fact that 68% of the agreements explicitly mention flow variability strongly indicates the degree to which the issue is an important element in transboundary water management.

Furthermore, even some of the agreements without specific reference to variability implicitly include mechanisms for its management. For example, the Joint Minutes Concerning the Provisional Division of the Waters of the Euphrates Rivers signed between Iraq and Syria and the Agreement on the Teesta Waters signed between Bangladesh and India both establish flexible methods for allocation based on percentage shares of flows, although the treaties do not mention flow variability as a problem. In fact, of the 16 agreements which do not explicitly mention flow variability, 7 are framework treaties laying down general principles of cooperation between states or creating joint management institutions, and another 8 deal exclusively with water quality. As our analysis will show, even these agreements which would not generally be assumed to concern themselves with variability also frequently incorporate mechanisms for its management. Thus, it is important to look beyond the explicit text of agreements in considering mechanisms which might facilitate or influence variability management. The remainder of this section provides more insights into these possible mechanisms and the frequency of their use in treaties.

3.1. Allocation mechanisms

As discussed above, allocation is a key topic in transboundary water management and the manner in which it is codified can have significant implications for the resilience of agreements as resource conditions vary. The mechanisms through which allocation may be addressed can be divided into three general categories. First, direct allocation mechanisms can be used to explicitly divide waters between co-riparians. Second, indirect allocation mechanisms can be used to establish the processes through which allocation will be determined, but without codifying the specific quantities or proportions to be shared. Consultations as a step to determine later allocations, an obligation to notify co-riparians when new water needs arise, a requirement for co-riparians to consent to any increased water use, prioritization of water uses and vague commitments on the need to allocate shared-water resources can all be considered as indirect allocation mechanisms. Finally, Principles for Allocations can establish the broader ideas or concepts for determining how water should be allocated now or in the future. These principles include concepts discussed in the 1997 UN Convention such as equitable and reasonable use, rational use, sustainable use, the requirement not to cause significant harm and the protection of existing uses.

At least one of the three allocation mechanisms was included in 60% of the agreements and 26% of the

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agreements included one or more direct allocation methods. More than half of those agreements that contained direct allocation mechanisms tied water rights at least to a certain degree to water availability (16% of the whole treaty sample). Some treaties allocate percentages of flow (6%), such as the agreement between Greece and Bulgaria for the use of the Nestos River Waters. Others allocate fixed quantities which themselves vary depending on water availability (10%) such as in the Treaty on the Development and Utilisation of the Water Resources of the Komati River Basin Between the Government of the Kingdom of Swaziland and the Government of the Republic of South Africa. Such an allocation mechanism is more appropriate for the management of intra-annual flow variability, in particular when a large part of the variability is regular and predictable. Alternatively, and more appropriate for the management of inter-annual flow variability, some treaties, like the Treaty on the Lesotho Highlands Water Project, allocate fixed quantities with the provision that in the case of insufficient water the deficit will be recouped in the following period.

Indirect allocation mechanisms were used in almost half of the treaties (48%). However, in some cases, the indirect mechanisms operated only as complements to a direct mechanism. For example, in Article 2 of the Additional Protocol to the Convention on Cooperation for the Protection and Sustainable Use of the Waters of Portuguese-Spanish Hydrological Basins, the quantity of water the lower riparian should receive is given but subject to availability. When the flow is less than 65–70% (dependent on the individual river) of normal conditions, the parties to the agreement should inform the Commission, which then divides the available water on the basis of a set of Allocation Principles stated in Article 1 of the Additional Protocol.

Interestingly, all of the agreements which allocate water also incorporate at least one Principle of Allocation, and Principles of Allocation are rarely employed independently. In situations of unexpected flow variability, these principles allow parties to maintain the spirit of agreements and in disputes they provide guidelines on which tribunals can base their decisions. Equity in allocation is the principle employed most frequently; it appears in 22% of the studied agreements. It is followed by rational use (18%), no significant harm (16%), protection of existing uses (8%) and sustainability (8%).

3.2. Adaptation mechanisms

An alternative to allocating existing resources is to change the level of resource availability. Some of the surveyed agreements (14%) provide for the common construction of infrastructure to increase available water supplies or to disperse water supply throughout time. An additional 16% of agreements vaguely mention that the riparians would like to take joint measures to increase water supply, but without specifying the form that cooperation would take. For example, Bangladesh and India signaled their intent to increase water supply at the Farakka barrage during dry periods but did not specify how or when such work would take place (Bangladesh and India, 1996). Another set of agreements address the opposite force of variability, i.e. flooding. The establishment of joint flood control mechanisms (30%) and warning systems (18%) to manage unexpected high flows in fact forms a major theme in recent international water treaties.

In 14% of agreements, riparians consented to assist each other in the event of unforeseen flow variability. For instance, the Convention on Cooperation for the Protection and Sustainable Use of the Danube states in Article 17 that "in the interest of enhanced cooperation and to facilitate compliance with obligations of this Convention, in particular where a critical situation of riverine conditions should arise, Contracting Parties shall provide mutual assistance upon the request of other Contracting Parties". Such clauses suggest that the riparians respect a shared responsibility to keep treaty provisions in the face of flow variability.

Finally, 42% of the agreements in the sample included provisions for the transfer of technology, which might be used to address variability. However, it is not generally clear from the treaty text to what extent the technology will be used for variability management.

In sum, 38% of agreements incorporate at least one mechanism increasing the adaptability to flow variability in the form of the construction of common infrastructure either for increasing water availability or flood control, early warning systems or assistance in case of unforeseen flow variability. A further 26% of agreements incorporate mechanisms such as technology transfers or a vague reference to a potential increase of water supply, which could, but do not have to be used for the management of flow variability.

3.3. Formalized communication

As discussed above, variability can also be managed through the establishment of formalized channels of communication. The specific communication mechanisms identified in the sample treaties include the formation of joint management institutions (88%), regular political consultations (46%), consultations as conflict resolution (90%), data exchange (86%) and arbitration (42%). While the incorporation of these mechanisms within treaties does not provide any guarantee that the parties will effectively address flow variability, it provides at least an institutional environment conducive for the search of cooperative solutions. Ultimately, in any concrete situation of variability, it depends upon the political will and agency of states or political entrepreneurs to use the existing institutional environment for the mutual benefit of each riparian.

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3.4. Broadened cooperation

Within the sample agreements, non-water linkages in allocation appeared in 16% of treaties. For example, the Agreement between the Governments of the Republic of Kazakhstan, the Kyrgyz Republic and the Republic of Uzbekistan on the Use of Water and Energy Resources of the Syr Darya Basin links water deliveries with non-hydro energy supplies such as coal, gas and fuel oil as well as with the "rendering of other types of products" (labor, services). Thus, in case the basin would suffer exceptionally low flows in one year making it for political, economic or technological reasons difficult for the parties to comply with the treaty, Kazakhstan could potentially offer more coal and gas to Uzbekistan for obtaining the same amount of water. Issue-linkages make the finding of compromises under extreme conditions easier to obtain. Broadening negotiations beyond flow variability and water as a "consumable resource" through a focus on hydropower generation is also an important form of cooperation and was included in 28% of the cases. Finally, treaties can move beyond the quantitative focus on surface water. For example, groundwater is mentioned in 24% of the treaties and water quality issues are mentioned in 70%. However, the degree to which this content is developed within treaties is highly variable, as Matsumoto (2002) and Giordano (2003) have shown for groundwater and water quality, respectively. Finally, it is also clear from the data that many treaties, which broaden cooperation beyond direct water quantity issues, often do so using more than one of the mechanisms highlighted here.

3.5. Synthesis

Fig. 1 provides a picture of the frequency with which the four variability management mechanisms outlined here have been used. A further distinction is made in the diagram to highlight those mechanisms which explicitly manage flow variability (e.g. allocation by percentage of flow), those which may hinder it (e.g. fixed allocations) and those which may be used for flow variability management but whose role is not explicitly for that purpose (e.g. data sharing).

The majority of treaties (60%) address water allocation between riparians. Sixteen percent use allocation mechanisms consistent with flow variability management. In contrast, 10% allocate based on fixed flows, a mechanism likely hindering variability management. Another 34% of the treaties allocate water in a vague way, which could, but does not have to be conducive for the management of variable flows.

Sixty four percent of agreements provide mechanisms increasing the adaptability of the parties to flow variability. In 38% of the treaties, these mechanisms were incorporated with the clear purpose to facilitate flow variability management and another 26% of treaties incorporate mechanisms which could potentially increase the adaptability to flow variability, but it is neither obvious from the text of the treaty whether they have been included into the treaty for that purpose, nor whether they will serve this purpose in practice.

In 74% of the treaties, cooperation is broadened through the incorporation of issues not directly related to flow variability. Finally, 90% of the agreements incorporate some level of formalized communication channels. Both broadening of issue and formalizing communication produce an institutional environment likely more conducive for trans-border cooperation, but whether this environment is actually used for flow variability management depends to a large degree upon agency. Further, as has been noted earlier, it is important to remember that the inclusion of a mechanism, which might form part of a strategy to manage flow variability, does not necessarily mean that it has improved cooperation on cross-border variability management.

Finally, it is also important to note that the mechanisms outlined here are rarely employed in isolation. Instead they tend to form part of larger treaty packages, with all four mechanisms being incorporated in 34% of the agreements, three mechanisms in 26%, two mechanisms in 34% and one mechanism in only 6%.

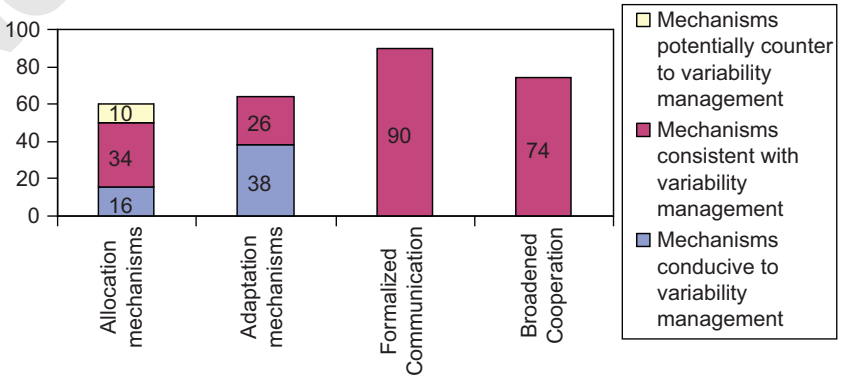

Fig. 1. Frequency (%) of flow variability management mechanisms, by type, in transboundary water agreements, 1980–2002.

4. Evaluation: governance strategies to address variability

The nature of the mechanisms identified here for managing the flow variability of rivers shared between states can be conceptualized as consisting of two primary dimensions. The first is related to the degree of flexibility in the mechanism for coping with changed conditions—for example, inflexible fixed allocations versus highly flexible allocations based on percentages of flow. The second is the degree of enforceability, for example an agreement which has specific penalties for failure to deliver agreed quantities of water arbitrated through an outside body versus a vague voluntary agreement to share water equitably. To manage variability, we can thus think of states as choosing strategies which combine varying degrees of both flexibility and enforceability for any given mechanism they employ. Fig. 2 provides a conceptual framework for considering the flexibility/enforceability relationship, and the resulting quadrants can be used to outline four basic variability management strategies. The figure is also used to indicate where each of the sub-mechanisms identified in the analysis above might fall within the strategy framework as well as the frequency with which each sub-mechanism occurred in our treaty sample.

It should, however, be noted that the figure is only a rough schematization and not intended to serve as a direct comparison between the different variability management mechanisms, since they are not substitutable. Some specifically contribute towards problem-solving in a situation of hydrological extremes, others provide only a process to do so for the future and thus would not necessarily resolve a potential conflict around variability.

The figure conceptualizes strategies for managing flow variability in transboundary water treaties resulting from the interplay between the flexibility and enforceability of any given governance mechanism. The mechanisms identified in the study sample of 50 treaties signed between 1980 and 2002 are located within the conceptual framework with percentage of use indicated in brackets. Of note is the finding that the vast majority of flow variability management mechanisms are either flexible or enforceable, but not both.

Using strategies which are both highly flexible so as to account for unforeseen conditions as well as binding so as to ensure credibility and action appear to have a number of advantages for variability management. However, it is clear from Fig. 2 that only a minority of mechanisms fall strongly within this category (Strategy I). The only sub-mechanism with a very high degree of both flexibility and enforceability is the allocation of waters based on percentage of flow. The use of this mechanism in the treaty sample was in fact very low. Some of the sub-mechanisms most often adopted in practice are those which provide a high degree of flexibility and have a low degree of enforceability (Strategy II) including consultations as conflict resolution, principles of allocation and broadening of cooperation. The high propensity to incorporate cooperation broadening clauses is not surprising, since many of the cooperation broadening sub-mechanisms (in particular non-water and water linkages) have been found to contribute to the stability and longevity of treaties during their implementation phase (Fischhendler et al., 2004). Relatively few sub-mechanisms had a high degree of enforceability and were relatively inflexible (Strategy III).

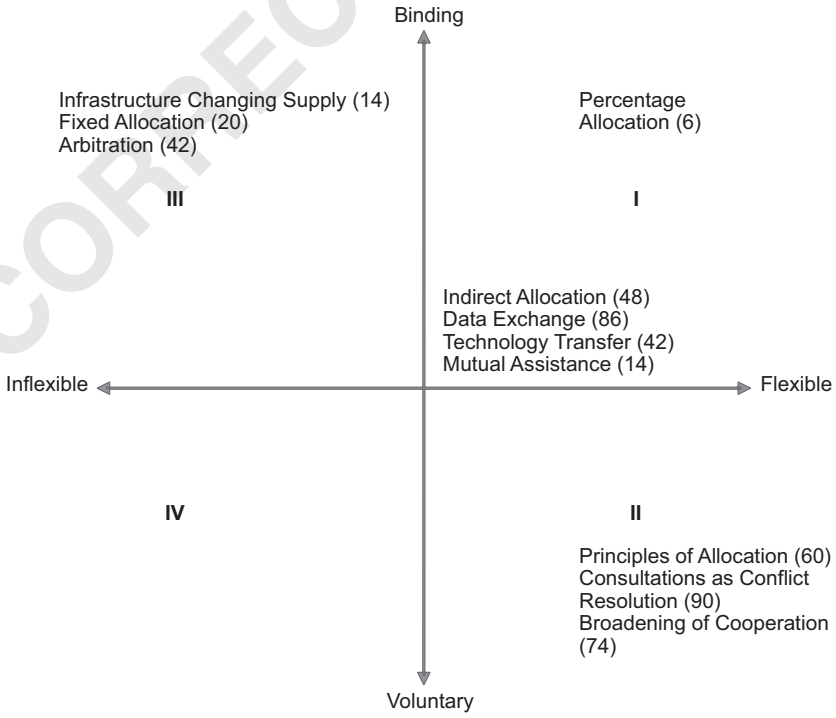

Fig. 2. Governance strategies and mechanisms in transboundary water law to address flow variability.

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No mechanisms were found that are both voluntary and inflexible (Strategy IV).

Another set of mechanisms with a high degree of adoption is located somewhere towards the center of the figure and include data exchange, mutual assistance, indirect allocation and technology transfer. While joint management institutions have a very high degree of flexibility, their degree of enforceability varies considerably by treaty. Thus, we did not locate joint management institutions in the figure.

There are three important points to keep in mind when considering the figure and the placement of mechanisms on it. First, the exact nature of the classifications presented can be debated and without doubt depends in part on the precise form each mechanism takes in actual basin law. Second, as has been noted, a relatively high percentage of recently signed treaties deal with floods, not water scarcity. What might be "ideal" for the management of unexpected shortages (e.g. allocation based on percentages of flow) does not necessarily contribute to flood management. Finally, none of the individual mechanisms is likely to operate in isolation. Thus, for example, the fact that a particular mechanism is not in and of itself enforceable does not necessarily mean that other elements of the agreement in which it exists will not add additional constraints to make it binding.

With those caveats in mind, it is still striking that only a minority of mechanisms adopted are both flexible and binding. This at least suggests certain barriers to the use of this "ideal" management form. This finding is supported by several in-depth case studies, which have revealed some of the barriers that hinder incorporating mechanisms to handle changes in resource availability (Fischhendler, 2004; Goldenman, 1990). Some barriers may be technical, for example when a system relies on massive water infrastructure it is often less adjustable because of high sunk-costs (Pahl-Wostl, 2005). On the other hand, the very same sunk-costs frequently make non-cooperation very expensive and therefore increase the longevity of cooperation. Other barriers may be more political, for example competition and power struggles between institutions have often been found to block innovation at the individual level (Adger and Kelly, 1999).

The finding also suggests a trade-off between flexibility and enforceability; i.e. the risk of too much flexibility, which increases the likelihood of a treaty breach, against the risk of entering an agreement so constraining that it impedes state actions in regime implementation. A high degree of flexibility may be of particular importance under conditions of resource uncertainty, while a high degree of enforceability may be of relevance in situations when a high degree of distrust prevails among the parties (Cook et al., 2005). Thus, in particular, in cases where there is a high degree of trust between the parties, flexibility in treaties does not necessarily prove a lack of commitment to the treaty regime, but can actually be a measure undertaken in order to allow sufficient scope for action in the event of an unpredictable change of circumstances.

While it is true that Fig. 2 reveals a certain preponderance of flexible mechanisms, there is also a high frequency of mechanisms located towards the center of the figure and reflecting a compromise between flexibility and enforceability. The trade-off between flexibility and enforceability can also explain the commonality of informal, broad commitments and institutions prevailing in international climate change negotiations (Karkkainen, 2004). These agreements that are flexible and less binding are often referred to as "soft" law (Abbott and Snidal, 2000). Unlike hard law, soft law does not create formally binding obligations (Craik, 1998). Instead, it sets out only general rules or ideas to be followed, leaving exact interpretation and implementation to the signatories (Birnie and Boyle, 1992). The trade-off may also explain why under conditions of uncertainty many environmental agreements, and water agreements in particular, tend to incorporate ambiguity, thus increasing the degree of flexibility and decreasing the degree of enforceability. In the case of the Israel–Jordan water agreement this ambiguity allowed riparians to avoid confining themselves to irreversible allocations of the natural resource, assuming that the ambiguity will be clarified in the future when more complete information is available (Fischhendler, in press).

Variability of water flows can create risks for the longevity of agreements, because it is a change of circumstances which may cause states to change preferences, thereby reducing incentives to follow existing agreements. In addition, unpredicted variability is also arguably a force majeure which could allow states to use a legal vacuum in general international law[3] to abrogate treaty obligations and thereby escape the logic of appropriateness. Lower riparians in particular may be interested in filling this vacuum on a case-by-case basis in order to guarantee a degree of certainty about the behavior of their upstream neighbors as those neighbors themselves react to uncertainty in water availability. In contrast, upper riparians may not want to make concrete commitments related to an unpredictable natural world which might impose on them unknown future costs. The emergence of a flexible and not fully binding agreement can be interpreted as a compromise between these two extreme positions.

5. Conclusion

In recent years, the concepts of resiliency, vulnerability and adaptability have increasingly been used in research on the human dimensions of global environmental change.

[3]Article 23 of the Draft Articles on Responsibility of States for Internationally Wrongful Acts states that "the wrongfulness of an act of a State not in conformity with an international obligation of that State is precluded if the act is due to force majeure, that is the occurrence of an irresistible force or of an unforeseen event, beyond the control of the State, making it materially impossible in the circumstances to perform the obligation".

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While a few studies have analyzed these issues on a case-by-case basis, there is a lack of knowledge about the potential mechanisms available to address flow variability and about the frequency of their actual employment in international water treaties. This study is a first look at the use of mechanisms to manage flow variability and uncertainty in transboundary water treaties, a subject area of rapidly increasing importance in an age of growing understanding and awareness of potential climate change. The study showed that flow variability can be and has been governed using a variety of mechanisms. Some mechanisms, such as allocation of waters based on a percentage of flows, explicitly address variability while the majority of mechanisms use less direct approaches that create open-ended rules for regulating water. Broadening of cooperation, establishing communication channels and adopting indirect allocation mechanisms are three examples for this approach. These open-ended governance mechanisms may provide a means for addressing variability while at the same time accommodating the sovereignty and power concerns that are still a corner stone of water negotiations. They also may provide a structure to facilitate cooperation, while it depends upon the agency of the individual actors to effectively use this structure in order to find cooperative solutions to flow variability.

While each of the mechanisms discussed was shown to play a possible role in variability management, the study did not attempt to determine the actual intent of negotiators in including the mechanisms in agreements nor the role the individual mechanisms actually played in mitigating, or exacerbating, the impacts of variability on the relations of signatory states. Flexibility and enforceability in rules regulating transboundary waters are often stressed as key positive attributes for governing shared-water resources, in particular in regions where water scarcity is important. However, flexibility can reduce the certainty around the actual flows of water parties will receive from an agreement, and enforceability can increase negotiation costs and may impinge on sovereignty. In agreements dealing with the zero-sum game of allocation, countries have generally tried to find a compromise between these two extreme and possibly contradicting positions. The apparent demand for this trade-off between flexibility and enforcement should encourage researchers and policy makers to seek hybrid mechanisms that can combine the two qualities into single governance structures that still meet environmental and political feasibility requirements. Allocations based on percentage flows would be one example for such a hybrid mechanism, the installation of a joint water commission with binding mandate would be another one, although without adequate stakeholder participation mechanisms, the problem of accountability and legitimacy of such an institution might loom large on the agenda.

At the same time we should also remember that a treaty becomes operative as a whole and thus other enforceability clauses can complement flexible mechanisms. The lack of enforceability in one particular clause of an agreement can be compensated by enforceability mechanisms incorporated in other parts. The study clearly found that flow variability mechanisms are rarely employed in isolation but rather as part of larger treaty packages. Nonetheless, it did not examine how the mechanisms interact, and possibly counteract each other. Hence, additional holistic analysis is still required for the study of transboundary water resource treaties in order to understand how flow variability and other mechanisms complement or contradict each other over time.

Since countries not only have to sign treaties but also comply with them, further study is also required on the effectiveness of each of the mechanisms to mitigate extreme events and to defuse the potential conflicts they might create. This also requires the study of potentially important side-effects such as changes in trust levels between signatories and beliefs about the certainty of co-riparian behavior in addition to examining each mechanism's primary impact on the management of flow variability. To carry out such work would require moving from the content analysis of signed treaties provided here to a more detailed case study approach. Attention is also needed on informal agreements not concluded in written form. Even at the transboundary level, institutions and governance structures do not have to be explicitly codified to have impact in general or for flow variability management in particular.

In the face of climate change, it is of crucial importance to identify the factors which make a society vulnerable and how a society can physically and socially adapt to a modifying environment (e.g. Adger et al., 2005; Füssel, 2007). With increasing water variability and scarcity, the ability of countries sharing a water resource to adapt partly depends upon the type, number and effectiveness of mechanisms to address variability incorporated in water agreements. Some mechanisms allow changing the rules of the game, while others enhance the capacity to absorb unexpected shocks. Some are based on high flexibility while others are based on high enforceability. This study is an attempt to identify the broad range of mechanisms, which have already been adopted and which are crucial for the sustainable use of the resource. The next step is to develop a better understanding of the function of these mechanisms, alone and in concert, and to ensure that the mechanisms most appropriate for particular basin conditions are in fact incorporated in future basin level agreements.

Uncited references

Allan (2002), Axelrod and Keohane (1985), Chenoweth and Feitelson (2001), Keohane (1982), Kindler (2000), Oye (1985), Stiftel, Shah and Van Koppen (2006).

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References

Abbott, K.W., Snidal, D., 2000. Hard and soft law in international governance. International Organization 54, 421–456.

Adger, W.N., Kelly, P.M., 1999. Social vulnerability to climate change and the architecture of entitlements. Mitigation and Adaptation Strategies for Global Change 4, 253–266.

Adger, W.N., Nigel, W., Tompkins, E.L., 2005. Adapting to climate change: perspectives across scales. Global Environmental Change 15, 75–76.

Adler, E., 1991. Cognitive evolution: a dynamic approach for the study of international relations and their progress. In: Adler, E., Crawford, B. (Eds.), Progress in Postwar International Relations. Columbia University Press, New York, pp. 43–88.

Akerlof, G.A., Maun, M., 1970. The market for 'Lemons': quality, uncertainty and the market mechanism. Quarterly Journal of Economics 84, 488–500.

Allan, J.A., 2002. Hydro-peace in the Middle East: why no water wars? A case study of the Jordan river basin. SAIS Review 22, 255–272.

Arvai, J., et al., 2006. Adaptive management of the global climate problem: bridging the gap between climate research and climate policy. Climatic Change 78, 217–225.

Axelrod, R., Keohane, R., 1985. Achieving cooperation under anarchy: strategies and institutions. World Politics 38, 226–254.

Bangladesh and India (1996) Treaty Between the Government of the Republic of India and the Government of the People's Republic of Bangladesh on Sharing of the Ganga/Ganges Waters at Farakka, 12 December.

Berlin Rules (2004) International Law Association, Berlin Rules on Water Resources.

Boockmann, B., Thurner, P.W., 2006. Flexibility provisions in multilateral environmental treaties. International Environmental Agreements 6, 113–135.

Chenoweth, J., Feitelson, E., 2001. Analysis of factors influencing data and information exchange in international river basins. Can such exchange be used to build confidence in cooperative management? Water International 26, 499–512.

Conca, K., Wu, F., Mei, C., 2006. Global regime formation or complex institution building? The principled content of international river agreements. International Studies Quarterly 50, 263–285.

Conway, D., 2005. From headwater tributaries to international river: observing and adapting to climate variability and change in the Nile basin. Global Environmental Change 15, 99–114.

Cook, K.S., Hardin, R., Levi, M., 2005. Cooperation Without Trust? Russel Sage Foundation, New York.

Craik, A.N., 1998. Recalcitrant reality and chosen ideals: the public function of dispute settlement in international environmental law. Georgetown International Environmental Law Review 10, 551–580.

Cutter, S.L., Boruff, B.J., Shirley, W.L., 2003. Social vulnerability to environmental hazards. Social Science Quarterly 84, 242–261.

Dai, A., Trenberth, K.E., Karl, T.R., 1998. Global variations in droughts and wet spells: 1900–1995. Geophysical Research Letters 25, 3367–3370.

Dietz, T., Ostrom, E., Stern, P.C., 2003. The struggle to govern the commons. Science 302, 1907–1912.

Dinar, S., 2006. Assessing side-payment and cost-sharing patterns in international water agreements: the geographic and economic connection. Political Geography 25, 412–437.

Feitelson, E., 2003. Packaging policies to address environmental concerns. In: Hensher, D.A., Button, K.J. (Eds.), Handbook of Transport and the Environment. Elsevier, Amsterdam.

Feitelson, E., Haddad, M., 1999. Identification of joint management structures for shared aquifers, a comparative Palestinian-Israeli effort. World Bank Technical Paper, no. 415.

Fischhendler, I. Harnessing ambiguity to resolve environmental disputes: the Case of the Jordan Basin. Journal of Peace Research, in press. Q6

Fischhendler, I., 2004. Legal and institutional adaptation to climate uncertainty: a study of international rivers. Water Policy 6, 281–302.

Fischhendler, I., Zilberman, D., 2005. Packaging policies for reforming the water sector: the Californian experience. Water Resources Research 41.

Fischhendler, I., Eaton, D., Feitelson, E., 2004. The short and long term ramifications of linkages involving natural resources: the US–Mexico transboundary water case. Environment and Planning C 22, 633–650.

Füssel, H.-M., 2007. Vulnerability: a generally applicable conceptual framework for climate change research. Global Environmental Change 17, 155–167.

Giordano, M.A., 2003. Managing the quality of transboundary rivers: international principles and basin-level practice. Natural Resources Journal 43, 111–136.

Gleick, P., 1993. Water and conflict, fresh water resources and international security. International Security 18, 79–112.

Goldenman, G., 1990. Adapting to climate change: a study of international rivers and their legal arrangements. Ecology Law Review 17, 741–802.

Haas, E.B., 1961. International integration: the European and the universal process. International Organization 15, 366–392.

Haas, P.M., 1992. Introduction: epistemic communities and international policy coordination. International Organization 46, 1–35.

Hamner, J., Wolf, A., 1998. Patterns in international water resource treaties: the transboundary freshwater dispute database, 1997 Yearbook of the Colorado. Journal of International Environmental Law and Policy, 157–177.

Intergovernmental Pannel on Climate Change, 2001. Climate Change 2001: The Scientific Basis. Cambridge University Press, Cambridge. 〈http://www.ipcc.ch/ipccreports/tar/wg1/pdf/TAR-09.PDF〉. Q7

Jury, A.W., Vaux Jr. H., 2004. The role of science in solving the world's emerging water problems, Arthur M. Sackler Colloquium entitled The Role of Science in Solving the Earth's Emerging Water Problems, 8–10 October.

Karkkainen, B.C., 2004. Post-sovereign environmental governance. Global Environmental Politics 4, 72–96.

Keohane, R.O., 1982. The demand for international regimes. International Organization 36, 185–205.

Kindler, J., 2000. Integrated water resources management: the meanders. Water International 25, 312–319.

Koremenos, B., 2001. Loosening the ties that bind: a learning model of agreement flexibility. International Organization 55, 289–325.

Matsumoto, K., 2002. Transboundary groundwater and international law: past practices and current implications. Master's Dissertation, Oregon State University.

McCaffrey, S.C., 2003. The need for flexibility in freshwater treaty regimes. Natural Resources Forum 27, 156–162.

McIntyre, O., 1998. Case law analysis: environmental protection of international rivers. Journal of Environmental Law 10, 80–91.

Mitchell, R.B., Keilbach, P.M., 2001. Situation structure and institutional design: reciprocity, coercion, and exchange. International Organization 55, 891–917.

Moench, M., Dixit, A. (Eds.), 2004. Adaptive Capacity and Livelihood Resilience: Adaptive Strategies for Responding to Floods and Droughts in South Asia. The Institute for Social and Environmental Transition, Kathmandu.

Oye, K., 1985. Explaining cooperation under anarchy: hypothesis and strategies. World Politics 38, 1–24.

Pahl-Wostl, C., 2005. Transitions towards adaptive management of water facing climate and global change. Presented at the International

Conference on Integrated Assessment of Water Resources and Global Change: A North–South Analysis, Bonn, Germany, 23–25 February.

Pahl-Wostl, C., Gupta, J., Petry, D., 2006. Governance and the global water system: towards a theoretical exploration. Paper Presented at the GWSP International Workshop "Governance and the Global Water System," Bonn, Germany, 20–23 June 2006.

Salman, S.M.A., Uprety, K., 2002. Conflict and Cooperation on South Asia's International Rivers. World Bank Publications, Washington, DC.

Q8 Scholz, T., Stiftel, B., 2005. The challenges of adaptive governance. In: Scholz, T., Sebenius, J., (Eds.) 1983, Negotiation Arithmetic: Adding and Subtracting Issues and Parties, vol. 37(2). International Organization, pp. 281–316.

Shah, T., Van Koppen, B., 2006. Is India ripe for integrated water resources management? Economic and Political Weekly 41, 3413–3421.

Stiftel, B. (Ed.), Adaptive Governance and Water Conflict: New Institutions for Collaborative Planning. RFF Press, Washington, DC.

Susskind, L.E., 1994. Environmental Diplomacy, Negotiating More Effective Global Agreements. Oxford University Press, Oxford and New York.

TFDD. Transboundary Freshwater Disputes Database. 〈http://www.transboundarywaters.orst.edu〉.

Thompson, A., 2005. The rational choice of international institutions: uncertainty and flexibility in the climate regime. In: Proceedings of the Annual Meeting of the American Political Science Association, Washington, DC, 1–4 September.

UNEP, 2002. Vital Water Graphics. 〈http://www.unep.org/dewa/assessments/ecosystems/water/vitalwater/03.htm〉.

UNEP, 2006. Human Development Report. Beyond Scarcity: Power, Poverty, and the Global Water Crisis. Palgrave Macmillan, Basingstoke.

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

Walker, B., et al., 2002. Resilience management in social-ecological systems: a working hypothesis for a participatory approach. Conservation Ecology 6, 14.

Weinthal, E., Marei, A., 2002. One resource two visions, the prospects for Israeli-Palestinian water cooperation. Water International 27, 460–467.

Weinthal, E., 2001. Sins of omission: constructing negotiating sets in the Aral Sea basin. Journal of Environment and Development 10, 50–80.

Wolf, A., 1998. Indigenous approaches to water conflict resolution and implications for international waters. In: Conference on Water and Food Security in the Middle East, Nicosia, Cyprus, 20–23 April.

Wolf, A., 1999. Criteria for equitable allocations: the heart of international water conflict. Natural Resources Forum 23, 3–30.

Yoffe, S., Wolf, A., Giordano, M., 2003. Conflict and cooperation over international freshwater resources: indicators of basins at risk. Journal of the American Water Resources Association 39, 1109–1126.

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