

TRANSBOUNDARY RIVER FLOODS AND INSTITUTIONAL CAPACITY¹

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ABSTRACT: While transboundary flood events have become more frequent on a global scale the past two decades, they appear to be overlooked in the international river basin (IRB) cooperation and management arena. The present study therefore combined geopolitical measures with biophysical and socioeconomic variables in an attempt to identify the IRBs with adequate institutional capacity for management of transboundary floods. It also classified basins that would possibly benefit from enlarging the institutional capacity related to transboundary floods. Of the 279 known IRBs, only 78 were represented by a transboundary rivers institution. A mere eight of the 153 identified institutions had transboundary flooding listed as an issue in their mandate. Overall, 43 basins, where transboundary floods were frequent during the period 1985-2005, had no institutional capacity for IRBs. The average death and displacement tolls were found to be lower in the 37 basins with institutional capacity, even though these basins experienced twice as much transboundary floods with significant higher magnitudes than those in basins without institutional capacity. Overall, the results suggested that institutional capacity plays a role in the reduction of flood-related casualties and affected individuals. River basins such as the Juba-Shibeli, Han, Kura-Araks, Ma, Maritsa, Po, Coco/Segovia, Grijalva, Artibonite, Changuinola, Coatan Achute, and Orinoco experienced more than one transboundary river flood, but have not yet set up any institutions for such events, or signed any appropriate treaties focused on floods. These basins were therefore recommended to consider focusing attention on this apparent lack of institutional capacity when it comes to managing transboundary flood events.

(KEY TERMS: flood management; water policy; transboundary floods; international river basins; international water institutions.)

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INTRODUCTION

Flood management is complicated enough in river basins controlled by a single authority, and becomes even more challenging when dealing with transboundary floods, i.e., floods that originate in one country or jurisdiction and then propagate downstream to another country or jurisdiction. Under such circum-

stances, the demands on international cooperation and management in all aspects of flood management are particularly important, especially because institutional capacity in an international river basin (IRB) should be able to absorb changes in the basin in order to decrease the chances for conflict (Wolf *et al.*, 2003). Nevertheless, not much is known about the institutional structures set up specifically for IRBs, let alone whether this institutional capacity is exclusively or

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partly designed for transboundary flood events. Previous studies have focused on water or flood management in specific countries (Arnell, 1998; Olsthoorn and Tol, 2001; Dixit, 2003; Enserink *et al.*, 2003; van Steen and Pellenbarg, 2004; among others), and integrated water resource management (Biswas, 2004; Blomquist and Schlager, 2005) or water institutions in general (Gopalakrishnan *et al.*, 2005). It is only recently, that researchers have begun to look at the phenomenon of shared or transboundary floods (Marsalek *et al.*, 2006) or water treaties concentrated on flooding in a sample of global basins (Drieschova *et al.*, 2008). However, these studies, while providing a background for understanding the problem at hand, continue to be basin-specific (Beaumont, 1998; Feitelson, 2000; Middelkoop and Kwadijk, 2001; Maganga *et al.*, 2003; Muckleston, 2003), rather than providing the worldwide picture of the current global institutional capacity in the area of floods in IRBs. The goals of this study are therefore to fill this knowledge gap by focusing on the global state of affairs of institutional capacity related to transboundary floods. In doing so, this paper will be the first attempt of a large *N*-study that provides insight into the vulnerability of IRBs to transboundary river floods. Institutional capacity herein and for the remainder of this paper means – international water management bodies and freshwater treaties, related to transboundary river flood events.

The above goals of the study were accomplished by first producing a database that summarizes the institutional capacity per IRB. The second step was to find out whether transboundary flood events were a priority for the identified institutions – i.e., were transboundary flood events mentioned as an objective in the mandate of the institution?

Given that floods are not as recurrent as other natural disasters in certain regions, policy makers might find it complex to warrant putting time, effort, and financial resources into it. In regions where floods do take place regularly, the events might be too complicated to capture in official forms of international cooperation, such as institutions and treaties. Consequently, the working hypothesis of this study is that transboundary flood events are underrepresented as principal issues of institutions and treaties.

Linked to this hypothesis is the justification to look for connections between conflict and institutional capacity related to transboundary floods. While cooperation around extreme weather events such as floods intuitively would seem to be the norm, the possibility for conflict increases when institutional capacity to absorb such rapid changes in the physical system is absent (Wolf *et al.*, 2003). Thus to accurately gauge vulnerability to transboundary floods, these two aspects (i.e., institutional capacity and rapid change

within the basin) must be assessed together. The database created herein therefore combined publicly available data to identify international freshwater treaties that dealt with transboundary flood events and investigate whether transboundary floods have caused a disproportional number of conflicts. The answers to the questions posed will not only clarify which IRBs have institutions, but more importantly, they will highlight the basins that are recommended to look into increasing their institutional capacity when it comes to the management of transboundary floods.

This paper is structured as follows. The Floods – General Synopsis section introduces facts and figures on (transboundary) floods, which is then proceeded by a discussion on how floods affect different countries in different ways. The Methodology section discusses the methodology used including definitions used throughout the remainder of the paper. The section Results and Discussion presents the results. The section Summary and Conclusions discusses the results, offers recommendations, and draws conclusions.

FLOODS – GENERAL SYNOPSIS

The United Nations Development Programme (UNDP) estimated that in 2004 on average about 196 million people in more than 90 countries were exposed every year to catastrophic flooding (UNDP, 2004). Many more are exposed to minor or localized flood hazards that can have a cumulative dampening impact on development, but do not cause major human losses in single events. Consequently, very few countries and very few parts of the world's population are spared the effects of floods. Over the last 21 years, a little more than 85% of all countries have experienced one or more flood events. On a global scale, flood losses are increasing dramatically, mainly because of population and capital moving into harm's way (Mitchell, 2003). The flood events of last year (excluding flash floods) caused 4,240 fatalities worldwide (4% of the total number of casualties) and accounted for US\$16 billion of losses (7% of the total). The total number of river floods differs per year, but a steady increase is visible. In the period 1985–2005, river floods alone (1,760 in total) caused over 112,000 people their lives, affected more than 354,000,000 people and resulted in $\text{US\$}6.9 \times 10^{11}$ in financial damages (Bakker, 2006).

It should be noted that an increase in flood frequency can be due to the fact that these events do indeed occur more often (possibly due to changes in climate patterns). However, while a thorough attempt was made by the author to obtain all data available

about global flood events, it must be kept in mind that measuring the global flood problem is fraught with problems because of (1) gaps and numerous deficiencies in data and (2) the highly variable quality of available data. As media penetration and information communication have improved, events that might not have been reported in previous years are now routinely reported. Still, in many parts of the world there are no reliable data on the extent of exposure of people and property to flood hazards and reports of the effects of flood disasters are always likely to be less complete in regions with limited resources.

The Case of Transboundary Floods

Over the last 21 years, only 29 of 194 countries have not experienced some type of flood event (Bakker, 2009); a little more than 85% of all countries experienced one or more flood events in the last two decades. Population growth and urbanization has led to more people in flood-prone areas, so that damages associated with (transboundary) floods would have increased whether or not the frequency of the events themselves have increased. Still, some 175 of the 1,760 river floods were shared by two or more countries, but globally accounted for 32% of all casualties, almost 60% of all affected individuals and 14% of all financial damage (Bakker, 2006) – clearly a sign of the massive impacts of transboundary flood events on a global scale.

Water Management Institutions

By definition, institutions are humanly devised constraints that shape human interaction or, less formally, the rules of the game in society (North, 1990). The broadest definitions of institutions include both formal institutions, such as administrative structures, and informal institutions, such as customs and practices (Olsson, 2003). However, in the remainder of this paper the term “institutions” is used in the sense of formal institutions only. As a result, whenever the term “institutions” is used, it will point to formal, government-based institutions specifically designed for the management of IRBs.

River Basin Management. Water management is based on certain (implicit or explicit) principles, rules and decision-making procedures that enable to converge between the actors’ expectations. Such a set of principles, rules, and procedures is called a regime. Transboundary water regimes usually include both formal rules such as international water conventions, statutes of transboundary water commissions, cooper-

ative agreements adopted by national governments and aimed at coordinating national water management activities in transboundary water basins, relevant national laws, and procedures as well as informal rules such as, for an example, traditional ways of using natural resources (traditional ways of transport or fishing, etc.) that are informally accepted in transboundary water basins but are not documented as formal norms in agreements or contracts (Roll *et al.*, 2008). It may be clear that to prevent and resolve (potential) conflicts, and avoid severe effects of floodings, droughts, accidents, etc., especially in transboundary waters, countries sharing a water resource need to agree on common rules and procedures of cooperation to jointly manage these water resources (Nilsson, 2006). Moreover, since any action in one part of the basin has impacts in the other parts, joint and cooperative management of water resources is a desirable goal sought by many governments, policy experts, and water management professionals (Ostrom, 1990; Dellapenna, 2001; Kliot *et al.*, 2001; Jägerskog, 2002; Turton and Henwood, 2002; Phillips *et al.*, 2006). Over time, cooperation may be established on different water management issues, like joint projects or even joint planning (Enderlein, 1999).

The notion that measures to reduce flood risks should, as far as possible, be coordinated for a river basin as a whole, in particular for transboundary basins, is widely accepted – see for instance the EU Flood Directive (Directive 2007/60/EC). Countries throughout the world have created various special purpose agencies to develop and manage the waters locally, regionally, or for IRBs. Managing IRBs complicates water management because control of international rivers that cross political boundaries indiscriminately is tangled with power issues, economic opportunity, national security, society, and culture. As an institution influences behavior and thus the number of conflicts arising over behavior differences, one dominant role of a water institution is to reduce conflict (Lynne *et al.*, 1990). Giordano and Wolf (2001) indeed showed that where relatively strong, sustainable institutions are in place, international water disputes do get resolved, even among enemies.

Flood Management. Although floods are basin-wide phenomena that do not respect administrative, cultural, tribal, linguistic, religious, political, or other humanly devised borders, whether they are national, regional, local, or institutional, flood management at root is and ought to be a national endeavor, especially as the sovereignty principle advocates that each nation has the right to develop its own policies, laws and institutions, and its own strategies for natural resources development and utilization principles.

However, local or national flood protection measures can have negative effects both downstream and upstream. Therefore, national flood protection measures ought to always take into account possible impacts on the other riparian states they share the watercourse with. That way, measures taken within the catchment area and along the main rivers to improve safety against flooding will, theoretically, not lead to negative effects downstream. Furthermore, national efforts to protect citizens from floods need to maintain synergy with efforts at bilateral and regional levels.

There are several advantages of a river basin approach. For instance, knowledge on the flood formation processes can be shared and opportunities may arise to find better and more cost effective solutions. Enlarging the planning space enables the implementation of measures at locations where they create optimum effect. Finally, calamity management is highly depending on early information and requires forecasts and data from the river basin as a whole.

Despite the clear benefits outlined above, cross-border cooperation in flood management does not always come naturally nor does it come easy. Strengthening regional cooperation is a process that requires political will and commitment, time, effort, financial resources, and meaningful technical cooperation, preferably from all the riparians. Successful transboundary cooperation in the area of floods furthermore heavily depends on a common understanding of the problem, the needs, and interests of all the regions in the river basin and the causes of and solutions to the problem with respect to natural, economical, social, and political processes. In addition, common and shared goals and visions, agreed upon strategies and compensation mechanisms such as cross-border financing or other tradeoffs to balance the costs and benefits, are essential. These requirements can only be met if there is a level of confidence and trust, which can be a barrier in conflict-stricken IRBs where the management of transboundary water resources might not be the overt priority of the riparians (as is the case, for example, in the Jordan and the Tigris-Euphrates river basins). In unstable regions like these, successful transboundary water cooperation depends heavily on power relations and the political dynamics prevailing in a given region. Riparians might fear that they may have to surrender sovereign powers in transboundary water cooperation, limiting their options. As a consequence, the benefits of distributing the problems and benefits of a transboundary resource might get overlooked and it may appear more profitable on a financial and political level to opt for national endeavors only and minimize the vulnerability of the region without investing in new and costly institutional processes. Transbound-

dary water cooperation is to benefit all stakeholders. The clearer these advantages are made from the outset, the greater is the riparian states' willingness to cooperate. In order for these advantages to materialize, there is not only a need for transboundary dialog but also for investment and regulation.

In summary, river basin management, which includes flood management, should have a solid national foundation with firm within country policies, but ought to be based on the boundaries of the river basin, not on administrative or country borders. Transboundary cooperation between local and regional flood management authorities has the ability to improve the overall effectiveness of flood management services, which will eventually result in better protection of citizens and the environment and a reduction of risks and damages. To be sure, the only way to truly approach basin-wide events like floods in an integrated manner is via transboundary cooperation. However, transboundary water cooperation can only emerge through efforts made by the riparians themselves. Examples of how this widely accepted vision is being implemented can be found in the Danube river basin (Tóth, 2004), the Rhine river basin (Becker *et al.*, 2007) and the Mekong river basin (MRC, 2007), to name but a few. In addition, the inclusion of water cooperation issues in institutional frameworks such as the G8 Africa Action Plan and the EU Flood Directive provide riparians with incentives for cooperation.

METHODOLOGY

Selected Variables and Definitions

In order to test the hypothesis, examine the institutional capacity and overall vulnerability linked to transboundary floods, several variables were identified. This section presents those variables selected along with brief definitions.

Institutional Capacity: International River Basin Institutions and Treaties. The knowledge gap on institutional capacity in IRBs was filled by creating a global database of river basin organizations and river basin commissions, collectively called international river basin institutions (IRBIs) principally erected for IRBs. Since the concepts "commission" and "organization" are somewhat fuzzy throughout the literature, both terms can and are used loosely and possibly even interchangeably. Therefore, in the remainder of this paper, IRBIs will be used to refer to both concepts.

An attempt was made to summarize the number and nature of multilateral institutions that deal with international waters issues. To this end, data were collected by sending out surveys, conducting interviews, and searching the World Wide Web to compile an empirical database of institutions and organizations which added to some type of institutional capacity in the IRBs around the world. When looking more closely at IRBIs, information sought after were indications of how active the institutions appeared to be. When no tangible forms of cooperation (projects in progress, recently updated websites with publicly accessible data on the river basin, signed treaties, etc.) were found, the IRBI was not included in the list. The resulting list of IRBIs was then categorized per IRB, and included the principal issues of the organizations as stated by the organizations themselves (via a mission statement, or otherwise), why and when they were erected, which riparians were part of the IRBI, and what topics they were concerned with.

To examine how many international freshwater treaties dealt with transboundary flood events, data from the Transboundary Freshwater Dispute Database (TFDD) were ordered according to continent and IRB. Subsequently, the categorization of the TFDD was used to retrieve only those treaties that dealt with transboundary flood issues.

The distinction between treaties and IRBIs was made for several reasons. First of all, the presence or absence of a treaty does not automatically indicate the presence or absence of an IRBI, and vice versa. For instance, the International Commission for the Protection of the Rhine against Pollution was created on an informal basis by France, Germany, the Netherlands, Switzerland, and Luxembourg. Secondly, it can take years before the erection of a joint body called for in a treaty takes place in reality. Consequently, by distinguishing treaties from IRBIs, the research resulted in a maximum number of IRBIs detected.

Water Events. To find out whether transboundary floods have caused a disproportional number of conflicts, Yoffe's (2001) data on what kind of issues sparked water events during the period 1948-1999 were combined with the author's data for the period 2000-2004. A water event is defined by Yoffe (2001) as instances of conflict and cooperation that occur within an IRB, that involve the nations riparian to that basin, and that concern freshwater as a scarce or consumable resource (e.g., water quality and water quantity) or as a quantity to be managed (e.g., flooding or flood control and managing water levels for navigational purposes). This definition was also used during the search for water events for the period 2000-2004. Note, however, that a lack of events making the news does not necessarily mean there were

no events; in some countries, governments can deliberately hold back data, or communication lines in general can be poor.

The search for the period 2000-2004 was based on Yoffe's protocol, but redesigned to be more inclusive; the search criteria were narrowed down by basin and the news sources were expanded. Due to a lack of time, this search excluded the IRBs of South America and Africa.

The Basins at Risk (BAR) scale (Yoffe, 2001), a measurement of the intensity of an event that ranges from -7 to +7 (with -7 denoting the most conflictive events, 0 denoting neutral events, and +7 denoting the most cooperative events) was used to identify the level of cooperation of the flood-related events.

Vulnerability to Transboundary Floods: Physical, Socioeconomic, and Geopolitical Measures Combined. Lastly, to establish whether or not institutions made a difference when it came to transboundary floods, data from the vulnerability assessment of Bakker (2009) (i.e., physical and socioeconomic variables of transboundary floods: the magnitude of the river floods, financial damages, number of casualties, and number of displaced individuals) were added to the data on geopolitical capacity from the present study (i.e., presence or absence of institutions). The flood magnitude is a variable used by the Dartmouth Flood Observatory (DFO) and is the result of the following calculation:

$$\text{Flood magnitude} = \ln(\text{duration}) \times \text{severity class} \times \sqrt{\text{affected region}/100} \quad (1)$$

in which the severity class is a magnitude assessment and floods are ranked on a 1-3 scale. For more details, see Bakker (2006) or the DFO (2007 – website: <http://www.dartmouth.edu/~floods/>).

By merging these two datasets, more light was shed on vulnerability to and institutional capacity set up for transboundary flood events. The statistical relevance of found linkages was tested using the non-parametric two-sided Wilcoxon's rank sum test.

RESULTS AND DISCUSSION

Global Database on Institutional Capacity for Transboundary River Floods

At present, there are 279 rivers around the world that cross the boundaries of two or more nations

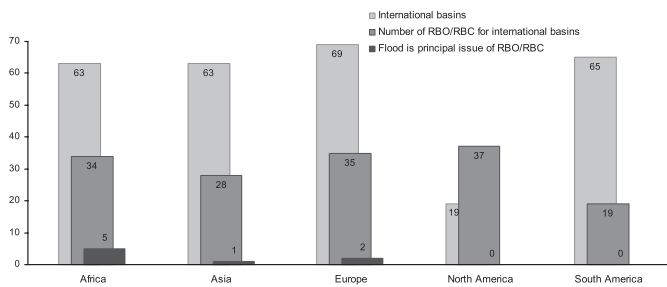


FIGURE 1. The Number of International River Basins (IRB) Per Continent, Followed by the Basins With an International River Basin Institution (IRBI), and the Number of Institutions That Had Transboundary Floods Listed as a Principal Issue in Their Mandate.

(Bakker, 2006). For these 279 identified IRBs, 153 IRBIs were found. Slightly more than 12% of all the IRBs (i.e., 34) had more than one institution that dealt with transboundary water issues. Consequently, only 78 of the 279 IRBs (almost 28%) were represented by a commission or organization.

Note, however, that a value of zero institutions found does not necessarily reflect the absence of an IRBI; it merely means that no such body was found at the time of the search. Furthermore, a higher number of IRBIs does not automatically result in better management or relative better international cooperation in the specific basins, if such a variable can be gauged at all. Lastly, the presence of an IRBI in an IRB does not imply that all riparian countries were parties to the institution; some forms of international water collaboration include all the riparian states, while others do not. See Bakker (2006) for a detailed summary per continent with specific examples.

When categorized per continent (Figure 1), South America had the fewest number of institutions set up for IRBs resulting in more than 80% (or 53) of their IRBs without a form of organization specifically designed to deal with transboundary water issues. Africa, Asia, and Europe do slightly better: 25, 27, and 29% of their IRBs were represented by an IRBI, while the 37 institutions in North American represent all IRBs.

Principal Issues IRBIs

On a global scale, transboundary water institutions were mostly classified as set up for joint management. Water quality and technical cooperation/assistance were two other important issues as indicated by the IRBIs, while territorial issues were not a high priority. Out of the 153 transboundary institutions, only eight were principally concerned with flooding, five of which were located in Africa, two in Europe, and one in Asia. North America and South America did not have any form of institution that had been created with floods as one of the reasons (Figures 1 and 2).

Flood-Related Events

By isolating the events related to water in the period 1948-2004 (Yoffe, 2001; to which data from the author were added), almost 3% (59 out of 2,269) of the events were related to flood control or flood relief. Figure 3 shows how these events were divided per continent; Africa, the continent with the highest

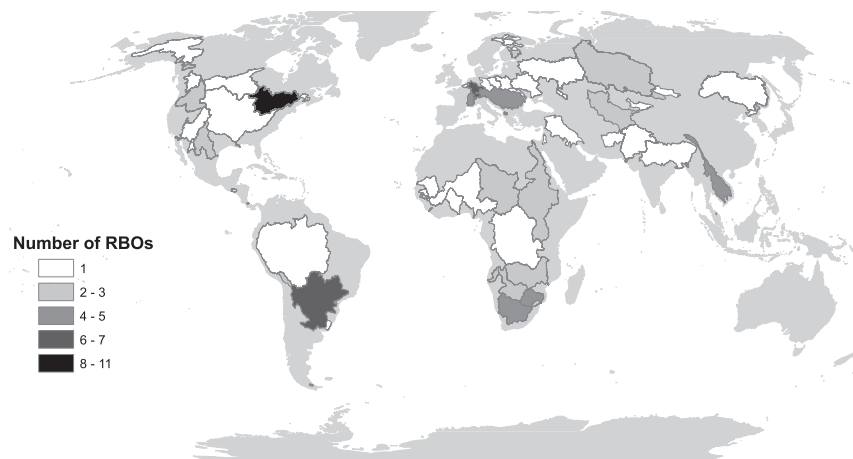


FIGURE 2. Global Map Indicating the Number of International River Basin Organizations Per International River Basin (IRB).

The IRBs in South America had the least amount of shared water institutions; more than 80% did not have some form of organization specifically designed to deal with transboundary water issues. In Africa, Asia, and Europe, 25, 27, and 29% of the IRBs were represented by some form of institution. All of the North American IRBs had institutional capacity linked to IRBs.

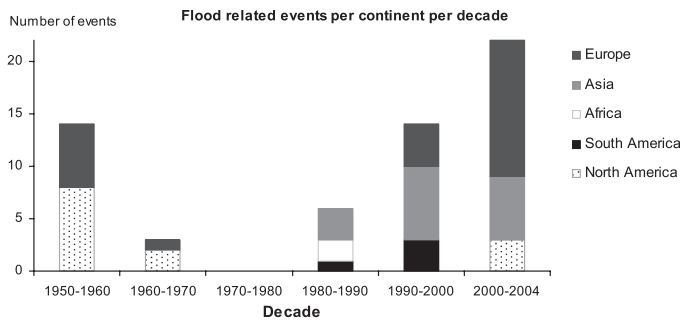


FIGURE 3. Flood-Related Events Categorized Per Continent and Per (half) Decade Show That Transboundary Flood-Related Events Were Relatively New on the Asian Continents, and Have Been Increasing on the European Continent Since the Beginning of the 21st Century. African and South American flood-related events appear to be rather exceptional, although this might be due to poor or missing data. Note that South America and Africa were not included for the period 2000-2004.

number of institutions that had floods as one of their principal issues, experienced the fewest flood events (two back in 1988), while Asia and Europe, with one respectively two institutions that deal with floods, had to cope with the most (16 respectively 24 events). North America experienced 13 events, South America 12, but neither continents had institutions with floods as a principal issue.

Most of the flood-related events took place in Europe, in the Danube river basin (Figure 3). The La Plata river basin was second with 10 events, whereas the Ganges–Brahmaputra–Meghna basin has had eight events related in some degree to floods during the period 1948-2004. When events were broken up by continent and by decade (Figure 3), flood-related events seemed to be increasing particularly on the Asian and European continent. On the African continent, flood-related events rarely made the news, although 39 transboundary flood events took place on that continent. Careful examinations furthermore showed that, after a rather rapid decline in events related to floods, there had been an increase from 1980 onwards; it appeared that the number of flood-related events increased the last 25 years, especially when taking into consideration that the last column was only for the period 2000-2004, not a full decade.

Intensity of Flood-Related Events. When categorized using the BAR scale (Yoffe, 2001), the identified flood-related events were mostly found to be in the cooperative range (BAR 1, 2, and 3) (Figure 4). Events in North America had the broadest range, while events taking place on the European and South American continent were all cooperative. Nine incidents have been ranked as the single most cooperative event (BAR 6), but these all took place

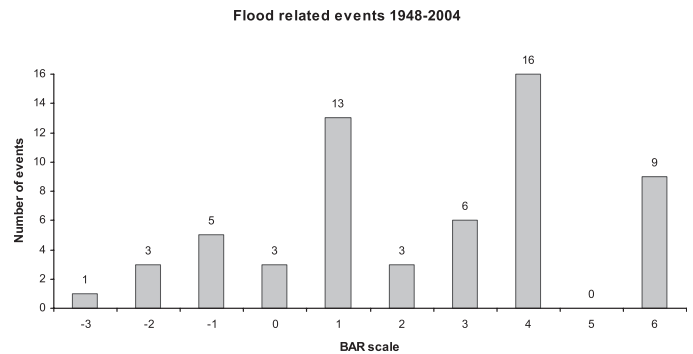


FIGURE 4. When All the Flood-Related Events Were Ranked on the BAR Scale, It Was Evident That Most of the Events Were in the Cooperative Range, and Only 13.2% Have Been Ranked as Conflicting. The BAR scale ranges from -7 (formal declaration of war) to +7 (voluntary unification into one nation). For more information on BAR, see Yoffe, 2001.

before 1970. While all flood-related events were overwhelmingly cooperative, an alarming increase of less cooperative incidents over the past 15 years was noticeable.

The topics of the cooperative flood-related events were mostly assistance during or after floods, agreements on data sharing, and agreements to jointly study how to control floods. Less cooperative events were related to placing the blame on each other for floods, or criticizing constructions that affected other riparians.

International Freshwater Treaties and Transboundary Floods

At the time of writing, the TFDD had 692 international water documents in its database, some of which are treaties, while others are amendments, protocols, or other legal records. According to the TFDD categorization system, a mere 24 of these were labeled as dealing with flood-related issues. Globally, no more than 11 basins (or 3.6%) had international freshwater treaties with floods as their principal issue. Note that this database was not updated by the author – the numbers found for international water treaties only apply to the period 1948 to 1999. In addition, the database is being adjusted by lawyers to more accurately depict the nature and consequences of the different structures of international treaties (J. Landovsky, personal communication). Finally, treaties that might appear to focus on areas other than flood-related matters can actually include actions related to flood control, but not be defined as such. As a result, these treaties will not show up in the search and were consequently not included.

Europe had the most international water treaties that deal with flood issues, while in Africa and Asia, despite the presence of a substantial number of international freshwater treaties, none of the treaties had floods as their principal issue. Except for one treaty drafted for the Rhine basin, all of the treaties related to floods were bilateral. Although Europe had the highest number of freshwater treaties dealing with flood events, percentage wise, the North American IRBs had the highest coverage. However, a noteworthy observation is that six out of the eleven IRBs with flood-related international treaties did not experience any transboundary flood events during the last 21 years. Only the Danube, Po, Rhine, Rio Grande/Rio Bravo and the Nelson-Saskatchewan river basins experienced transboundary floods, the others did not.

The Importance of Institutional Capacity

The results described above did not yet clearly establish whether institutions made a difference when it came to transboundary floods. Therefore, available physical and socioeconomic variables of transboundary floods (i.e., the vulnerability framework data from Bakker, 2009) were added to the geopolitical measure (i.e., presence or absence of institutions). Consequently, linkages to institutional capacity could be made (Figures 5a through d; complemented with data from Bakker, 2006). Although statistically inconclusive (p -values were equal or higher than 0.19, with sample sizes n varying from three to 14 on a global scale; see also Tables 1 and 2) the average death and displacement tolls relative to the million population living in the IRBs, were lower

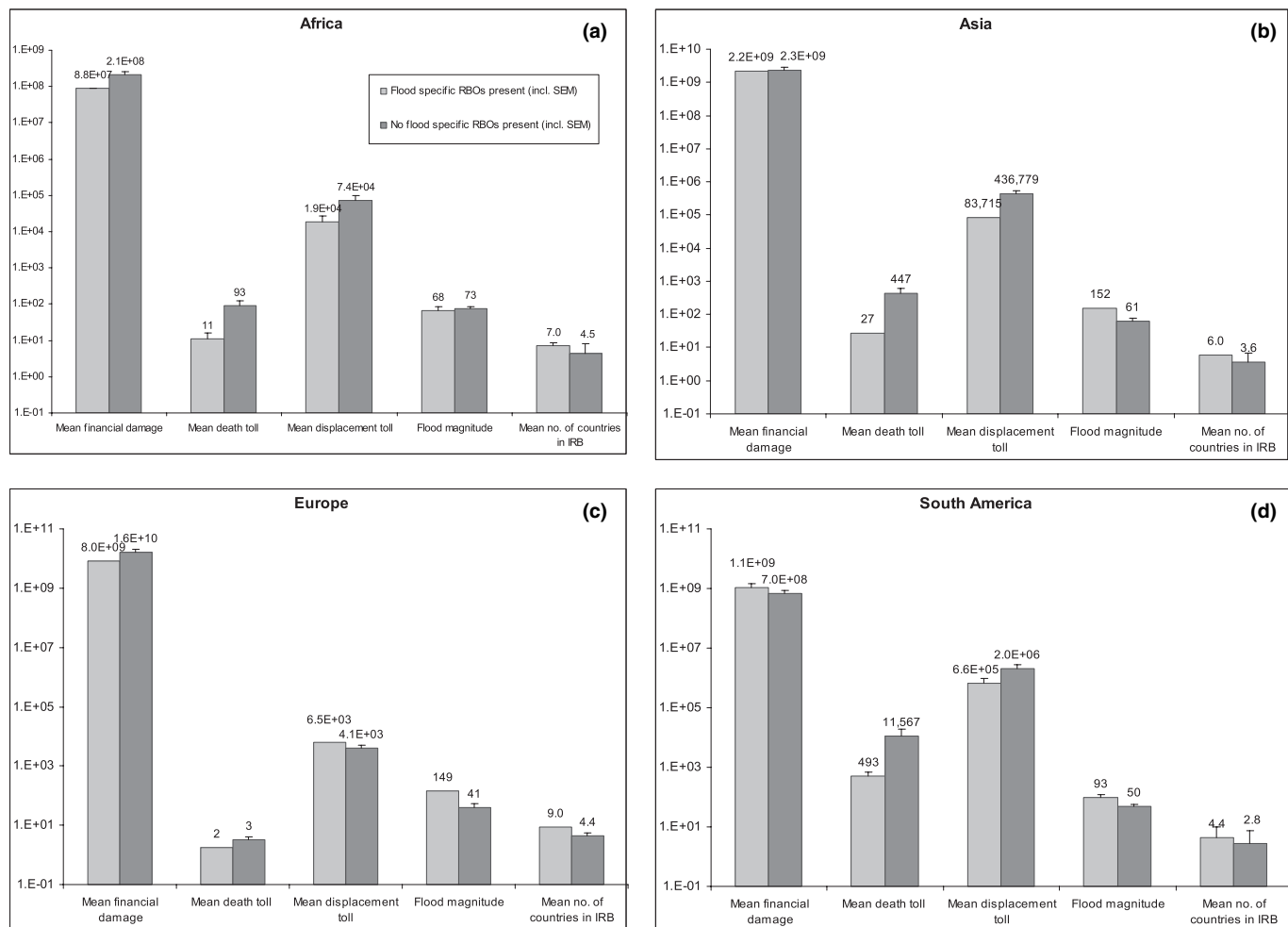


FIGURE 5. (a-d) Mean Financial Damage, Mean Death Toll, Mean Displacement Toll, Flood Magnitude, and Mean Number of Countries in IRBs With (light gray) and Without (dark gray) Institutional Capacity. Values for North America were not compared, because all IRBs had institutional representation. Flood-related institutional capacity present in the IRB seemed to result in lower death and displacement tolls, although the flood magnitudes were significantly higher in these basins. Severity and the number of countries present in the basin may both be responsible for higher average financial damages. The same trends were visible on a global scale.

TABLE 1. Results of Wilcoxon's Two-Sided Rank Sum Test: A Comparison Between IRBs With and Without Institutional Capacity.

| | Financial Damage | Average Death Toll | Average Displacement Toll | Total Flood Magnitude | Average Flood Magnitude | Number of Countries in IRB |
|---------------|------------------|--------------------|---------------------------|-----------------------|-------------------------|----------------------------|
| Africa | 1;7-4 | 0.27; 14-6 | 0.59; 14-6 | 0.08; 14-6 | 0.16; 14-6 | 0.01; 14-6 |
| Asia | 0.29; 5-4 | 0.80; 8-8 | 1; 8-9 | 0.24; 8-10 | 0.46; 8-10 | 0.01; 9-10 |
| Europe | 0.27; 2-4 | 0.48; 4-6 | 0.50; 3-8 | 0.21; 4-8 | 0.81; 4-8 | 0.23; 4-8 |
| South America | 0.35; 4-10 | 0.19; 4-14 | 0.35; 4-13 | 0.13; 5-14 | 0.49; 5-14 | 0.01; 5-14 |
| Global | 0.25 | 0.22 | 0.51 | 8.0E-04 | 0.03 | 6.52E-08 |

Notes: H_0 : medians are equal; H_1 : medians are not equal; IRB, international river basin.

There are no comparisons for North America due to the fact that this continent has no IRBs without institutional capacity.

p -values followed by the n -values of the sample with institutional capacity and the n -values of the sample without institutional capacity.

TABLE 2. Results of Wilcoxon's Two-Sided Rank Sum Test: A Comparison Between IRBs With and Without Flood-Related Institutional Capacity.

| | Financial Damage | Average Death Toll | Average Displacement Toll | Total Flood Magnitude | Average Flood Magnitude | Number of Countries in IRB |
|--------|------------------|--------------------|---------------------------|-----------------------|-------------------------|----------------------------|
| Africa | 1; 1-10 | 0.34; 5-15 | 0.66; 25-15 | 0.60; 5-15 | 0.54; 5-15 | 0.15; 5-15 |
| Asia | 0.89; 1-8 | 0.75; 1-15 | 0.82; 1-16 | 0.33; 1-17 | 0.56; 1-17 | 0.63; 1-18 |
| Europe | 1; 1-5 | 1; 1-9 | 0.73; 1-10 | 0.33; 1-11 | 0.5; 1-11 | 0.33; 1-11 |
| Global | 0.38 | 0.81 | 0.58 | 0.02 | 0.03 | 0.01 |

Notes: H_0 : medians are equal; H_1 : medians are not equal; IRB, international river basin.

There are no comparisons for North America and South America due to the fact that these continents have no IRBs with floods as their principal issue. The global comparison therefore is without the Americas.

p -values followed by the n -values of the sample with flood-related institutional capacity and the n -values of the sample without flood-related institutional capacity.

TABLE 3. Summary of All the IRBs That Experienced Transboundary Floods.

| Continent | Floods in IRB | IRB | Institution Y/N | Number of IRBs | Flood principal issue? | Flood related treaties? | Continent | Floods in IRB | IRB | Institution Y/N | Number of IRBs | Flood principal issue? | Flood related treaties? | |
|-----------|--------------------------------|--------------|-----------------|----------------|------------------------|-------------------------|------------|---------------|---------------------|-----------------|----------------|------------------------|-------------------------|---------------|
| Africa | 5 | Congo/Zaire | Y | 1 | Y | N | Europe | 11 | Rhine | Y | 6 | 1 | 4 | |
| | 1 | Gambia | | 24 | | | | Danube | 4 | | | 7 | | |
| | 1 | Geba | | 3 | | | | Maritsa | 1 | | N | N | | |
| | 2 | Niger | | 1 | | | | Ebro | 1 | | | 3 | | |
| | 1 | Senegal | | 2 | | | | Po | | | | | | |
| | 1 | Incomati | | 2 | | | | Dnieper | | | | | | |
| | 1 | Kunene | | 1 | | | | Douro/Duero | | | | | | |
| | 1 | Lake Chad | | 2 | | | | Elbe | N | | | N | | |
| | 2 | Limpopo | | 1 | | | | Neretva | | | | | | |
| | 8 | Nile | | 1 | | | | Nestos | | | | | | |
| | 1 | Okavango | | 1 | | | | Seine | | | | | | |
| | 1 | Orange | | 1 | | | | Vardar | | | | | | |
| | 2 | Volta | | | | | | | | | | | | |
| | 6 | Zambezi | | | | | | | | | | | | |
| Asia | 1 | Gash | N | 3 | | | N. America | 1 | Nelson-Saskatchewan | Y | 1 | N | 1 | |
| | 1 | Gaur | | | | | | 2 | Rio Grande | | 4 | | | |
| | 4 | Juba-Shabeli | | | | | | 1 | Skagit | | 1 | | N | N |
| | 1 | Oueme | | | | | | 1 | St. John | | 1 | | | |
| | 1 | Sabi | | | | | | 2 | Tijuana | | 2 | | | |
| | 1 | Umbeluzi | | | | | | | | | | | | |
| | 8 | Mekong | | | | | | Y | 5 | | 1 | | N | South America |
| 3 | Aral Sea | 3 | | 4 | La Plata | 7 | | | | | | | | |
| 24 | Ganges-Brahmaputra-Meghna | 1 | | 1 | Lake Titicaca-Poopo | 3 | | | | | | | | |
| 3 | Golok | 2 | | 3 | Lempa | 1 | | | | | | | | |
| 1 | Ilh/Kunes He | 1 | | 2 | Suxaola | 1 | | | | | | | | |
| 7 | Indus | 1 | | 2 | Artibonite | | | | | | | | | |
| 1 | Jordan | 1 | | 1 | Chamelecon | | | | | | | | | |
| 1 | Karnaphuli | 1 | | 2 | Changuinola | | | | | | | | | |
| 1 | Tigris-Euphrates/Shatt al Arab | 1 | | 1 | Choluteca | | | | | | | | | |
| 1 | Bei Jiang/Hsi | | | 2 | Coatan Achute | | | | | | | | | |
| 1 | Dasht | | | 5 | Coco/Segovia | | | | | | | | | |
| 4 | Han | | | 1 | Corredores/Colorado | | | | | | | | | |
| 1 | Irrawaddy | | | 3 | Grjalva | N | | | | | | | | |
| 2 | Kura-Araks | N | | | | | 1 | | Hondo | | | | | |
| 1 | Loes | | | | | | 1 | Negro | | | | | | |
| 2 | Ma | | | | | | 2 | Orinoco | | | | | | |
| 1 | Salween | | | | | | 1 | Pedernales | | | | | | |
| 1 | Sembakung | | | | | | 1 | Rio Grande | | | | | | |
| 1 | Terek | | | | | | 1 | San Juan | | | | | | |
| | | | | | | | 1 | Tumbes | | | | | | |

Note: IRB, International River Basin.

in the basins with flood-related institutional capacity. This despite the fact that the flood magnitudes were significantly higher ($p = 0.03$ on a global level with $n = 31$ and 38) and these basins experienced more floods in total (134 *vs.* 60 floods in basins without institutions).

When the geopolitical measure was narrowed down to the absence or presence of flood-specific institutions, i.e., IRBIs that had transboundary floods as one of their principal issues, the p -value increases. This however was partly because the dataset, small to begin with, became even smaller.

Evidence indicated that basins with institutional capacity had more than two countries in it ($p < 0.01$ except in Europe), while basins that had not set up institutions to deal with transboundary water issues, typically had no more than three countries in the basins. Even when only the presence or absence of flood-specific institutes was considered, the statistical relevance was still moderately convincing on a global scale ($p = 0.01$ with $n = 7$ and 44). The trends noticeable with the broadest geopolitical measure were similar to those with the narrow geopolitical measure, except for the total financial damages; IRBs with general institutional capacity always experienced higher mean financial damages than IRBs without this capacity, while IRBs with flood-specific institutions always experienced lower mean financial damages. However, these differences were never statistically convincing. All the general (statistical) trends visible per continent for institutional capacity, be it general or flood-specific, were also visible on a global scale.

When examining all the basins that experienced transboundary flooding and combining it with the

data found on institutional capacity and international water treaties (see Table 3), the Juba-Shibeli river basin in Africa could possibly benefit from an increase in institutional capacity to deal with transboundary floods. In this basin, transboundary flood events took place multiple times, yet no institution was set up, nor were any treaties signed. The Zambezi and Nile river basins had set up international cooperation over transboundary waters, but none of these forms of cooperation dealt with transboundary flooding, although transboundary flood events took place on a rather regular basis. On the Asian continent, the same holds true for the Kura-Araks basin, where no institutional capacity was found. The Aral Sea, Ganges, Golok, Han and Indus river basins all had transboundary water institutions, but none were focusing on transboundary floods. In Europe, the Maritsa basin had no flood-related institutional capacity, and while the Danube basin had institutions, none of them deal with flood issues, although seven treaties were flood-related, which was also the case for the Po river basin. In North America, the five basins that experienced transboundary floods, all had transboundary water institutions set up for them, but none of them had floods as a principal issue, and only the Nelson-Saskatchewan had one flood-related treaty. However, two basins experienced only two transboundary floods, the remaining three only one, indicating that transboundary flood events were probably not a priority possibly due to their lack of occurrence. In South America, the Amazon, Grijalva, Coco/Segovia, La Plata, and Lempa river basins all experienced five or less transboundary flood events but no flood-related treaties were in place for any of the basins. The Amazon, Plata, and Lempa did have

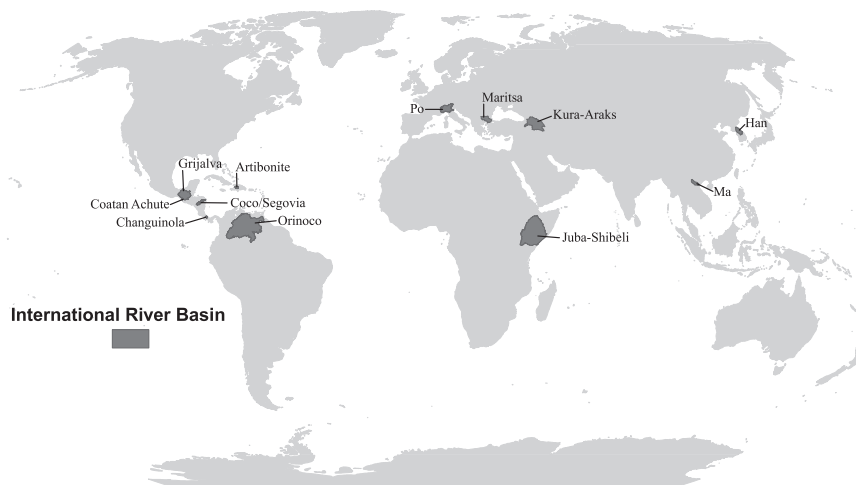


FIGURE 6. Map Indicating Basins Where Transboundary Flood Events Were Frequent Enough to Justify Creating Specialized Institutions for Such Events. When combined with the basins at risk from Wolf *et al.* (2003), the two basins with the greatest potential for political stresses in the coming years are the Han and Kura-Araks basins.

transboundary water institutions, but none of these focused on transboundary flood events.

As resilience is enhanced by the presence of international agreements and institutions (Wolf *et al.*, 2003), the absence of these characteristics hypothetically increases the changes for conflict in these basins. Should a transboundary flood occur in a basin that lacks the capacity to absorb such a change, the likelihood of conflict between the riparians increases. Therefore, the basins that experienced more than one transboundary flood in the past 21 years, but have not set up any institutions for such events, nor signed any treaties focusing on floods, are recommended to consider increasing their institutional capacity aimed at transboundary flood events. These 12 basins are: the Juba-Shibeli in Africa; the Han, Kura-Araks, and Ma in Asia; the Maritsa and Po in Europe; and six basins in South America: the Coco/Segovia, Grijalva, Artibonite, Changuinola, Coatan Achute, and Orinoco river basins (Figure 6). Transboundary flood events were frequent enough in these 12 basins to focus the attention on when considering creating specialized institutions for such events.

Not only these 12 most vulnerable basins, but all IRBs without any official form of international cooperation over their transboundary rivers, are greatly encouraged to put flood-related issues on their agendas and institutionalize the link between riparians in a transboundary basin. The IRBs that already set up institutions to cooperate over their shared waters, but omitted to include flood events, should consider including flood-related issues in their mandate, to be prepared for such events. This will increase the institutional capacity which in turn will decrease the likelihood of future flood-related conflicts.

SUMMARY AND CONCLUSIONS

This study attempted to identify the IRBs with sustainable institutions and basins that are encouraged to increase their institutional capacity for the management of transboundary flooding. To this end, available information from the TFDD (2006) was expanded, updated, and combined with data compiled by the author to create a global picture of the existing transboundary flood institutions, past events, and international freshwater treaties related to transboundary flood events. As such, it is hoped to become a foundation and stepping stone for future discussions and research (see Future Research on next page). Below, the major findings and conclusions are presented. When reading these, the serious limita-

tions of this study must be reiterated: the conclusions are based on datasets which might be incomplete (with regards to both the number of treaties and IRBIs) and this might have caused bias, while the event data could be prejudiced as well. In addition, the small number of observations limits the level of confidence.

- In total, 153 transboundary water institutions were found, representing 78 (of the 279) IRBs around the world. Out of these 153 transboundary institutions, only eight were principally concerned with flooding, none of which were located in North or South America. The transboundary water institutions found were mostly set up for joint management.
- Over the years 1948-2004, almost 3% (59 out of 2,269) of the events were related to flood control or flood relief. While only nine events fall in the "conflictive range," an alarming increase of less cooperative incidents over the past 15 years was clearly visible. A possible explanation is that the number of transboundary river floods has increased (Bakker, 2009) resulting in more interactions between countries.
- Of the 692 international water treaties in the TFDD database (TFDD, 2006), only 24 were categorized as dealing with flood-related issues, 16 of which cover five basins with past transboundary flood events. All of the five IRBs with flood-related treaties experienced comparatively low numbers of casualties or displaced people, which might point to an additional argument for the creation of institutional capacity. However, further examination of the actual content of the treaties and subsequent actions during times of transboundary flood disasters is necessary in order to strengthen this argument.
- Forty-three basins in which transboundary floods took place in the period 1985-2005 did not have any type of institutional capacity in the form of international institutions or organizations for IRBs. The average death and displacement tolls relative to the million population living in the IRBs were lower in the 37 basins that did have (flood-related) institutional capacity. Although statistically inconclusive, similar trends were found when only IRBs with flood-specific institutional capacity were compared with IRBs without such specific capacity. Or, in other words, IRBIs seem to play a role in lessening the sting of transboundary floods.
- In addition, the 43 basins without institutional capacity did not have international water treaties focused on floods (exceptions: the Po river basin in Europe and the Rio Grande river basin in South America). Since resilience is enhanced by

the presence of international agreements and institutions (Wolf *et al.*, 2003), the absence of these characteristics hypothetically increases the changes for conflict in these basins.

- Provided the results presented above hold, transboundary flood events were frequent enough in the following 12 basins to suggest to the relevant authorities to consider the creation of specialized institutions for such events: the Juba-Shibeli in Africa; the Han, Kura-Araks, and Ma in Asia; the Maritsa and Po in Europe; and six basins in South America: the Coco/Segovia, Grijalva, Artibonite, Changuinola, Coatan Achute, and Orinoco river basins (Figure 6).

Because floods cannot be prevented all together, it is necessary to determine how best to reduce their impact on affected areas, so as to minimize loss, damage and threats to human life. To reduce this overall vulnerability to floods, the technical capabilities to predict and monitor their magnitude, duration, timing, and location are needed. The call for early warning mechanisms and disaster-response systems is heard frequently. Flood-prone IRBs could thus hugely benefit from emerging satellite missions. Satellite remote sensing of rainfall along with stream gauges and other satellite-derived surface parameters can potentially increase the forecasting lead time for riparians. A longer forecasting range would make downstream nations more independent in monitoring (Hossain and Katiyar, 2006; Hossain *et al.*, 2007), and will increase transboundary cooperation which in turn is key to promoting human and environmental security and will reduce the likelihood of future flood-related conflicts.

Future Research

While this study provided unique data on the phenomenon of transboundary river flood events, related institutional capacity on several scales, and is seen as an essential first step to study this very complex problem, additional works needs to be done to confirm the reported conclusions. Next to the (statistical) limitations inherent to a large generalizing *N*-study and mentioned in the Results section related to the size of the dataset, there are other considerations to be taken into account when continuing research on this topic.

The applied research method to determine which international freshwater treaties were flood-related had the potential to exclude treaties that address aspects of flood-related matters without explicitly mentioning it as such. This could be avoided by executing a more thorough, qualitative study (as performed by Drieschova *et al.*, 2008) that would involve

carefully reading every treaty in the TFDD to identify whether or not flood issues are addressed without having been categorized as a TFDD principal issue area. While Drieschova *et al.* made an excellent start by identifying the number of treaties that address flooding, the considered period was 1980-2002, thus it cannot be assumed that both studies refer to similar treaties. In addition, the TFDD has just been updated and now includes treaties up until 2007. Hence, a first step would be to compare the treaties found in both studies, carefully reading the recently added treaties, and combine the results for a more inclusive overview of flood-related treaties.

Outside of the scope of this present research was whether or not the origin of a flood specific institution was always and/or only linked to a transboundary flood event. In addition, a more qualitative measure for effectiveness of the identified IRBIs could be added and used for future analyses. Furthermore, as with treaties, flood control does not have to be explicitly mentioned for an IRBI in order to deal with it in practice. As a general rule of thumb, these joint management bodies are ideally flexible and set up in such a way that issues that are, as previously stated, difficult to capture in official forms and codes, can still be discussed as a deviation from the treaty in place (Fischhendler, 2004; Drieschova *et al.*, 2008).

When trying to gauge overall vulnerability of river basins, other variables excluded in the present work ought to be considered; for example, indigenous coping methods that minimize personal risk, the national regulations and flood control infrastructures in place that minimize the risk to and/or effect of transboundary floods, and other characteristics of a basin e.g., climatological characteristics (variability in) river flow rates. Including such variables could shed more light on potential links between the presence and absence of institutions, which in turn could help identify factors that facilitate or impede the creation of effective institutions.

Although it might be extremely difficult and distorting to classify river basins according to geopolitical variables like regime type, wealth, inequality, and political instability, such factors may be of crucial importance when trying to further explain links between flood-related conflict and cooperation (e.g., see Toset *et al.*, 2000; Drieschova *et al.*, 2008).

Finally, future research could also focus on reasons of exclusion of flooding and flood control in the mandates of institutions.

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