Water Policy 5 (2003) 29–60

International waters: identifying basins at risk

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Received 23 October 2001; accepted in revised form 31 January 2003

Abstract

Despite the growing literature on water and conflict in international river basins, little empirical work has been done to bolster common conclusions which are so widely reported. In order to address this gap, we set out to assess *all* reported events of either conflict or cooperation between nations over water resources during the last 50 years and to use these events to inform the identification of basins at greatest risk of political stress in the near future (5–10 years). The study is divided into three components:

1. Compilation and assessment of relevant biophysical, socio-economic and geopolitical data in a global Geographic Information System (GIS), and use of these factors to determine history-based indicators for future tensions along international waterways.
2. Using these indicators, identification of basins at risk for the coming decade.
3. Identification and assessment of the potential for mitigating factors and new technologies resulting in a future different than that predicted by history-based indicators.

In general, we find that most of the parameters regularly identified as indicators of water conflict are actually only weakly linked to disputes, but that institutional capacity within a basin, whether defined as water management bodies or treaties, or generally positive international relations are as important, if not more so, than the physical aspects of a system. It turns out then that very rapid changes, either on the institutional side or in the physical system, which outpace the institutional capacity to absorb that change, are at the root of most water conflict, as reflected in two sets of indicators: 1) "internationalized" basins, i.e. basins which include the management structures of newly independent states, and 2) basins which include unilateral development projects *and* the absence of cooperative regimes. By taking our parameters of rapid change as indicators—internationalized basins and major planned projects in hostile and/or institution-less basins—we are able to identify the basins with settings which suggest the potential for political stresses in the coming five to ten years. These basins include: the Ganges–Brahmaputra, Han, Incomati, Kunene, Kura-Araks, Lake Chad, La Plata, Lempa, Limpopo, Mekong, Ob (Ertis), Okavango, Orange, Salween, Senegal, Tumen and Zambezi.

We then identify "red flags," or markers related to these indicators, which might be monitored in the future.

Finally, recognizing that history-based indicators may lose validity over time in a rapidly changing world, we ask, "what about the future, which may look nothing like the past," and focus on four topics: new technologies for negotiation and management; globalization, privatization and the WTO; the geopolitics of desalination; and the changing sources of water and the changing nature of conflict.

Keywords: Conflict; Cooperation; Environmental security; Fresh water resources; Indicators; International river basins

Background

Much of the thinking about the concept of "environmental security" has moved beyond a presumed causal relationship between environmental stress and violent conflict to a broader notion of "human security"—a more inclusive concept focusing on the intricate sets of relationships between environment and society. Within this framework, water resources—their scarcity, distribution and quality—have been named as the factor most likely to lead to intense political pressures. Water ignores political boundaries, evades institutional classification and eludes legal generalizations. Worldwide, water demands are increasing, groundwater levels are dropping, water bodies are increasingly contaminated and delivery and treatment infrastructure is aging. Although wars over water have not occurred, there is ample evidence showing that the lack of clean freshwater has led to intense political instability and that acute violence has occasionally been the result. As water quality degrades—or quantity diminishes—over time, the effect on the stability of a region can be unsettling.

Nonetheless, the record of acute conflict over international water resources is overwhelmed by the record of cooperation. The only recorded incident of an outright war over water was 4500 years ago between two Mesopotamian city-states, Lagash and Umma, in the region we now call southern Iraq. Conversely, between the years 805 and 1984, countries signed more than 3600 water-related treaties, many showing great creativity in dealing with this critical resource (Wolf, 1998). Overall, shared interests, human creativity and institutional capacity along a waterway seem to consistently ameliorate water's conflict-inducing characteristics. Furthermore, once cooperative water regimes are established through treaties, they turn out to be impressively resilient over time, even when between otherwise hostile riparians, and even as conflict is waged over other issues. These patterns suggest that the more valuable lesson of international water may be as a resource whose characteristics tend to induce cooperation, and incite violence only in the exception.

Despite the growing literature on water and conflict, there is currently little empirical work being done to bolster any of the common conclusions being so widely reported. Westing (1986) suggests that "competition for limited . . . freshwater . . . leads to severe political tensions and even to war"; Gleick (1993) describes water resources as military and political goals, using the Jordan and Nile as examples; Remans (1995) uses case studies from the Middle East, South Asia and South America as "well-known examples" of water as a cause of armed conflict; Samson and Charrier (1997) write that "a number of conflicts linked to freshwater are already apparent," and suggest that "growing conflict looms ahead"; Butts (1997) suggests that "history is replete with examples of violent conflict over water," and names four Middle Eastern water sources particularly at risk; and Homer-Dixon (1994), citing the Jordan and other water disputes, comes to the conclusion that "the renewable resource most likely to stimulate interstate resource war is river water". To be fair, there is also a smaller body of work which argues more strongly for the possibilities and historic evidence of cooperation between co-riparians. See, for example, Libiszewski (1995), Wolf (1998) and Salman & Boisson de Chazournes (1998) for historic assessments of cooperation, while Delli Priscoli (1998) suggests water as a "training ground for civilization."

There are several problems with the approaches of much current literature and, as a consequence, questions about their conclusions as well:

- Loose definitions. Terms such as conflict, dispute, tensions and war are regularly used interchangeably. So too are several types of incidents all relating to water but which are otherwise vastly dissimilar, such as water as a tool, weapon or victim of warfare[1].
- Exclusion of cooperative events. An entire branch of the conflict–cooperation spectrum is missing from almost all studies relating water to international relations, such that any tests of causality are, by definition, incomplete.
- Lack of consideration of spatial variability. Such popular measures as "water stress" are regularly determined by country (e.g. population per unit of water), whereas political interactions over water generally are precipitated at the basin (watershed) level. The variability of spatially diverse parameters such as population, climate, water availability and national groups are either ignored or their significance is generalized[2].
- Case studies selected only from the "hottest" basins. Most studies of trends in international basins tend to focus on the world's most volatile basins—the Jordan, Tigris–Euphrates, Indus and Nile, for example—making general conclusions concerning international basins as a whole incomplete and questionable.

Each of these issues informs the design of the current study, pointing to the need for work that includes: consistent and precise definitions of conflict and cooperation; events along the entire spectrum of conflict and cooperation, ranked by intensity; allowance for spatial variability; and inclusion of the widest possible set of international basins—*all* of the world's international watersheds.

Study objectives

Given our design criteria as outlined above, we set out to develop a study of international waters which would allow for the settings of historic events to be identified, and which would in turn inform the identification of basins at greatest risk of political stress in the near future (5–10 years).

The study is divided into three components:

1. Compilation and assessment of relevant biophysical, socio-economic and geopolitical data in a global Geographic Information System (GIS), and use of these factors to determine history-based indicators for future tensions along international waterways.
2. Using these indicators, identification of basins at risk for the coming decade.
3. Identification and assessment of the potential for mitigating factors and new technologies which may result in a future different from that predicted by history-based indicators.

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[1] For thorough documentation of these other types of violence associated with water, see Peter Gleick's excellent chronology at www.worldwater.org/conflict.htm.

[2] A useful exception, at least for physical parameters, is Revenga *et al*. (1998), which describes 15 biophysical variables for 145 of the world's major watersheds.

Methodology[3]

To aid in the systematic assessment of the process of water conflict resolution, we have been working over the past nine years to develop the Transboundary Freshwater Dispute Database (TFDD), a project of the Oregon State University Department of Geosciences, in collaboration with the Northwest Alliance for Computational Science and Engineering. The database currently includes: a digital map of the world's 263 international watersheds; a searchable compilation of 400 water-related treaties and 39 US interstate compacts, along with the full texts of each; an annotated bibliography of the state of the art of water conflict resolution, comprising approximately 1000 entries; negotiating notes (primary or secondary) from fourteen detailed case studies of water conflict resolution; a comprehensive news file of all reported cases of international water-related disputes and dispute resolution (1948–2000); and descriptions of indigenous/traditional methods of water dispute resolution[4].

As mentioned above, much of the prevailing wisdom on the dynamics of international watersheds has been informed by incomplete assessments. In order to identify indicators of water conflict/cooperation as completely as possible, we took the following approach:

1. We identified the set of basins to be assessed as *all*[5] of the world's international river basins (as defined in Wolf *et al*. 1999)[6], and our period of study as being from 1948–1999.
2. We attempted to compile a dataset of *every* reported interaction between two or more nations, whether conflictive or cooperative, which involved water as a scarce and/or consumable resource or as a quantity to be managed—i.e. where water is the *driver* of the event[7]. We drew these events primarily from five sources:

   a. Foreign Broadcast Information Service (FBIS), 1978–2000. The Foreign Broadcast Information Service (FBIS) is an agency of the U.S. Central Intelligence Agency (CIA) which has been translating foreign news sources since 1978. Prior to 1996, FBIS articles were indexed both in paper and CD-ROM format. The FBIS CD-ROM covers 1978 to mid-1996 and was accessed to identify international water-related "events" during this period. Once citations were identified via

[3] For a more detailed methodology, see Yoffe (2001) online at: www.transboundarywaters.orst.edu. Click "publications" and "Basins at Risk."

[4] Online at: www.transboundarywaters.orst.edu.

[5] This includes a total of 265 basins for historical analysis. There are currently 263 international basins: 261 were identified by Wolf *et al*. (1999), two from that list were merged as one watershed as new information came to light (the Benito and Ntem), and three additional basins were "found" (the Glama, between Sweden and Norway; the Wiedau, between Denmark and Germany; and the Skagit, between the US and Canada). In historical assessments, we also include two basins which were historically international, but whose status changed when countries unified (the Weser, between East and West Germany; and the Tiban, between North and South Yemen).

[6] In that paper, "river basin" is defined as being synonymous with what is referred to in the U.S. as a "watershed" and in the UK as a "catchment," or all waters, whether surface water or groundwater, which flow into a common terminus. Similarly, the 1997 UN Convention on Non-Navigational Uses of International Watercourses defines a "watercourse" as "a system of surface and underground waters constituting by virtue of their physical relationship a unitary whole and flowing into a common terminus". An "international watercourse" is a watercourse, parts of which are situated in different states [nations].

[7] Excluded are events where water is incidental to a dispute, such as those concerning fishing rights, access to ports, transportation or river boundaries. Also excluded are events where water is not the driver, such as those where water is a tool, target or victim of armed conflict. For more details of how the event data were compiled, structured and assessed, see Yoffe & Larson.

keyword searches, the full-text microfiche articles were collected from the Oregon State University and University of Oregon libraries for the relevant news events. The World News Connection (WNC) is the on-line, searchable version of FBIS which covers material from 1996 to the present day. Full-text articles were retrieved via an on-line subscription. Since FBIS systematically covers only non-US news sources, the New York Times was searched, through Lexis-Nexis, for water-related event data for North America.

b. Conflict and Peace Data Bank (COPDAB), 1948–1978. This dataset, directed by Professor Edward E. Azar, codes inter- and intra-national events for approximately 135 countries. Event records include variables for date of event, initiating actor, event target, information source, issue areas and textual information about the activity, and a number evaluating the event on a scale of conflict and cooperation. The dataset does not include any water-specific coding, but the textual information has enough detail to provide a guide to possible water related events. Basins at Risk (BAR) uses COPDAB data to identify water events from 1948 to 1978.

c. Global Event Data System (GEDS) Project, 1979–1994. GEDS tracks day-to-day interactions among nations and other international actors using online news reports. Directed by John Davies at the University of Maryland, GEDS builds on the Conflict and Peace Data Bank (COPDAB) of Edward Azar. Data archives contain over 300,000 event records from 1979 to 1994.

d. Transboundary Freshwater Dispute Database. OSU's TFDD project includes a collection of water-related treaties, 157 of which are applicable to our criteria and study period.

e. Literature review. A rich literature exists on various aspects of international waters, much of which has clear descriptions of international events. By tapping the available literature (described in Beach *et al*., 2000), we were able to confirm many of the events culled from the above sources, as well as to supplement many which have gone unreported in the press.

Over the course of one year, we were able to compile a seamless, systematic database for water conflict/cooperation of 1831 events—507 conflictive, 1228 cooperative and 96 neutral or non-significant. Each event includes a brief summary and source of information, and was coded by date, country pair (dyad), basin, issue area[8] and intensity of conflict/cooperation. For event intensity, we modified COPDAB's scale, adding water-specific actions and definitions, as described in Yoffe & Larson, to define events from –7, the most conflictive (war), through 0 (neutral events), and up to +7, the most cooperative (voluntary merging of countries) (see Table 1 and Fig. 1). In addition, we compiled a tributary database, which links a tributary's name to its major international basin, and a "friendship–hostility" scale—a ratio of all cooperative to conflictive events between nations from the COPDAB and GEDS data combined, to gage general (non-water) relations between countries (see Yoffe & Giordano (forthcoming) for more information on this last parameter).

3. We developed a Geographic Information System (GIS), including approximately 100 layers of global and/or regional spatial data falling into one of three general categories: biophysical (e.g. topography, surface runoff, climate), socio-economic (e.g. GDP, dependence on hydropower) and geopolitical

[8] Event issue areas were defined as: quantity, infrastructure, joint management, hydropower, quality, flood control, technical cooperation, irrigation, border issues, general economic development and navigation. As mentioned earlier, in order to be included, water had to be treated as a scarce and/or consumable resource or as a quantity to be managed. For example, navigation events were included *only* if the issue involved a quantity of water required to allow for ship passage, not if it only involved rules of conduct or tonnage.

Table 1. BAR Event intensity scale. (Modified from Azar's COPDAB International Conflict and Cooperation Scale.)

BAR scale	COPDAB scale	BAR event description
–7	15	Formal declaration of war; extensive war acts causing deaths, dislocation or high strategic costs
–6	14	Extensive military acts
–5	13	Small scale military acts
–4	12	Political–military hostile actions
–3	11	Diplomatic–economic hostile actions
–2	10	Strong verbal expressions displaying hostility in interaction
–1	9	Mild verbal expressions displaying discord in interaction
0	8	Neutral or non-significant acts for the inter-nation situation
1	7	Minor official exchanges, talks or policy expressions—mild verbal support
2	6	Official verbal support of goals, values or regime
3	5	Cultural or scientific agreement or support (non-strategic)
4	4	Non-military economic, technological or industrial agreement
5	3	Military economic or strategic support
6	2	International freshwater treaty; major strategic alliance (regional or international)
7	1	Voluntary unification into one nation

DATE	BASIN	COUNTRIES	BAR SCALE	EVENT SUMMARY	ISSUE TYPE
12/5/73	La Plata	Argentina--Paraguay	4	PRY AND ARG AGREE TO BUILD 1B DAM, HYDROELECTRIC PROJECT	Infrastructure
1/1/76	Ganges	Bangladesh--India--United Nations	-2	Bangladesh lodges a formal protest against India with the United Nations, which adopts a consensus statement encouraging the parties to meet urgently, at the level of minister, to arrive at a settlement.	Quantity
7/3/78	Amazon	Bolivia--Brazil--Colombia--Ecuador--Guyana--Peru--Suriname--Venezuela	6	Treaty for Amazonian Cooperation	Economic Development
4/7/95	Jordan	Israel--Jordan	4	Pipeline from Israel storage at Beit Zera to Abdullah Canal (East Ghor Canal) begins delivering water stipulated in Treaty (20 MCM summer, 10 MCM winter). The 10 mcm replaces the 10 mcm of desalinated water stipulated Annex II, Article 2d until desalinization plant completed	Quantity
6/1/99	Senegal	Mali--Mauritania	-3	13 people died in communal clashes in 6/99 along border between Maur. & Mali; conflict started when herdsmen in Missira-Samoura village in w. Mali, refused to allow Maur. horseman to use watering hole; horseman returned w/ some of his clansmen, attacking village on 6/20/99, causing 2 deaths; in retaliation that followed, 11 more died.	Quantity

Fig. 1. Events database: example.

(e.g. style of government, present and historic boundaries). We back-dated relevant parameters such that the GIS is both uniformly formatted and historically accurate (e.g. 1964 boundaries coincide with 1964 GDPs and government types). We used each international watershed, sub-divided by national boundaries, as the unit for analysis (see Table 2 and Fig. 2).

Table 2. GIS data layers.

Category	GIS layer	Coverage extent	Data source
GeoPolitical	International Boundaries	Global	ESRI
GeoPolitical	Intra-national Administrative Boundaries	Global	ESRI
Biophysical	International Basins	Global	TFDD
Biophysical	Area of International Basins for 1999, total & by country	Global	TFDD
Biophysical	International Basins from 1950 to current	Global	TFDD
GeoPolitical	Intersection of Basins with Countries	Global	TFDD
GeoPolitical	International River Treaties	Global	TFDD
GeoPolitical	Basin Tributary Names	Global	TFDD
Biophysical	Riparian Position of Basin Countries	Global	TFDD
GeoPolitical	Water Conflict-Coop. Events 1948–1999	Global	COPDAB, GEDS, FBIS/WNC, Lexis-Nexus, TFDD
GeoPolitical	Additional Event Data (historical records, other sources)	Global	TFDD
GeoPolitical	Degree of democratization, by year from 1800	Global	Polity Data Archives
GeoPolitical	Date of change in government regime, by year	Global	Polity Data Archives
SocioEconomic	Gridded Population of the World	Global	Dobson, et al. *LandScan* 2000
SocioEconomic	Population by basin by year	Global	Dobson, et al. *LandScan* 2000, TFDD
SocioEconomic	Population by country by year	Global	Dobson, et al. *LandScan* 2000, TFDD
SocioEconomic	List and Location of Ethnic Minority Groups	Global	GEDS
SocioEconomic	Human Poverty Index	Global	UNDP
SocioEconomic	Human Development Index	Global	UNDP
SocioEconomic	Future Major Dams or Water Development Projects	Global	TFDD
SocioEconomic	Major Dams or Development Projects by basin and year	Global	ICOLD, TFDD
SocioEconomic	Roads and Railways	Global	ESRI
SocioEconomic	Major Cities	Global	ESRI
SocioEconomic	Utilities, Electricity Grids	Global	ESRI
SocioEconomic	Hydroelectric Capacity and Production by Country, 1996	Global	WRI
SocioEconomic	Hydroelectric Production as Fraction of Total Energy Produced, by Country	Global	WRI
SocioEconomic	Commercial Electricity Production—Total, by Country and Year	Global	WRI
SocioEconomic	Commercial Electricity Production—Hydroelectric, by Country and Year	Global	WRI
SocioEconomic	Electricity Imports and Exports	Global	WRI
SocioEconomic	Desalination Capacity by Country, January 1, 1996	Global	WRI
SocioEconomic	Water Stress Index by country and by basin	Global	Fekete, et al., TFDD
SocioEconomic	Social Water Stress Index—1975–1999, by basin and by country	Global	Fekete, et al., Ohlsson, TFDD
SocioEconomic	Gross National Product	Global	WRI
SocioEconomic	Gross National Product Per Capita	Global	WRI
SocioEconomic	Mean Rate of Population Growth by Country	Global	WRI
SocioEconomic	Labor Force—Percent in Agriculture	Global	WRI
SocioEconomic	Total Urban Population	Global	WRI
SocioEconomic	Urban Population Percent	Global	WRI
SocioEconomic	Urban Population Growth Rates	Global	WRI

Table 2. *(continued)*

Category	GIS layer	Coverage extent	Data source
SocioEconomic	Total Rural Population	Global	WRI
SocioEconomic	Rural Population Growth Rates	Global	WRI
SocioEconomic	Rural Population With Access to Safe Water	Global	WRI
SocioEconomic	Urban Population With Access to Safe Water	Global	WRI
SocioEconomic	Population With Access to Safe Water: Urban and Rural	Global	WRI
SocioEconomic	Urban Population With Access to Adequate Sanitation	Global	WRI
SocioEconomic	Rural Population with Access to Adequate Sanitation	Global	WRI
SocioEconomic	Population With Access to Adequate Sanitation: Urban and Rural	Global	WRI
SocioEconomic	Total Forest Deforestation	Global	WRI
SocioEconomic	Total Freshwater Catch by Country	Global	WRI
SocioEconomic	Aquaculture Production—Freshwater Fish	Global	WRI
SocioEconomic	Technical Disasters by Country—Oil spill/Chemical Fires. . .	Global	USAID-CRED
Biophysical	Natural Disasters by Country—Flood/Drought. . .	Global	USAID-CRED
Biophysical	Renewable Freshwater Supply by Basin and by Country	Global	Gleick, Peter. *The World's Water*, 1998, Fekete, et al., TFDD
SocioEconomic	Freshwater Withdrawal by Country and Sector	Global	Gleick, Peter. *The World's Water*, 1998
Biophysical	USGS Land Use/Land Cover	Global	USGS
Biophysical	Global Assessment of Human Induced Soil Degradation	Global	UNEP/GRID—EROS Data Center
Biophysical	Global Vegetation, Intensity of Cultivation	Global	UNEP/GRID—EROS Data Center
Biophysical	Global Map of Irrigated Areas	Global	Petra Döll
SocioEconomic	Irrigated Area by Basin and by Country	Global	TFDD
Biophysical	Water pollution, runoff, sediment load (selected rivers)	80 Rivers	UNEP/GEMS
GeoPolitical	State of Water Management by Country	Limited	Gleick, Peter. *The World's Water*, 1998
SocioEconomic	Sources and Uses of Surface/Groundwater Resources	Global	Gleick, Peter. *The World's Water*, 1998
Biophysical	Wetlands of International Importance—Number/Area	Global	WRI
SocioEconomic	Distribution of Gross Domestic Product—Agric/Ind/ Services/Manufact	Global	WRI
SocioEconomic	Total Fertilizer Consumption	Global	WRI
Biophysical	Arable Land	Global	WRI
Biophysical	Land in Permanent Crops	Global	WRI
SocioEconomic	Fertilizer Production	Global	WRI
SocioEconomic	Fertilizer Imports	Global	WRI
SocioEconomic	Fertilizer Exports	Global	WRI
SocioEconomic	Annual fertilizer use	Global	WRI
SocioEconomic	Grain Fed to Livestock as % of Total Grain Consumption	Global	WRI
SocioEconomic	Labor Force—Percent in Industry, Percent in Services	Global	WRI
SocioEconomic	Total Economically Active Population	Global	WRI
SocioEconomic	Number of Cholera Cases and Deaths from Cholera	Limited	Gleick, Peter. *The World's Water*, 1998
Biophysical	Land Area by Country	Global	WRI
Biophysical	Arable and Permanent Cropland	Global	WRI

Table 2. *(continued)*

Category	GIS layer	Coverage extent	Data source
SocioEconomic	Population Density by Country	Global	WRI
Biophysical	Permanent Pasture	Global	WRI
Biophysical	Forest and Woodland	Global	WRI
Biophysical	All Other Land	Global	WRI
Biophysical	Domesticated Land as a Percent of Land Area	Global	WRI
Biophysical	Natural Forest Extent and Change	Global	WRI
Biophysical	Extent of Plantations and Change	Global	WRI
Biophysical	Extent of Total Forest	Global	WRI
Biophysical	Hydrologic Network (Rivers)	Global	USGS-EROS-HYDRO1k, ESRI
Biophysical	River length	Global	ESRI, TFDD
Biophysical	Climatic Data (Temp, Precip)	Global	IPCC
Biophysical	Climatic Zones of basins	Global	UNFAO, TFDD
Biophysical	Digital Elevation Models	Global	USGS-EROS-GTOPO30
Biophysical	Slope in basin by percent area	Global	USGS-EROS-GTOPO30/LandScan, TFDD
Biophysical	Global Soil Texture	Global	UNEP/GRID—EROS Data Center
Biophysical	River Discharge	Global	Vörösmarty, et al.
Biophysical	Flooding since 1995	Global	Dartmouth Flood Observatory
Biophysical	Annual river flows	Global	Fekete, et al., TFDD
Biophysical	Freshwater Fish Species Information	Global	WRI
GeoPolitical	Protected Areas	Global	WRI

Table 2. Sources and abbreviations

COPDAB: Azar, Edward E. *Conflict and Peace Data Bank (COPDAB), 1948–1978*. [Computer file]. 3rd release. College Park, MD: University of Maryland, Center for International Development and Conflict Management [producer], 1993. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 1993.

Dartmouth Flood Observatory: Dartmouth Flood Observatory—NASA supported. http://www.dartmouth.edu/artsci/geog/floods/.

Dobson, et al. *LandScan* 2000: Dobson, J.E., Bright, E.A., Coleman, P.R., Durfee, R.C. & Worley, B.A. (2000). LandScan: a global population database for estimating populations and risk. *Photogrammetric Engineering & Remote Sensing*, *66* (7), 849–857.

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ESRI: Environmental Systems Research Institute. http://www.esri.com/.

FBIS: Foreign Broadcast Information Service, US Central Intelligence Agency.

Fekete, et al.: Fekete, B., Vorosmarty, C.J., Grabs, W. (2000) Global, composite runoff fields based on observed river discharge and simulated water balances. February 4, 2000.

GEDS: Davies, J.L. (1998) The Global Event-Data System: Coders' Manual, Center for International Development and Conflict Management and Department of Government and Politics, University of Maryland, College Park, MD, August, 1998 Revision, http://geds.umd.edu/geds/.

Gleick, Peter. *The World's Water*, 1998: Gleick, P.H. (1998) *The World's Water: The Biennial Report on Freshwater Resources.* Island Press, Washington, D.C..

ICOLD: International Commission on Large Dams, *World Register of Dams,* 1998.

IPCC: Intergovernmental Panel on Climate Change, Leemans, R. & Cramer, W.P.(1991). The IIASA Database for Mean Monthly Values of Temperature, Precipitation and Cloudiness of a Global Terrestrial Grid. IIASA, Laxenburg, Austria, RR-91–18. http://ipcc-ddc.cru.uea.ac.uk/.
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Polity Data Archives: McLaughlin, S., Gates, S., Hegre, H., Gissinger, R. & Gleditsch, N.P. (1998). Polity 3D: the timing of polity changes. *Journal of Conflict Resolution*, April. http://www.colorado.edu/IBS/GAD/spacetime/data/Polity.html.
UNDP: United Nations Development Programme, *Human Development Report*, http://www.undp.org/hdro/indicators.html#developing.
UNEP/GEMS: United Nations Environment Programme/Global Environment Monitoring System; Fraser, A. S., Meybeck, M. & Ongley, E. D. (1996). Annotated Digital Atlas of Global Water Quality (computerized). UNEP GEMS/Water Collaborating Centre, Canada. Global Environment Monitoring System (GEMS/Water); http://www.cciw.ca/gems/intro.html.
UNEP/GRID—EROS: http://grid2.cr.usgs.gov/; http://edcwww.cr.usgs.gov/
UNFAO: United Nations Food and Agriculture Programme; FAO's Environment and Natural Resources Service (SDRN) global climate maps series.—FAO-SDRN Agrometeorology Group, 1997. http://www.fao.org/sd/eidirect/CLIMATE/EIsp0001.htm.
USAID-CRED: US Agency for International Development, Office of US Foreign Disaster Assistance (OFDA) & the WHO Collaborative Center for Research on the Epidemiology of Disasters (CRED); EM-DAT: The OFDA/CRED International Disaster Database—www.md.ucl.ac.be/cred—Université Catholique de Louvain, Brussels, Belgium.
USGS-EROS-GTOPO30: US Geological Service—EROS Data Center. http://edcdaac.usgs.gov/gtopo30/gtopo30.html
USGS-EROS-HYDRO1k: US Geological Service—EROS Data Center, http://edcdaac.usgs.gov/gtopo30/hydro/.
Vörösmarty, et al.: Vörösmarty, C.J., Fekete, B. & Tucker, B.A. (1998). River Discharge Database, Version 1.1 (RivDIS v1.0 supplement). Available through the Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham NH (USA) at http://pyramid.unh.edu/csrc/hydro/. Vörösmarty, C.J., Fekete, B. & Tucker, B.A. (1996). River Discharge Database, Version 1.0 (RivDIS v1.0), Volumes 0 through 6. A contribution to IHP-V Theme 1. Technical Documents in Hydrology Series. UNESCO, Paris.
WNC: World News Connection, US Central Intelligence Agency.
WRI: World Resources 1998–1999 Database, World Resources Institute, 1998.

With this GIS in place, we were able to assess the historical setting within which each event of conflict/cooperation took place. By hypothesizing the relevance of sets of parameters, and by testing each set running single and multivariate statistical analyses of the events against the parameters which define their historical settings, factors that seemed to be indicators of conflict/cooperation were able to be culled from the database as a whole[9].

Findings

Summary statistics

Our overall distribution of events over the 50-year period of assessment is shown in Fig. 3. In general, we delineated a total of 1831 events, and found the following:

a. No events on the extremes. In modern times, there has been no war (–7 on the BAR Scale) fought over water resources. In fact, one has to go back 4500 years to find the single historical example of a

[9] Details are provided in Shira Yoffe's online methodology, cf. footnote 4, and in Fiske and Yoffe (in review).

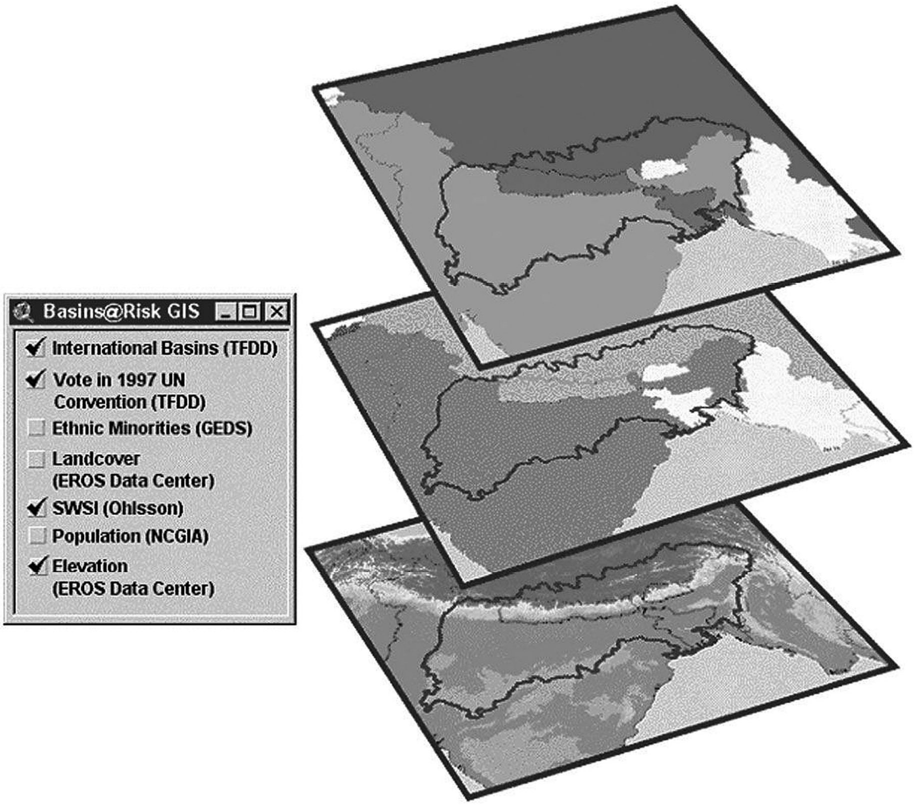

Fig. 2. Basins at risk: geographic information system.

true "water war," to a dispute between the city-states of Lagash and Umma on the Tigris–Euphrates (Wolf, 1998).

Likewise, there is no example of nations voluntarily unifying because of water resources (+7 on the BAR Scale).

b. Most interactions are cooperative. Cooperative events are more than twice as common as conflictive events—there are 1228 cooperative events (67.1%) and 507 conflictive events (27.7%). Ninety-six events (5.2%) were delineated as neutral or non-significant.

c. Most interactions are mild. Seven-hundred and eighty-four events, or 42.8% of all events, fall between mild verbal support (+1) and mild verbal hostility (–1). If we add the next level on either side—official verbal support (+2) and official verbal hostility (–2)—we account for 1138 events, or 62% of the total. Another way to look at this is that almost two-thirds of all events are only verbal and, of these verbal events, more than two-thirds are reported as having no official sanction at all.

Even the record of acute conflict, that in which violence ensues (–5 and –6 on the BAR Scale), is neither widespread nor recent. Of the 37 cases of acute conflict, 30 are between Israel and one or other of its neighbors, violence which ended in 1970. Non-Middle East cases account for only five acute events.

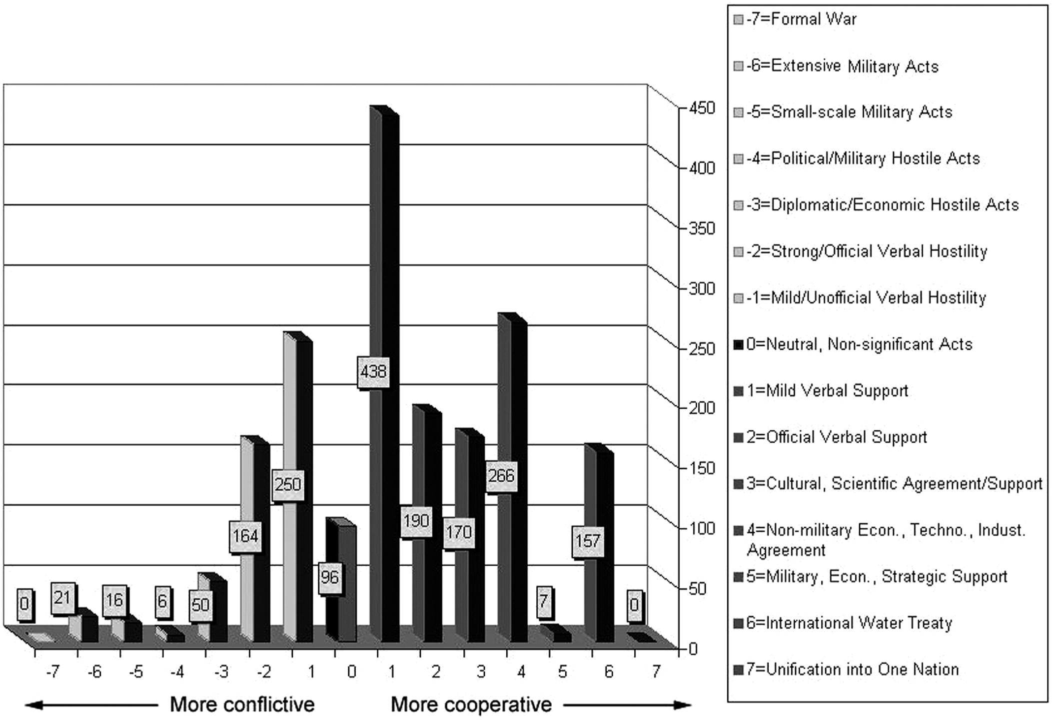

Fig. 3. Number of events by BAR Conflict/Cooperation Scale.

d. Water acts as an irritant. Despite the lack of violence, water resources can make good relations bad and bad relations worse. Threats and disputes have raged across boundaries with relations as diverse as those between Indians and Pakistanis and between Americans and Canadians. Water was the last and most contentious issue resolved in negotiations over a 1994 peace treaty between Israel and Jordan, and was relegated to "final status" negotiations—along with many other of the most difficult issues, such as Jerusalem and refugees—between Israel and the Palestinians.

e. Water acts as unifier. The historical record shows that water disputes *do* get resolved, even among bitter enemies, and even as conflicts rage over other issues. Some of the most vociferous enemies around the world have negotiated water agreements or are in the process of doing so. The Mekong Committee has functioned since 1957, exchanging data throughout the Vietnam War. Secret "picnic table" talks have been held between Israel and Jordan since the unsuccessful Johnston negotiations of 1953–55, even as these riparians, until only recently, were still in a legal state of war. The Indus River Commission survived through two wars between India and Pakistan. And all ten Nile riparians are currently involved in negotiations over cooperative development of the basin.

f. Overall, the major water-related issues are quantity and infrastructure. Figure 4 shows the number of events by issue area and the distribution of those events. Sixty-four percent of events are primarily about water quantity and infrastructure (which are often inextricably related). Quality-related events only account for 6% of the total (see Fig. 4).

g. Nations cooperate over a wide variety of issues. Figure 5 shows the distribution of cooperative events and indicates a broad spectrum of issue types. If we look specifically at treaties, the most cooperative type of event, the breadth of cooperative issues is even wider, including quantity, quality, economic development, hydropower and joint management (see Fig. 5).

h. Nations conflict over quantity and infrastructure. Finally, Fig. 5 shows the distribution of conflictive events by issue area—87% relate to water quantity and infrastructure. Again, if we look specifically at extensive military acts, the most extreme cases of conflict, almost 100% of events fall within these two categories.

Indicators

Little exists in the environmental security literature regarding empirical identification of indicators of future water conflict. The most widely cited measure for water resources management is Falkenmark's (1989) Water Stress Index, which divides the volume of available water resources for each country by its population. She then defines "stress" levels as follows:

— Above 10,000 m^3/person:	Limited management problems
— 10,000–1600 m^3/person	General management problems
— 1600–1000 m^3/person	Water stress
— 1000–500 m^3/person	Chronic scarcity
— Less than 500 m^3/person	Beyond the management "water barrier"

Though commonly used, Falkenmark's index has been critiqued on a number of grounds, mostly that it accounts neither for spatial variability in water resources within countries, nor for the technological or economic adaptability of nations at different levels of development. To account for the latter critique, but not the former, Ohlsson (1999) developed a "Social Water Stress Index," which incorporates "adaptive capacity" into Falkenmark's measure, essentially weighting the index by a factor based on UNDP's Human Development Index. While Ohlsson's is a useful contribution, he also misses the

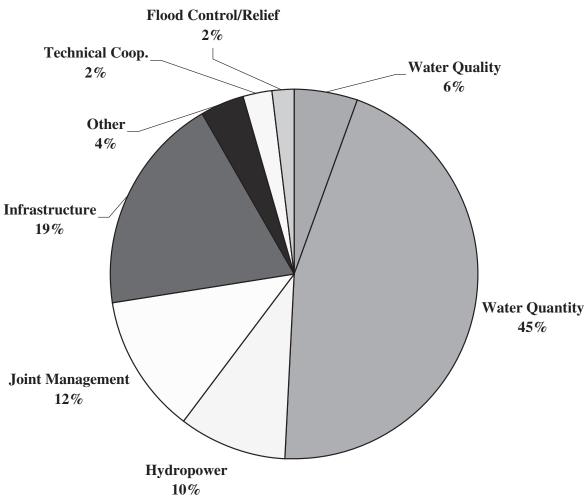

Fig. 4. Distribution of total events by issue area.

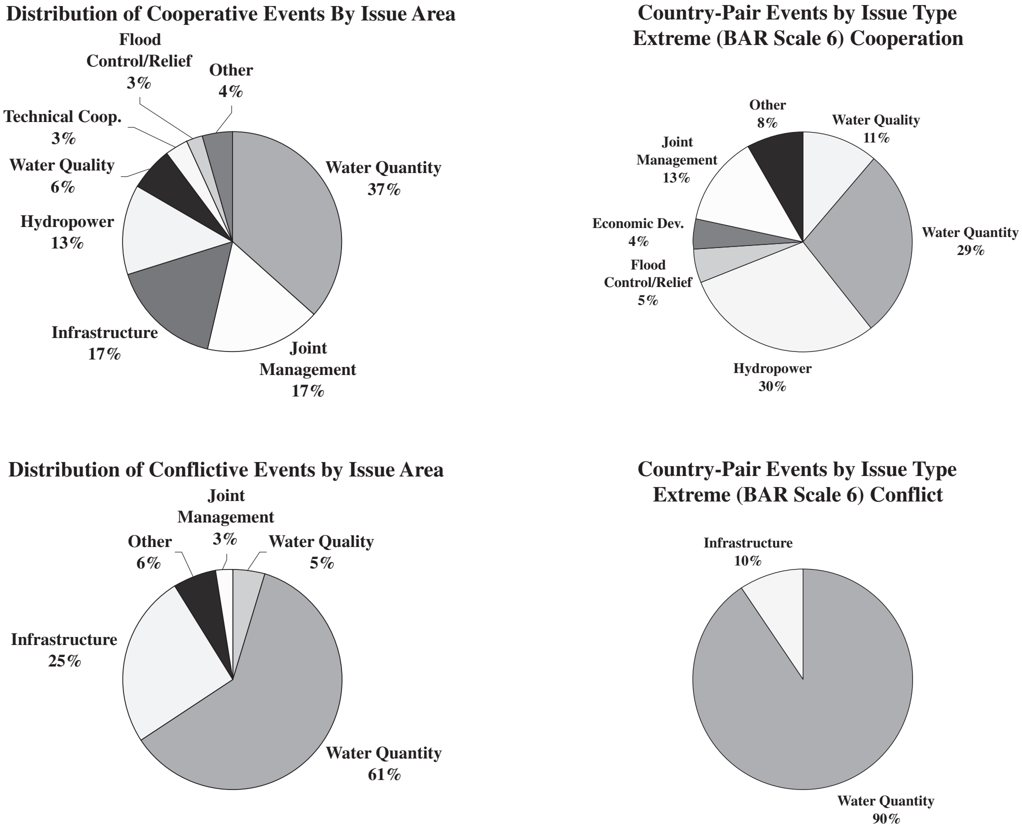

Fig. 5. Number of events by issue area.

spatial component. Similarly, neither Falkenmark nor Ohlsson suggest much about the geopolitical results of scarcity, focusing instead on implications for water management.

The only author to explicitly identify indices of vulnerability which might suggest "regions at risk" for international water conflicts is Peter Gleick who, in 1993, suggested four: 1) ratio of water demand to supply; 2) water availability per person (Falkenmark's water stress index); 3) fraction of water supply originating outside a nation's borders; and 4) dependence on hydroelectricity as a fraction of total electrical supply. Gleick's indices, like Falkenmark's and Ohlsson's, focus on the nation as the unit of analysis and on physical components of water and energy. These indicators were neither empirically derived nor tested.

In our approach, we consider two very distinct aspects as to why nations may choose to dispute or cooperate. First, along with the authors cited above, we look at the water resources themselves and various aspects of stress—supply versus demand, droughts, changes in the physical system. Since these changes take place within very distinct physical units, we use basins as our fundamental unit of analysis rather than nations. There is another side to the equation, though, related to the capacity of a nation to absorb the physical aspects of stress, either within a nation, between pairs of nations, or among all the nations of a watershed. This institutional capacity to absorb stress, we feel, is broader than simply a country's economic strength, although that certainly plays a major role. Other issues, such as the existence or absence of joint water management bodies or treaties, general friendship/hostility over non-water issues, and stability and types of governments within a basin, are all components contributing to functional institutional capacity.

The working hypothesis which we tested, then, regards the relationship between change in conditions in a basin and the attendant institutions, as follows:

"The likelihood and intensity of dispute rises as the rate of change within a basin exceeds the institutional capacity to absorb that change."

Indicators—prevailing wisdom

According to this hypothesis, most common measures of water stress should not, in and of themselves, be indicators of conflict. And, according to our data, they are not. The Appendix describes the results of single variable correlations of a number of parameters commonly assumed to indicate tensions, none of which explain much in terms of variation:

a. Countries which cooperate in general cooperate about water; countries which dispute in general, dispute over water (see Appendix, Fig. A1). Comparing general friendship/hostility with BAR events shows only a moderate positive correlation.
b. The higher the per capita GDP, or the lower the population density, the greater the cooperation—barely. Appendix, Fig. A2 show a weak relationship between a country's per capita GDP and the level of water related cooperation with its neighbors. The relationship is even weaker if we use the UN Human Development Index (not shown). Similar relationships are shown between the level of conflict/cooperation and population density in Fig. A3 and population growth rates in Fig. A4[10].
c. Regardless of how it is measured, water stress is not a significant indicator of water dispute. Appendix, Fig. A5 show Falkenmark's water stress index (water available per capita by country) and Fig. A6 shows water stress by basin. While there is a slight correlation in the former, neither parameter explains much of the variation in the data. Ohlsson's "Social Water Stress Index," which weights water stress by level of development, does not change either relationship (not shown).
d. Neither government type nor climate show any patterns of impact on water disputes. Appendix, Fig. A7 show governments by their level of democracy/autocracy and Fig. A8 shows dominant climate type within each basin; neither displays any discernible pattern. We should notice that prevailing wisdom seems to be challenged in both figures—Fig. A7 appears to suggest that democracies seem *not* to be more cooperative than other types of government (in fact, autocratic countries are only barely less cooperative than the strongest democracies) and Fig. A8 disputes the commonly held perception that disputes are more common in arid environments—there is little perceptible difference between most climate types (with the notable exception of humid mesothermal, apparently the most cooperative climate). We also do not seem to find disputes in "creeping problems," such as gradual degradation of water quality or climate change induced hydrologic variability.

Another set of preliminary findings regarding precipitation, shown in Appendix, Fig. A9, seems to confirm that, perhaps not surprisingly, years of normal precipitation tend to be the most cooperative, and

[10] Interestingly, Yoffe (2001, Chap. 5) found a better relationship between the rate of population growth and general (non-water) levels of conflict/cooperation.

that the greater the fluctuation in any given year *either* towards drought *or* towards flood, the more tense the basin[11].

Indicators—rapid change

If most commonly assumed indicators do not actually indicate water dispute, then what does?

The answer seems to lie in introducing the institutional side of the equation. If institutional capacity is a moderating factor, then it would stand to reason that the most significant indicators would be related to extremely rapid changes, either on the institutional side or in the physical system. The most rapid change institutionally would be associated with "internationalized" basins—i.e. basins whose management institution was developed under one single jurisdiction, but which was dramatically altered as that jurisdiction suddenly became divided among two or more nations. On the physical side, the most rapid change would be the development of a large-scale dam or diversion project. But here, too, the institutional capacity should make a difference.

a. "Internationalized" basins. The clearest examples of this "internationalizing" process is the break-up of empires, notably the British Empire in the 1940s and the USSR in the late 1980s. Figure 6 shows cooperative events as a percentage of total events from 1948–2000. We notice that this chronology suggests three distinct periods—1971–86 is relatively more cooperative, while 1948–70 and 1987–2000 are moderately more conflictive. These last two time periods coincide with years of intense internationalization—the former of the British Empire in the Middle East and South Asia, and the latter of the Soviet Union. This pattern is shown more clearly in Appendix, Figs. A10 and A11, which compare the conflict levels for these regions during these periods with those of the rest of the world. Conflicts in the world's most tense basins—the Jordan, Nile, Tigris–Euphrates, Indus and Aral—were all precipitated by these break-ups. Recent internationalization seems to be one of the most significant indicators of dispute.

b. Unilateral basin development in the absence of a cooperative transboundary institution. Appendix, Fig. A12 shows the relationship between dam density per basin and the level of dispute. Dams, by themselves, seem not to be strong indicators—Table 3 shows a 12% drop in overall conflict/cooperation level in basins with high dam density versus basins with low dam density (see Table 3). Yet, according to our hypothesis, physical changes such as dams or diversions are only half the equation. Institutional capacity, in the form of a treaty, river basin organization, generally good relations or even a technical working group, should help ameliorate the political impacts of change.

When we factor in the institutional capacity, as represented by the presence or absence of treaties (one readily quantifiable measure of capacity), the differences are, in fact, enhanced. Basins without treaties and high dam density are 11% lower in their average conflict/cooperation levels than basins without treaties and low dam density, but the overall level is more conflictive than those basins with treaties. Looking only at basins with treaties, the cooperation level is actually *higher* in basins with high dam density than in those with low dam density. Yet the conflict/cooperation level on basins with treaties and high dam density is 40% *lower* than on similar basins with treaties.

[11] These preliminary findings are based on detailed annual precipitation data for eleven basins: Aral, Danube, Ganges, Indus, Jordan, La Plata, Mekong, Nile, Orange, Salween and Tigris–Euphrates.

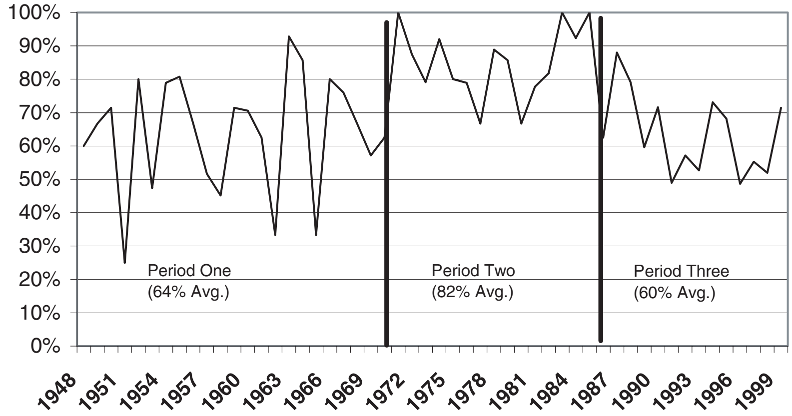

Fig. 6. Cooperative events as a percentage of total events.

To further assess the role of treaties as institutional mechanisms capable of mitigating conflict, we analyzed the impact of treaties on annual levels of conflict/cooperation for each country pair, dividing between country pairs which have treaties, and those that do not. Overall, basins without treaties were significantly more conflictive (2.6 on the BAR Scale) than basins with treaties (4.0). We also found that, in the three year period following treaty signature, average levels of conflict/cooperation were significantly higher (3.0) than in "normal" years (2.2). Perhaps surprisingly, we found that in the three-year period preceding treaty signature, the average level of conflict/cooperation was no different (2.3) than in "normal" years[12]. Treaty years, naturally, were the most cooperative (5.7). Since only 117 of the world's 263 international basins have treaties, these findings are significant.
Institutions matter.

Table 3. Development and institutional capacity.

Basin setting	BAR conflict/ cooperation scale†	Difference (%)
Basins with low dam density	4.2	
Basins with high dam density	3.7	–12
Basins with treaties and low dam density*	3.8	
Basins with treaties and high dam density*	4.2	+11
Basins without treaties and low dam density	2.8	
Basins without treaties and high dam density	2.5	–11
Basins with treaties and high dam density*	4.2	
Basins without treaties and high dam density	2.5	–40
Basins with treaties and low dam density*	3.8	
Basins without treaties and low dam density	2.8	–26
Basins with treaties post-treaty*	4.0	
All basins without treaties or prior to first treaty	2.6	–35

* Excludes first treaty event. †Higher values = greater cooperation.

[12] We had hypothesized that the years immediately preceding treaties would have a higher conflict level, assuming that a conflict is necessary to drive parties to negotiate to begin with.

c. Convergence of exacerbating factors. As demonstrated, with the exception of internationalized basins and unilateral development, no single parameter acts as a strong indicator of water disputes—the nature of international interaction over water resources seem more complex than most single issues. Yet we *can* identify sets of factors which, when they coalesce, provide conditions for greater likelihoods of hostility. For example, Table 4 shows the results of a multivariate analysis in which the overall level of friendship/hostility, the number of water related treaties signed by a country and per capita GDP were regressed against the average BAR Scale of each country; all parameters were found to be significant and of the hypothesized sign[13].

Other exacerbating factors include general hostility (non-water related) between co-riparians and, possibly, the presence of a downstream hegemon in a hostile basin (e.g. Israel, Egypt or India), although this last parameter has proven difficult to test.

We also hypothesized that, for a given pair of countries, relatively high heterogeneity between co-riparians in conditions such as population, per capita GDP, water availability, religious/ethnic groups and/or water stress levels in neighboring basins would be correlated with higher levels of conflict intensity, as might rapid growth rates in any of these parameters. In fact, we generally found no correlation with the growth rate of any parameter, and little between heterogeneity and conflict/cooperation[14], with two exceptions: 1) ardent democracies neighboring fervent autocracies seem to be more conflictive than other mixes of government type (Appendix, Fig. A13 shows heterogeneity in government types); and 2) high differences in population densities between countries within a basin[15] actually seem to tend towards a slightly greater level of *cooperation* between those two countries[16].

Basins at risk

By taking our parameters of rapid change as indicators—internationalized basins and major planned projects in hostile and/or institution-less basins—we are able to identify the basins with settings suggesting the potential for political stresses or conflicting interests in the coming 5–10 years. These

Table 4. Convergence of indicators.

	Coefficient	t value	Probability ($>t$)
Intercept	0.564	0.81	0.43
Friendship/hostility index	0.222	2.45	0.02*
Per capita GDP (ln)	0.234	2.44	0.02*
Number of treaties	0.100	5.89	0.00*

$R^2 = 0.3993$; *denotes significant at 5% level.

[13] The results of this and other multivariate regressions should be used with caution, because serial correlation between independent variables (for example, in this case correlation between per capita GDP and overall friendship/hostility) can cause the significance of regression results to be overstated.

[14] Interestingly, while we find no correlations between these parameters and water related conflict, Yoffe & Giordano (forthcoming) do find correlations with *general* levels of (non-water related) conflict.

[15] Measured as the ratio of densities in the two countries, not as absolute quantities.

[16] We have no explanation for why this might be so. This could be an interesting finding, worthy of more exploration.

basins include: the Ganges–Brahmaputra, Han, Incomati, Kunene, Kura-Araks, Lake Chad, La Plata, Lempa, Limpopo, Mekong, Ob (Ertis), Okavango, Orange, Salween, Senegal, Tumen and Zambezi. Each is mapped in Fig. 7, which also includes those basins currently in conflict or in the midst of active negotiations: the Aral, Jordan, Nile and Tigris–Euphrates.

Monitoring for indicators

Almost more important than helping identify the basins at risk themselves, these indicators allow us to monitor for "red flags," or markers which may suggest new basins at risk as they arise:

a. Tenders for future projects. The best sources for cutting through the rhetoric and wishful thinking inherent in public pronouncements of development projects are the public calls for project tenders. Tenders are not put out until project funding has been ascertained, so countries must be fairly certain that a project will actually be developed, but they still can give 3–5 years lead time (more for large projects) before any impact will be felt in neighboring countries—enough time to exercise preventive diplomacy. There are two good print sources for water development tenders: the Financial Times' Global Water Report (biweekly) and the Global Water Intelligence (monthly). Also, the website of Water International Publishing Ltd. (www.e-waternews.com/) provides daily updates of water project tenders and contracts in developing countries.

b. Countries with active nationalist movements. If internationalizing a basin provides a setting of potential dispute, one might monitor the world's nationalist movements and ethnic conflicts and, if

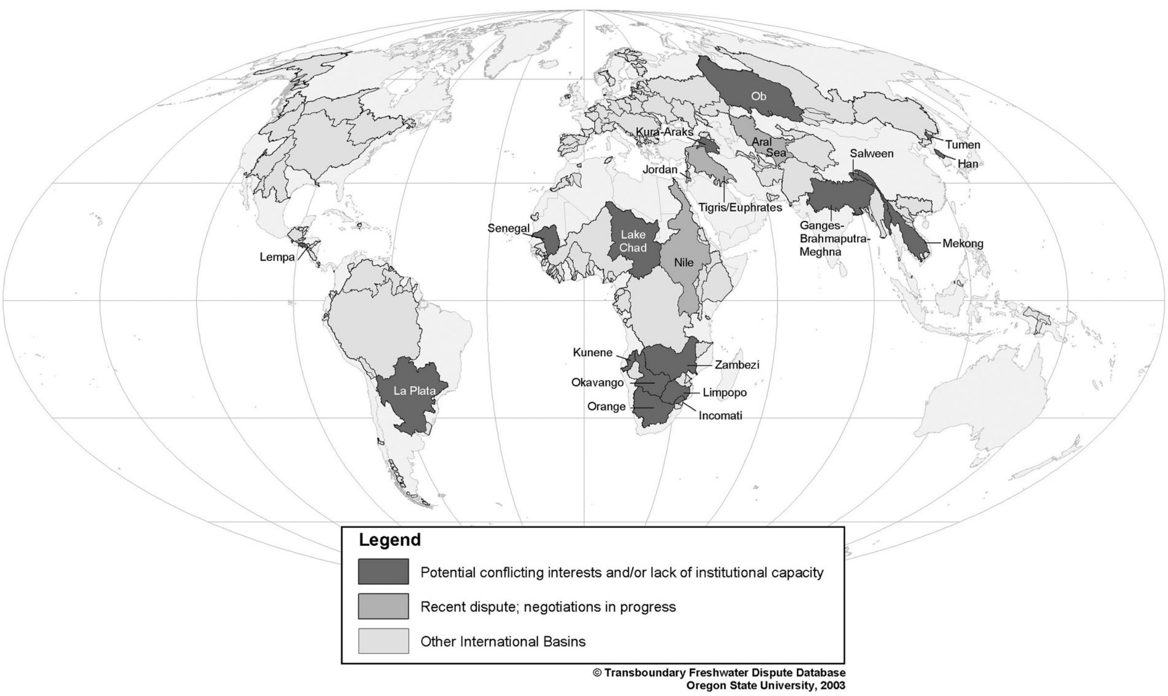

Fig. 7. Basins at risk.

one wanted to act proactively, one could assess the potential impacts of a successful drive for independence. Figure 8 maps those countries around the world with active nationalist movements. This draw from two sources: 1) armed self-determination conflicts in 2000 (with darker shading), as identified by Professor Ted Gurr's Minorities at Risk Project, at the University of Maryland's Center for International Development and Conflict Management (as of June 2000) [http://www.bsos.umd.edu/cidcm/mar/autonomy.htm]; and 2) Unrepresented Nations and Peoples Organisations (UNPO) (with moderate shading). Participation in UNPO is open to all nations and peoples who "are inadequately represented as such at the United Nations and who declare adherence to the Organisation's Charter". Since these principles espouse non-violence, the conflict level associated with many of these movements is lower. Data on unrepresented nations and peoples are drawn from the UNPO website [http://www.unpo.org/].

Why might the future look nothing like the past?

The entire basis of this study rests on the not unassailable assumption that we can tell something about the future by looking at the past. It is worth stopping at this point, then, and challenging the very foundation of that assumption: why might the future look nothing like the past? What new approaches or technologies are on the horizon to change or ameliorate the risk to the basins we have identified, or even to the whole approach to basins at risk?

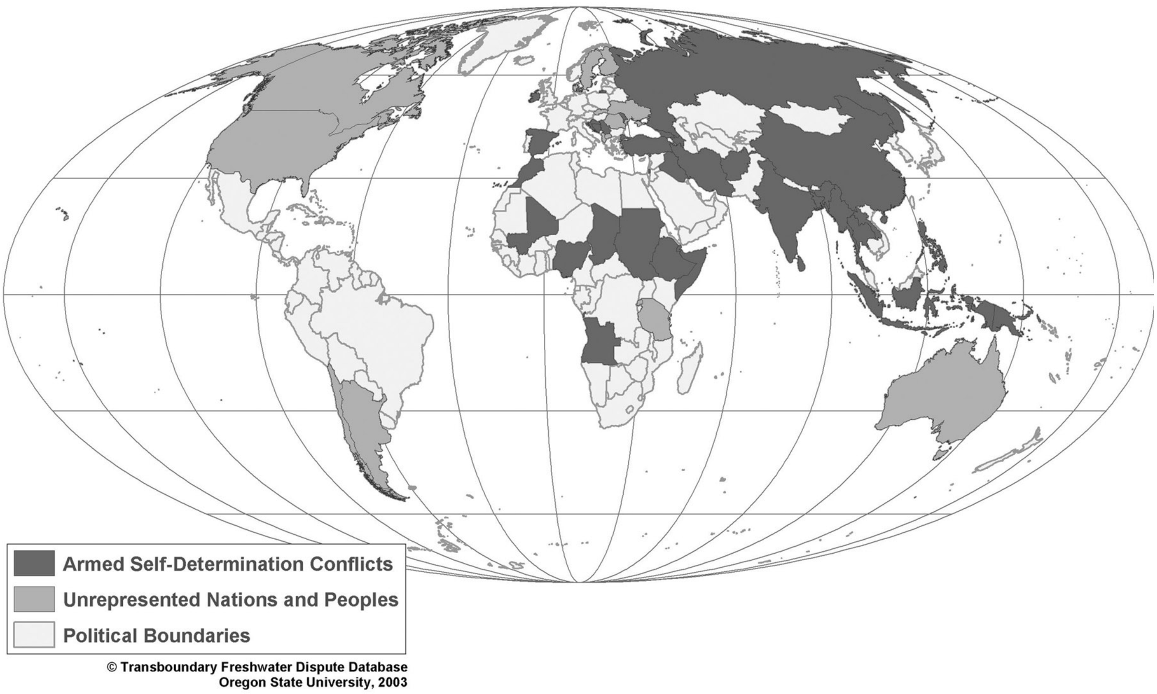

Fig. 8. Countries with active nationalist movements.

By definition, a discussion of the future cannot have the same empirical backing as a historical study—the data just do not yet exist. Yet there are cutting edge developments and recent trends which, if one examined them within the context of this study, might suggest some possible changes in store for transboundary waters in the near future. What follows, then, are four possibly fundamental changes in the way we approach transboundary waters.

a. New technologies for negotiation and management. Our event dataset goes back to 1948. In some ways, water management is very similar now as it was then (or, for that matter, as it was 5000 years ago). But some fundamental aspects are profoundly different. While global water stresses are increasing, institutions are getting better and more resilient, management and understanding are improving, and these issues are increasingly on the radar screen of global and local decision-makers. But most importantly, the 21st century has access to new technology which could not be dreamed of in 1948, and which adds substantially to the ability both to negotiate and to manage transboundary waters more effectively:

- Modular modeling systems (MMSs) such as STELLA, Waterware and Riverware can now be used for comprehensive modeling of hydrologic and human systems. Because of their modular design, they can also act as a facilitation tool by allowing managers/negotiators to cooperatively build the model, increasing the joint knowledge base and communications;
- GIS and remote sensing allow several spatial data layers, encompassing biophysical, socioeconomic and geopolitical parameters, to be viewed and analyzed graphically; and Graphical User Interfaces (GUIs) allow for each component to be brought together into an intuitive, user-friendly setting.
- Real-time monitoring tools, such as remotely controlled gaging stations, add new options for real-time management and allocations based on existing hydrologic settings rather than fixed quantities;
- Technologies and management practices which increase water use efficiency, such as drip irrigation, biotechnology and market mechanisms, help reduce political pressures on existing supplies.

While new technologies and data cannot replace the political goodwill necessary for creative solutions, nor are they widely available outside the developed world, they can, if appropriately deployed, allow for more robust negotiations and greater flexibility in joint management.

b. Globalization: private capital, WTO, and circumvented ethics. Very little of the recent attention on globalization and the World Trade Organization (WTO) has centered on water resources, but there is a definite water component to these trends. One of the most profound is the shift of development funds from global and regional development banks, such as the World Bank and the Asia Development Bank, to private multinationals, such as Bechtel, Vivendi and Ondeo (formally Lyonnaise des Eaux). Development banks have, over the years, been susceptible to public pressures and ethics and, as such, have developed procedures for evaluating social and environmental impacts of projects and incorporating them in decision making. On international waters, each development bank has guidelines that generally prohibit development unless all riparians agree to the project, which in and of itself has promoted successful negotiations in the past. Private enterprises have no such restrictions, and nations eager to develop controversial projects have been increasingly turning to private capital to circumvent public ethics. The most controversial projects of the day—Turkey's GAP project, India's Narmada River project and China's Three Gorges Dam—are all proceeding through the studied avoidance of development banks and their mores.

There is a more subtle effect of globalization, though, which has to do with the World Trade Organization (WTO) and its emphasis on privatization and full cost recovery of investments. Local and national governments, which have traditionally implemented and subsidized water development systems to keep water prices down, are under increasing pressure from the forces of globalization to develop these systems through private companies. These large multinational water companies in turn manage for profit and, if they use development capital, both push and are pushed to recover the full cost of their investment. This situation can translate not only into immediate and substantial rises in the cost of water, disproportionately affecting the poor, but also to greater eradication of local and indigenous management systems and cultures. If there is to be water related violence in the future, it is much more liable to be like the "water riots" against a Bechtel development in Bolivia in 1999 than "water wars" across national boundaries.

As WTO rules are elaborated and negotiated, real questions remain as to how much of this process will be *required* of nations in the future, simply to retain membership in the organization. The "commodification" of water as a result of these forces is a case in point. Over the last 20 years, no global water policy meeting has neglected to pass a resolution which, among other issues, defined water as an "economic good," setting the stage at the 2000 World Water Forum for an unresolved showdown against those who would define water as a human or ecosystem *right*. The debate looms large over the future of water resources: if water is a commodity, and if WTO rules disallow obstacles to the trade of commodities, will nations be forced to sell their water? While far-fetched now (even though a California company is challenging British Columbia over precisely such an issue under NAFTA rules), the globalization debate between market forces and social forces continue to play out in microcosm in the world of water resources.

c. The geopolitics of desalination. Twice in the last 80 years—during the 1960s nuclear energy fervor, and in the late 1980s, with "discoveries" in cold fusion—much of the world briefly thought it was on the verge of having access to close-to-free energy supplies. "Too cheap to meter" was the phrase during the Atoms for Peace Conference. While neither the economics nor the technology finally supported these claims, it is not far fetched to picture changes that could profoundly alter the economics of desalination.

The marginal cost of desalinated water (between US\$0.55–\$0.80/m^3) makes it currently cost-effective only in the developed world where: 1) the water will be used for drinking water; 2) the population to whom the water will be delivered lives along a coast and at low elevations; and 3) there are no alternatives. The only places not so restricted are where energy costs are especially low, notably the Arabian Peninsula. A fundamental shift either in energy prices or in membrane technology could bring costs down substantially. If either happened to the extent that the marginal cost allowed for agricultural irrigation with sea water (around US\$0.08/m^3 on average), a large proportion of the world's water supplies would shift from rivers and shallow aquifers to the sea (an unlikely, but plausible, scenario).

Besides the fundamental economic changes which would result, geopolitical thinking on water systems would also need to shift. Currently, there is inherent political power in being an upstream riparian, and thus controlling the headwaters. In the above scenario for cheap desalination, that spatial position of power would shift from mountains to the valleys, and from the headwaters to the sea. Many nations, such as Israel, Egypt and Iraq, currently dependent on upstream neighbors for their water supply would, by virtue of their coastlines, suddenly find their roles reversed. Again, unlikely, but plausible.

d. The changing sources of water and the changing nature of conflict. Both the worlds of water and of conflict are undergoing slow but steady changes which may obviate much of the thinking in this paper. Lack of access to a safe, stable supply of water is reaching unprecedented proportions. Furthermore, as surface water supplies and easy groundwater sources are increasingly exploited throughout the world, two major changes result: quality is steadily becoming a more serious issue to many than quantity, and water use is shifting to less traditional sources. Many of these sources—such as deep fossil aquifers, wastewater reclamation and interbasin transfers—are not restricted by the confines of watershed boundaries, our fundamental unit of analysis in this study.

Conflict, too, is becoming less traditional, increasingly being driven by internal or local pressures, or more subtle issues of poverty and stability. The combination of changes, in water resources and in conflict, suggest that tomorrow's water disputes may look very different from today's.

Conclusions

Despite the growing literature on water and conflict in international river basins, little empirical work has been done to bolster the common conclusions so widely reported. Existing works regularly self-select case studies from the most volatile basins and exclude cooperative events, spatial variability and precise definitions of conflict. In order to be as thorough as possible in our approach to international waters, our analysis included: consistent and precise definitions of conflict and cooperation; events over the entire spectrum of conflict and cooperation, ranked by intensity; allowance for spatial variability; and inclusion of the widest possible set of international basins—*all* of the world's international watersheds, over the past 50 years. Given our design criteria, we set out to develop a study of international waters that would allow for the settings of historic events to be identified, and which would in turn inform the identification of basins at greatest risk of political stresses in the near future (5–10 years).

The study was divided into three components:

1. Compilation and assessment of relevant biophysical, socio-economic and geopolitical data in a global GIS, and use of these factors to determine history-based indicators for future tensions along international waterways.
2. Using these indicators, identification of basins at risk for the coming decade.
3. Identification and assessment of the potential for mitigating factors and new technologies, resulting in a future different than that predicted by the history-based indicators.

In general, we found that most of the parameters commonly identified as indicators of water conflict are actually only weakly linked to dispute. These parameters include: climate, water stress, population; dependence on hydropower, dams or development *per se*, level of development or "creeping changes," such as gradual degradation of water quality or climate-change-induced hydrologic variability. In fact, our study suggests that institutional capacity within a basin, whether defined as water management bodies or treaties, or generally positive international relations are as important, if not more so, than the physical aspects of a system. The relationship was hypothesized as follows:

"The likelihood and intensity of dispute rises as the rate of change within a basin exceeds the institutional capacity to absorb that change."

If institutional capacity is a driver, then it would stand to reason that the most significant indicators would be related to extremely rapid changes, either on the institutional side or in the physical system. The most significant indicators, then, would reflect this relationship:

1. "Internationalized" basins. The most rapid changes institutionally are associated with "internationalized" basins—i.e. basins whose management institution was developed under a single jurisdiction, but which was altered or shattered as that jurisdiction suddenly became divided among two or more nations.
2. Unilateral development in the absence of a treaty or commission. On the physical system side, the most rapid change is typically the development of a large-scale dam or diversion project. But here, too, the institutional capacity makes a difference. In other words, high levels of animosity and/or the absence of a transboundary institution can exacerbate the setting, while positive international relations and/or the presence of transboundary institutions can mitigate the negative effects of such projects.

By taking our parameters of rapid change as indicators—internationalized basins and major planned projects in hostile and/or institutionless basins—we were able to identify the basins with settings which suggest the potential for tensions in the coming 5–10 years. These basins include: the Ganges–Brahmaputra, Han, Incomati, Kunene, Kura-Araks, Lake Chad, La Plata, Lempa, Limpopo, Mekong, Ob (Ertis), Okavango, Orange, Salween, Senegal, Tumen and Zambezi.

Almost more important than helping identify the basins at risk themselves, these indicators allow us to monitor for "red flags", or markers, which may suggest new basins at risk as they arise, among them tenders for future projects and nations with active nationalist movements.

Finally, recognizing that history-based indicators may lose validity over time in a rapidly changing world, we asked what if the future looks nothing like the past, and focused on four topics: new technologies for negotiation and management; globalization, privatization and the WTO; the geopolitics of desalination; and the changing sources of water and the changing nature of conflict.

Appendix: results of analyses

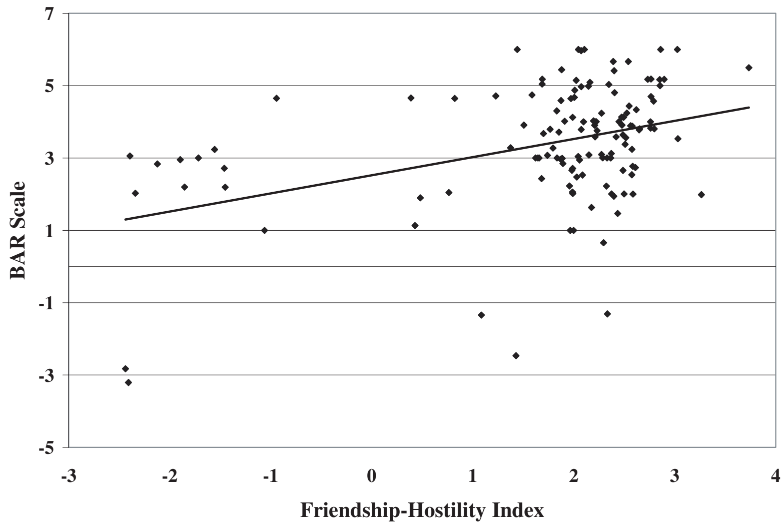

Fig. A1. Friendship/hostility (excluding water events) by country pair vs. BAR Scale. $n = 130$, $R^2 = 0.12$, coeff. = 1.74, significant at 5% level.

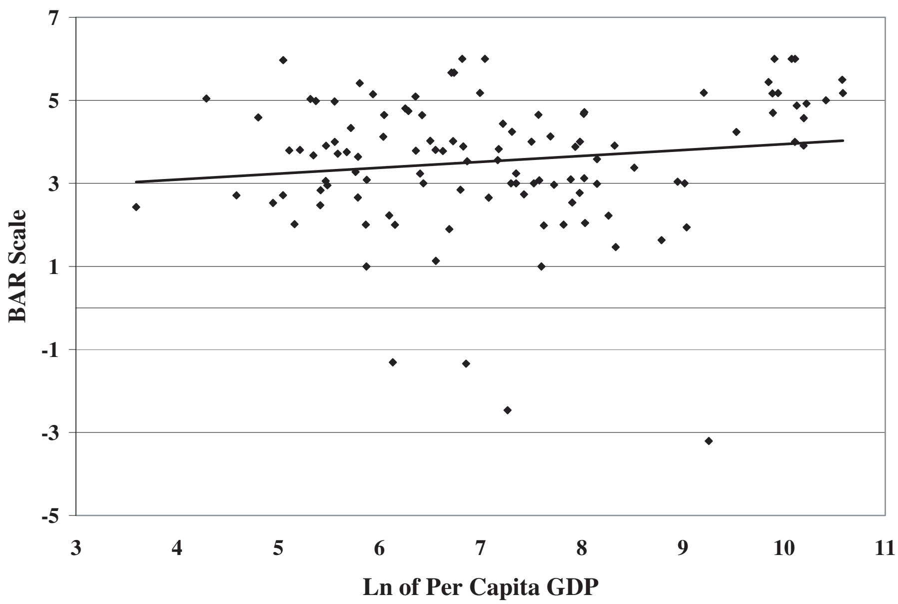

Fig. A2. Per capita GDP vs. BAR Scale. $n = 114$, $R^2 = 0.05$, coeff. = 5.11, significant at 5% level.

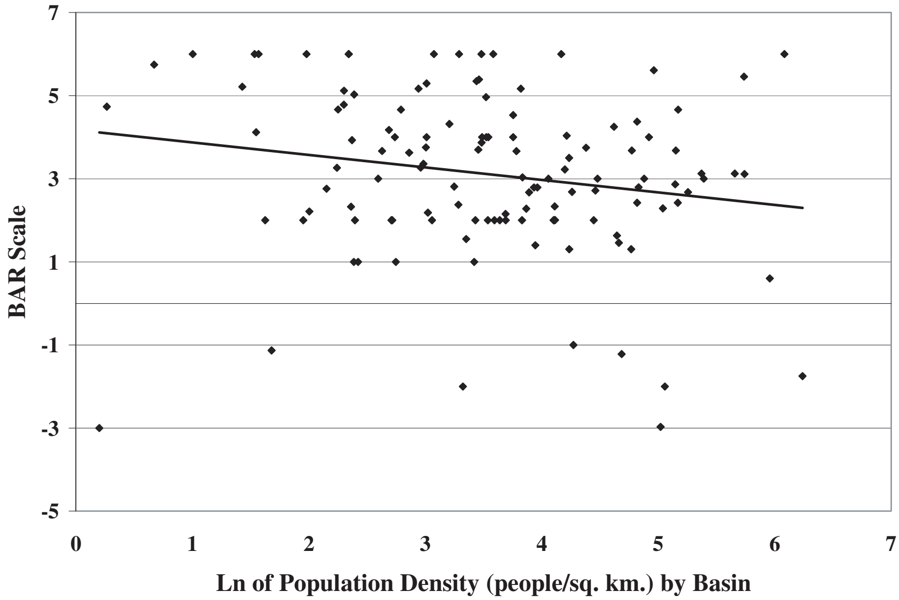

Fig. A3. Population density by basin vs. BAR Scale. $n = 121$, $R^2 = 0.04$, coeff. = –0.30, significant at 5% level.

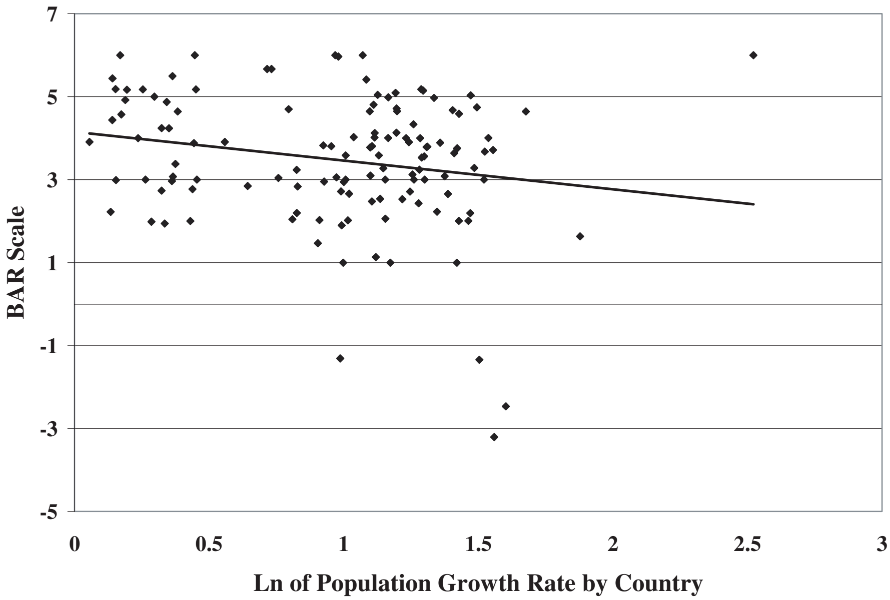

Fig. A4. Population growth rate by country vs. BAR Scale. $n = 126$, $R^2 = 0.02$, coeff. = –11.77, not significant at 5% level.

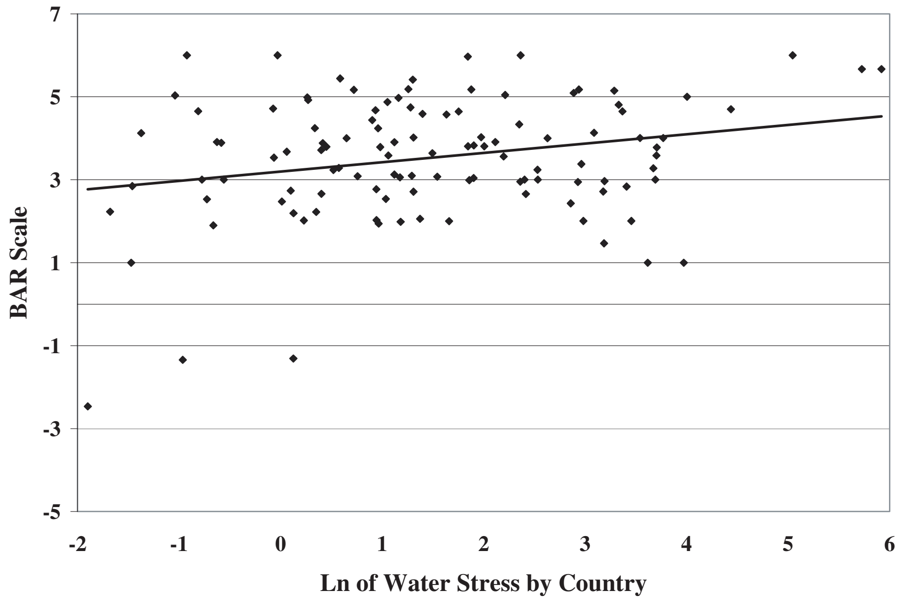

Fig. A5. Freshwater availability per capita by country vs. BAR Scale. $n = 113$, $R^2 = 0.04$, coeff. = 4.19, significant at 5% level.

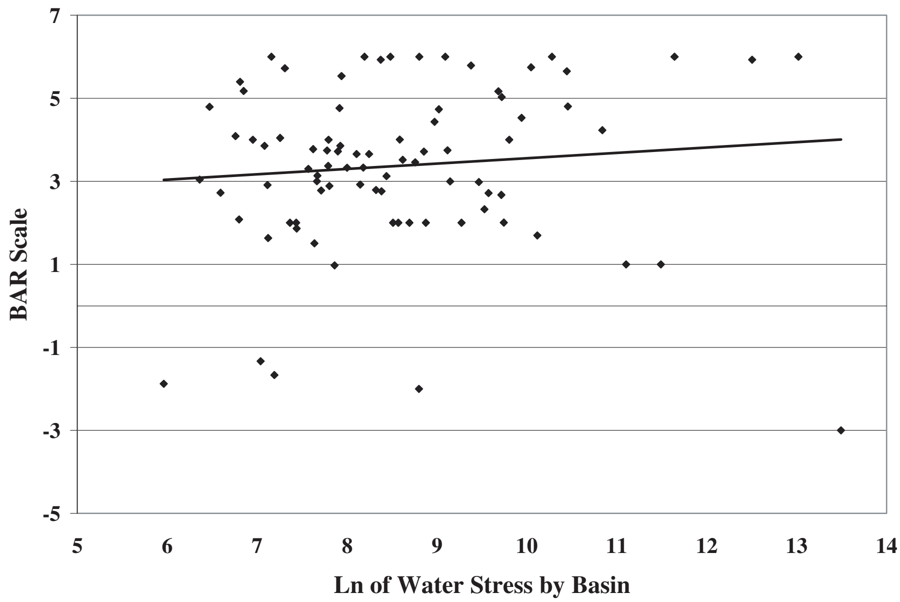

Fig. A6. Freshwater availability per capita by basin vs. BAR Scale. $n = 86$, $R^2 = 0.01$, coeff. = 6.56, not significant at 5% level.

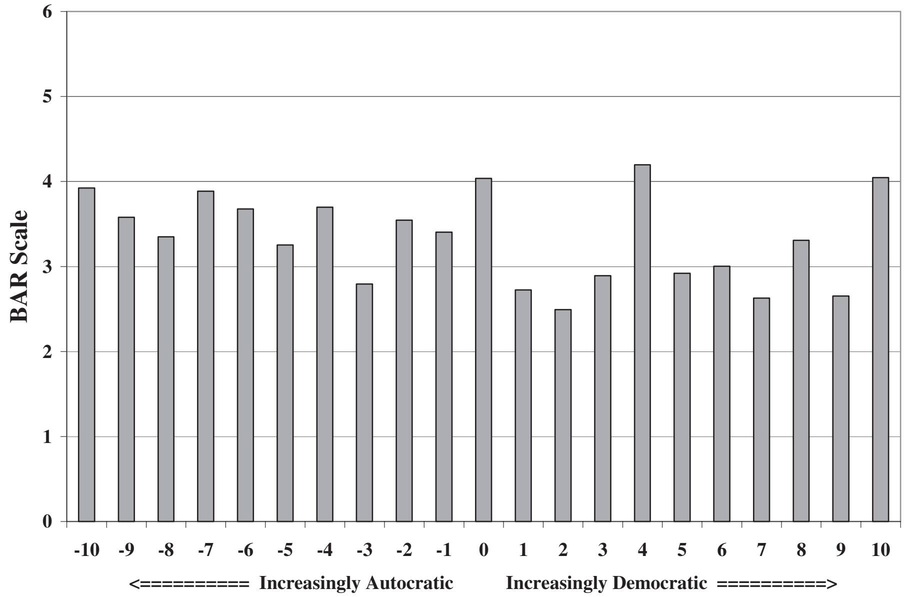

Fig. A7. Regime type vs. BAR Scale, 1948–1999.

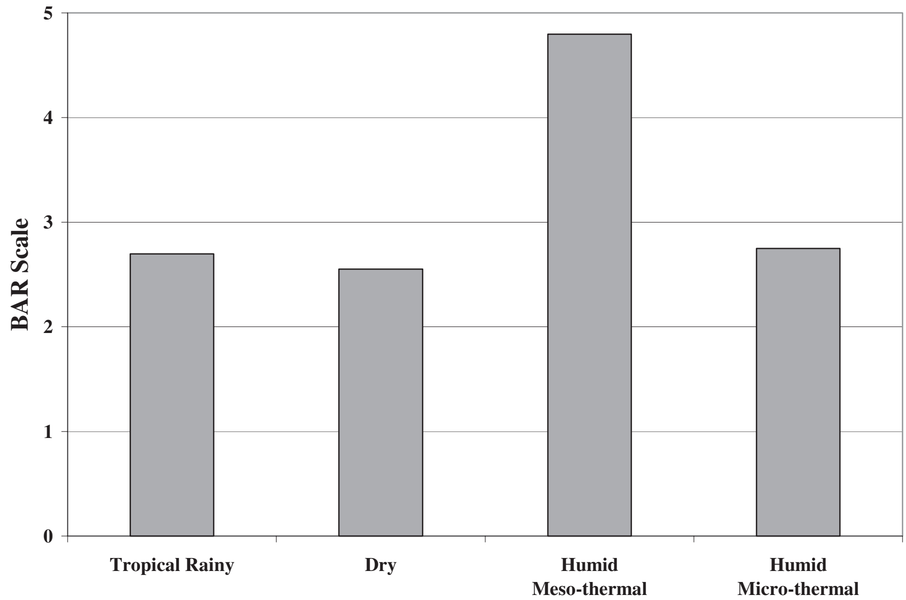

Fig. A8. Primary climate type vs. BAR Scale by basin.

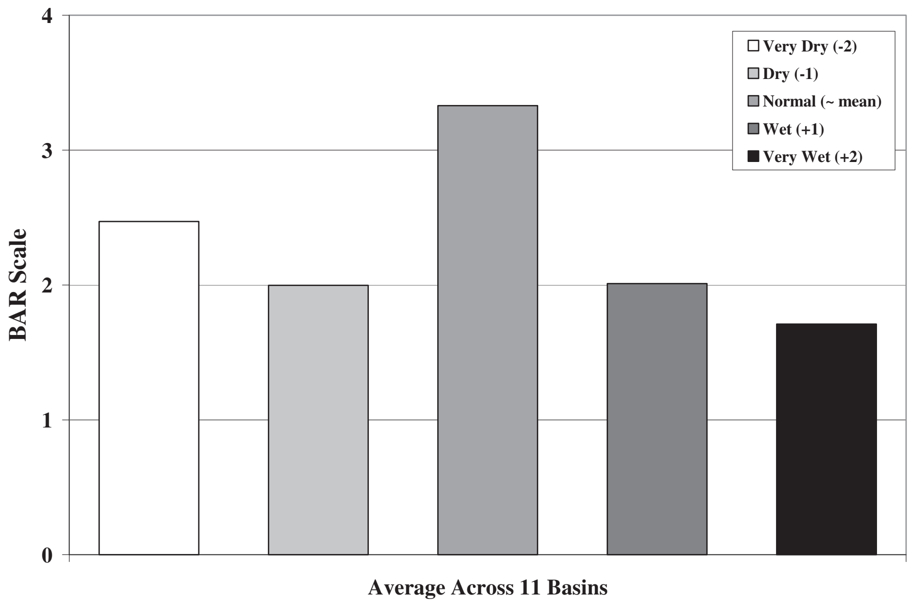

Fig. A9. Annual precipitation average across 11 basins vs. BAR Scale.

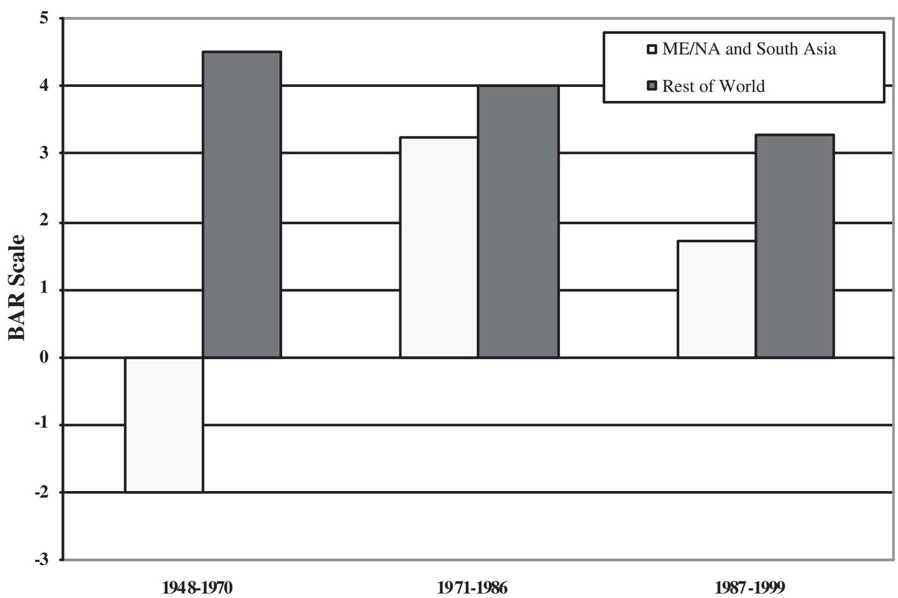

Fig. A10. Average BAR Scale by time period for Middle East and South Asia.

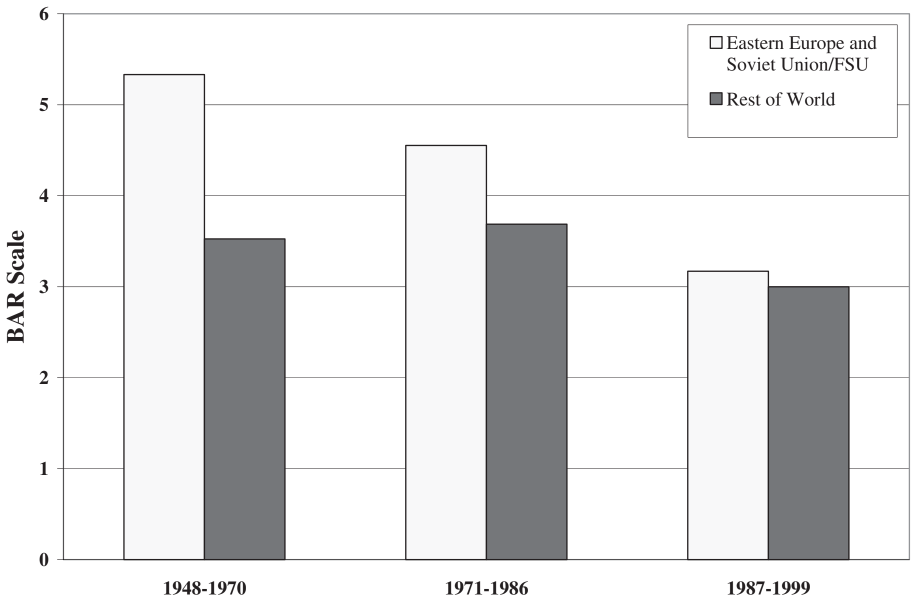

Fig. A11. Average BAR Scale by time period for Eastern Europe and Soviet Union/FSU.

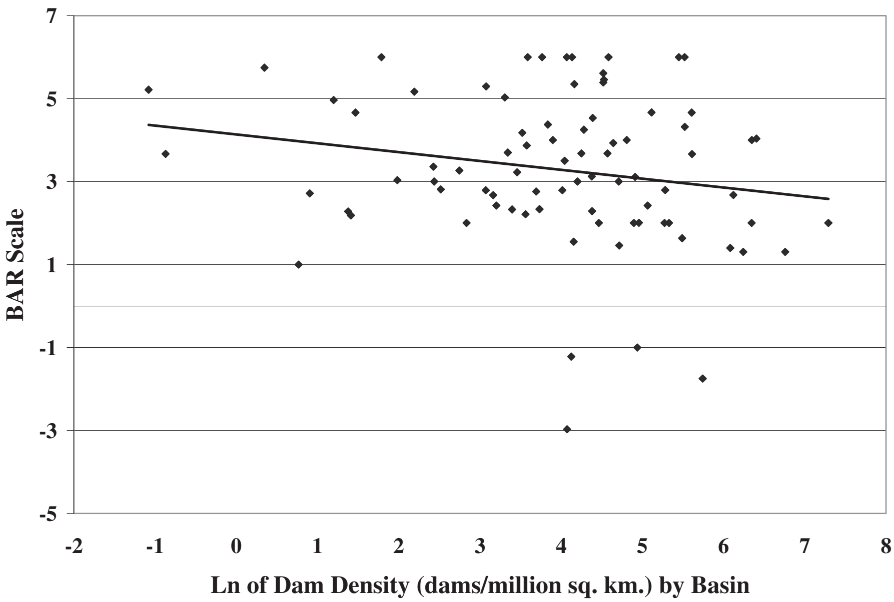

Fig. A12. Dam density by basin vs. BAR Scale. $n = 82$, $R^2 = 0.02$, coeff. = –3.93, not significant at 5% level.

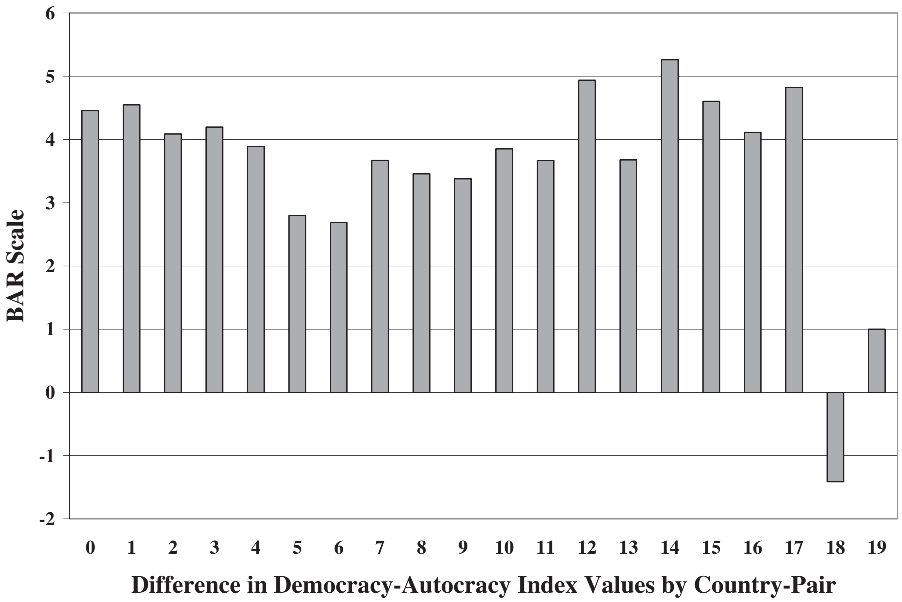

Fig. A13. Difference in regime type by country pair vs. BAR Scale, 1948–1999.

Acknowledgements

The BAR project was a team effort at its best, relying on the dedication and generosity of a vast number of researchers and professionals. I am more indebted than I can say for the commitment of the research group at OSU: Sara Ashley, Case Bowman, Kuuipo Burleigh, Becci Dale, Greg Fiske, Meredith Giordano, Jeanne Hoadley, Kelli Larson, Kyoko Matsumoto, Marc Rothgery and Daniel Wise. Their skill and long hours are extraordinarily appreciated.

This project simply would not have been possible without the support of a number of other individuals as well. First and foremost, we are grateful for the leadership, assistance and insight of Dr. Norm Kahn. Warm thanks too are due to Uri Shamir, Ken Hollett, David Hanig and Aaron Salzberg for their close reading and helpful comments on the manuscript. We would also like to thank Phil Jackson, Jon Kimerling, Chuck Rosenfeld and Dawn Wright of OSU's Department of Geosciences; George Taylor, Oregon State Climatologist, and his assistants Nathaniel De Young and Melanie Mitchell; Joe Toth and Carrie Ottow at the OSU Valley Library; Glenda Pearson at the University of Washington Library, and Brian Smith.

This was also an extraordinarily data-intensive project, which relied on the generosity of many researchers around the world who are committed to open distribution of their incredibly rich data sets, among them Mark Levy, Center for International Earth Science Information Network; Jake Brunner and Kirsten Thompson, World Resources Institute; Petra Doell, University of Kassel, Germany; Balazs Fekete, Complex Systems Research Center, University of New Hampshire; David B. Kynoch, President, Pacific Northwest GIS Consulting, Inc.; Michael D. Ward, Department of Political Science, University of Washington (Seattle); Jerome E. Dobson, Oak Ridge National Laboratory; Jeff Danielson and Kent

Lethcoe, EROS Data Center; researchers at the Global Event Data System, University of Maryland; and the National Geographic Society. Shira Yoffe's studies at OSU were funded by the National Science Foundation Landscape Studies Fellowship, for which we are grateful.

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