Water and Poverty in Southeast Asia –
The Research Agenda from a Global Perspective[1]

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ABSTRACT

The views of many scientists about water are evolving towards a systems approach that accommodates both the multi-faceted dimensions of water resources and the accelerating pace of globalization and human development. The water system includes the water cycle and three major interacting elements: the physical, biological and biogeochemical, and the human components. Major drivers of change that affect the system are climate change, population growth, land cover change, the development of water diversions, economic development, and governance. Changes in any component of the system will cascade throughout the whole system.

Research is needed to clarify the magnitude and mechanisms of change, and how society can best adapt to the system state changes. We need to develop condition indicators such as water availability per person, the water poverty index, pollution concentrations and source water quality. Also on the research agenda are new concepts, namely: blue and green water and environmental flows; virtual water in agricultural trade and associated nutrient flows; and the water systems discourse to integrate natural science and social science approaches. Water governance is a central issue to these concepts. There is a clear need to analyze the impacts of different types of governance of national and regional water resources in a global context.

INTRODUCTION

Water resources are receiving global attention, as human population growth and development wreak significant changes to the earth system. At its 58th session, the United Nations General Assembly adopted a draft resolution, without a vote (A/RES/58/217), proclaiming 2005 to 2015 as the International Decade for Action – Water for Life. At the beginning of this UN decade on Water for Life, it is therefore especially appropriate to examine the progress in our understanding of the state of water resources and future research needs in Southeast Asia. In this region, water is the linchpin of agriculture upon which the largest part of the largely rural population depends.

Pinstrup Andersen (2004) has catalogued the tremendous advances in agricultural production in Asia during the last half of the 20th century. He underlined the fact that agriculture remains the center of gravity of peoples' livelihoods and hence, of poverty and food insecurity in the region. He noted, however, that the proportion of food-insecure people in Southeast Asia is projected to decrease from 12% in the period 1997-99 to essentially zero in 2030. Other key issues for agriculture in the region will be the challenge of meeting the increasing demand for animal protein as incomes rise in Asia, and the accelerated pace of globalization and its implications for trade.

The physiography of most countries in Southeast Asia comprises large hilly or mountainous areas and floodplains where water

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accumulates during the monsoon season. The floodplains are the high-potential areas, and especially important are the irrigated alluvial deltas that are intensively cultivated to rice (Craswell 2000). In some countries, including the archipelagic countries, the coastal plains are narrow and, as so tragically demonstrated recently, exposed to the ravages of tsunamis.

Nevertheless, it is mainly in the extensive marginal hilly areas that one finds farms with low productivity and low incomes, with serious problems of food insecurity at the household level. It is in the high-potential area that the intensified production of staple grains has met demand and kept grain prices low for the urban poor. Continued high productivity from such areas is essential not only to provide food for urban populations, but also to reduce, at the national level, the pressure to intensify agriculture on marginal lands.

This paper reviews recent developments in scientific thinking about water resources. The driving forces affecting the water system are then discussed. The paper concludes with a discussion of new concepts that are shaping the research agenda on water, with a focus on governance-related issues.

THE GLOBAL WATER SYSTEM[2]

Most water research and management in the past have been concerned with regional and local processes. However, the recent postulation by Vörösmarty (2002) –that the hydrological cycle is accelerating – has led to the development of the concept of a global water system, parallel to climate change, which is driven by emissions of greenhouse gases (Vörösmarty et al. 2004). As Figure 1 shows,

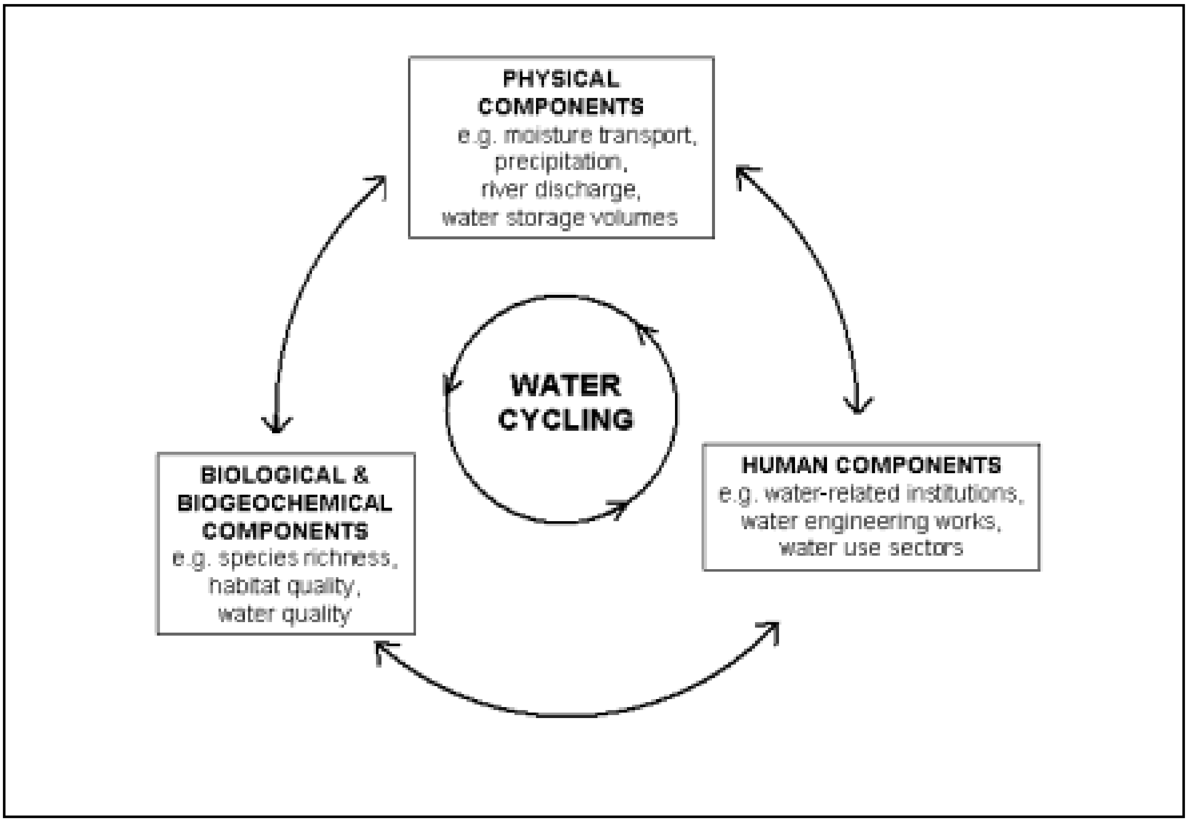

Figure 1. The main components of the global water system

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[2] The concepts in this section are derived from the Scientific Framework of the Global Water System Project (GWSP) (GWSP 2005). The GWSP is a project under the Earth System Science Partnership, comprised of the the International Geosphere-Biosphere Programme, the International Human Dimensions Programme on Global Change, the World Climate Research Programme, and DIVERSITAS.

the system can be defined as the global suite of water-related human, physical, biological and biogeochemical components and their interactions.

Human components

These are the sum of water-related organizations, engineering works, and water use sectors. Society is not only a component of the global water system but also a significant agent of change within the system because, apart from being exposed to changes in water availability, it also takes various actions to mitigate or adapt to these changes.

Physical components

These are the physical attributes and processes of the traditional global hydrologic or "water cycle", including runoff, geomorphology, sediment processes, evapotranspiration, moisture transport, and precipitation. The global water cycle encompasses not only hydrologic processes over and under the land surfaces of the earth, but also in its oceans and atmosphere.

Biological and biogeochemical components

This category includes the sum of aquatic and riparian organisms and their associated ecosystems and biodiversity. These organisms are also integral to the geochemical functioning of the global water system and not simply recipients of changes in the physico-chemical system. Hence the biogeochemistry of the global water system and water quality is also included.

The complexity of this system presents a major challenge to researchers, but it has become clear that past studies of the components in isolation has provided inadequate understanding of the impacts of the dynamic global change. Within the system, the human components are probably the least understood. For example, the global changes in society under the banner of globalization have brought parallel changes in the water system, but these are not well understood.

Alcamo (GWSP 2005) framed the following goal of the Global Water System Project (GWSP) to address the following overarching scientific question:

> How are human actions changing the global water system and what are the environmental and socioeconomic feedbacks arising from anthropogenic changes in the global water system?

An illustration of the interconnections of the issues is shown in Box 1.

Three core questions follow from the above overarching question, and these questions make up the three major *research themes* of the GWSP.

Theme 1. What are the magnitudes of anthropogenic and environmental changes in the global water system and what are the key mechanisms by which they are induced?

Theme 2. What are the main linkages and feedbacks within the earth system arising from changes in the global water system?

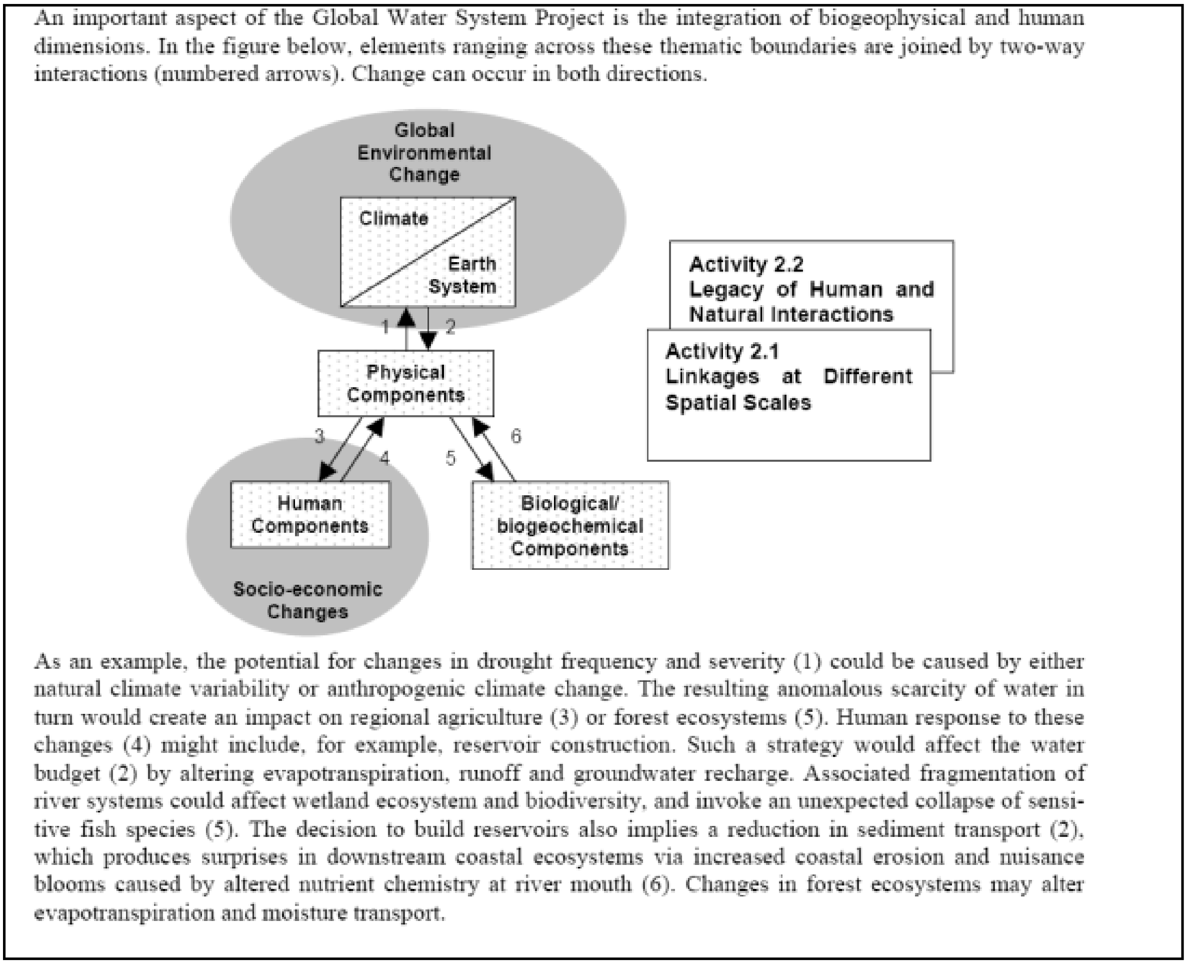
Theme 3. How resilient and adaptable is the global water system to change, and what are the sustainable water management strategies?

Under Theme 1, and emphasizing the importance of the main focus of this conference, the first activity revolves around the topic: *Water Governance and the Global Water System.* Systems of water governance have a profound impact on worldwide water use and water services. In this activity, researchers will compare and classify systems of water governance, analyze their impact on water resources, and catalog governance systems worldwide. A systematic database on water governance systems and their influence on the global water system will also be developed.

DRIVERS OF ENVIRONMENTAL CHANGE

A synthesis of current information indicates that the cumulative direct effects of human activities, such as land cover change, urbanization, industrialization, and water resources development, are likely to surpass the effects of recent and anticipated climate change over decadal time scales (GWSP 2005). The water system is subject to a series of change syndromes as shown in Box 2.

In Southeast Asia, several of these syndromes are a particular concern. Firstly, it is important to consider the issue of land use change in upper



An important aspect of the Global Water System Project is the integration of biogeophysical and human dimensions. In the figure below, elements ranging across these thematic boundaries are joined by two-way interactions (numbered arrows). Change can occur in both directions.

As an example, the potential for changes in drought frequency and severity (1) could be caused by either natural climate variability or anthropogenic climate change. The resulting anomalous scarcity of water in turn would create an impact on regional agriculture (3) or forest ecosystems (5). Human response to these changes (4) might include, for example, reservoir construction. Such a strategy would affect the water budget (2) by altering evapotranspiration, runoff and groundwater recharge. Associated fragmentation of river systems could affect wetland ecosystem and biodiversity, and invoke an unexpected collapse of sensitive fish species (5). The decision to build reservoirs also implies a reduction in sediment transport (2), which produces surprises in downstream coastal ecosystems via increased coastal erosion and nuisance blooms caused by altered nutrient chemistry at river mouth (6). Changes in forest ecosystems may alter evapotranspiration and moisture transport.

Box 1: Interactions, thresholds, and surprises are a key aspect of the questions dealt with by the Global Water System Project (GWSP 2005)

catchments, where the rural poor are often concentrated, and the consequential soil erosion and sediment flows.

Geologically unstable landscapes, combined with deforestation in upper catchment areas, create the potential for large and increasing net outflows of sediments to the oceans and seas in the region (Milliman and Meade 1983). The value of these sediments in Southeast Asia in terms of nutrient replacement costs was estimated by Craswell (2000) to be US$ 18,700 million annually. The sediments affect the ecology of wetlands and coral reefs, with serious impacts on biodiversity and tourism.

Secondly, water pollution is increasingly a concern. Penning de Vries et al. (2002) undertook a review of integrated land and water management for food and environmental security, as part of a comprehensive assessment of water for agriculture. They concluded that pollution by nutrients and pesticides, together with water-borne diseases and disease vectors, present major problems to many developing countries in Southeast Asia.

Pollution due to nutrients such as nitrates and phosphates can be a major problem in urban areas; Faerge et al. (2001) found that 25,000 metric tons (mt) of nitrogen and 900 mt of phosphorus annually flowed into the Chao Phrya River from urban Bangkok. The scope of ecological impacts in the region of such outflows will be exacerbated by the growing trend to urbanization. Only 7% of the nitrogen was recycled in Bangkok. Ways to recycle solid and liquid wastes through urban and

Box 2. Major syndromes transforming the contemporary global water system.

Biodiversity loss	Altered flow regimes, destruction of habitat and pollution have caused widespread loss of species and/or decline of fisheries (Jackson et al. 2001; Moyle and Leidy 1992).
Climate change impacts	Global surface temperature continues to rise throughout the instrumental record with new evidence of an accelerated hydrologic cycle. Regional increases in extreme precipitation, systematic reductions in snow cover and mountain ice, and more frequent and intense quasi-periodic events (e.g., ENSO, AO) have been tabulated during the last several decades (Arnell and Liu 2001).
Erosion	Sediment load to aquatic systems has been substantially high due to poor land management inducing erosion (UNEP 2002).
Eutrophication	Due to development and increasing use of water, the eutrophication of inland waterways continues to increase; impacts persist to the coastal zone where they cause anoxia and toxic algal blooms, and endanger fisheries (Meybeck et al 1989).
Groundwater contamination	Groundwater resources have been contaminated with salts, pesticides, and other substances from agricultural activities, and with chemicals and pathogens from industrial activities and settlements (see “Loadings of micropollutants”).
Intensive water abstraction	In heavily populated regions, water withdrawals sometimes exceed natural river flow and the rate of groundwater recharge (mining of aquifers); water is reused many times, with concomitant public health and pollution problems (UNEP 2002).
Interception of sediment flux	Dams trap 30% of global sediment flux with downstream impacts influencing many coastal zones of the world. Reservoir siltation from upland erosion results in substantial economic loss in many parts of the world (Vorosmarty et al. 2003).
Introduction of alien species	As a result of increasing world trade, invasive species are replacing native species and changing the biodiversity and character of natural ecological systems (e.g. Ricciardi and Rasmussen 1991 for North America).
Land-coastal linkages	Because of water diversion and evaporative (irrigation) losses, connections between the land and coastal zones are being severed with respect to water, nutrients, and sediment. Well-known examples include the Yellow and Colorado Rivers, among many others in arid regions (Vitousek et al 1997).
Loadings of micropollutants	The loadings of micropollutants to water systems are on the rise in many parts of the world including natural (e.g. arsenic and other metals) and engineered (e.g. pesticides) species, with impacts on human health and biodiversity (e.g. Stanners and Bourdeau 1995 for Europe).
Nitrogen loadings	Global nitrogen loadings of rivers have increased by a factor of 2 to 3 compared to pristine conditions with 10-fold increases in some regions (Green et al. 2004; Galloway et al. 2004).
Salinization	Intensive and prolonged agricultural activity has led to large scale leaching of slats from cultivated areas and caused elevated salinity concentrations in groundwater and surface waters, with impacts on terrestrial and freshwater ecosystems (Maybeck et al. 1989).

peri-urban agriculture should be explored more, with particular attention to potential health problems.

Thirdly, the potential problems due to diversions and dams on major trans-boundary rivers in the region must be considered. Dams have many benefits but, apart from acting as silt traps, can restrict water flows during the dry season when water supplies are most critical. In the case of the Mekong, Nesbitt et al. (2004) have highlighted some of the problems of increasing water abstractions.

Currently 80-90 % of the annual abstractions are for agriculture. However, water is becoming a major constraint to crop production as countries of the lower Mekong basin seek to expand agricultural production to meet the needs of their burgeoning populations, and capitalize on expanding demand for agricultural commodities in neighboring Asian countries. The increase in the number of dams in the Chinese headwaters of the Mekong may exacerbate the water shortages and seawater intrusions in the Mekong delta in the critical months of February to May. Nesbitt et al. (2004) highlighted the trans-boundary water governance issues and the critical importance of their resolution to agricultural expansion and poverty eradication in Cambodia, Lao PDR, and Vietnam.

The above examples of problems or syndromes illustrate the need to consider all three components of the water system, whether working at the local, national, regional, or global scales. Governance questions permeate through all of these issues.

INDICATORS OF CHANGE

An analysis of the global water system in terms of drivers of change, condition indicators and state variables (Figure 3) provides insights into

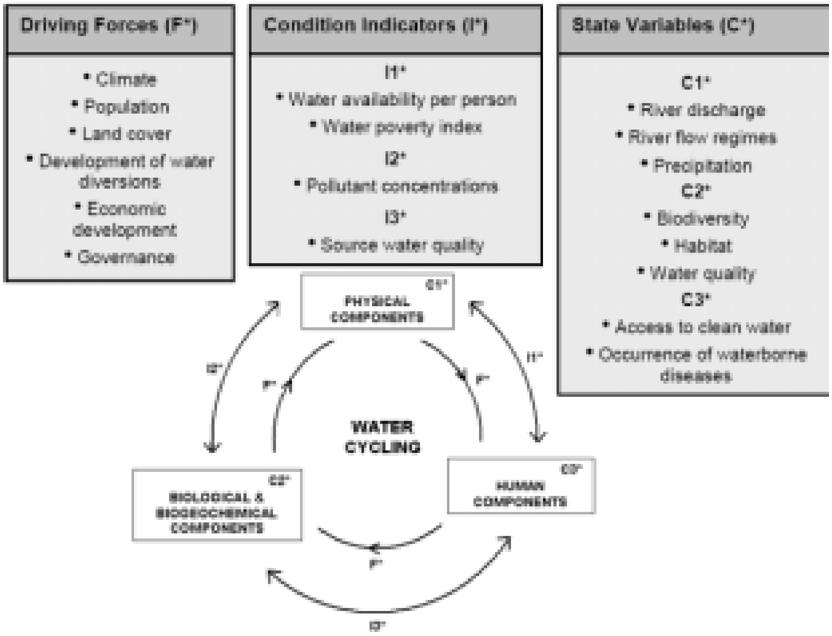


Figure 3. Elements of the Global Water System showing the three classes of data of particular importance in the GWSP – driving forces, condition indicators, and state variables (defined in the text). Also shown are their linkages and some examples. The box and arrows marked "F" show examples of different driving forces operating between the major components of the global water system. The box and items marked C1, C2 and C3 are examples of variables depicting the state of the physical, biological and biogeochemical, and human components (or "realms") of the global water system. The box and arrows marked "I" are special state variables (called "condition indicators") that provide information particularly relevant for policymaking. As shown in the diagram, condition indicators are derived from the interaction of two components of the GWS.

the data needed to improve our understanding of the effects of global environmental change and globalization on the water system at the global and regional levels.

Particularly important are the indicators that provide a means for monitoring progress, or lack of it, in meeting development and environmental goals. The Water Poverty Index (WPI) described by Sullivan and Meagh (2005) is particularly useful in the context of the theme of this meeting, because the WPI integrates a broad range of dimensions that are relevant to the systems approach advocated in this paper. The dimensions are:

- **Resources** – Taking account of seasonal and inter-annual variability and water quality, this measures how much water is available.
- **Access** – This is a measure of how well provisioned the population currently is, including their needs for domestic use and irrigation.
- **Capacity** – This refers to the ability to manage water resources, based on education, health, and access to finance.
- **Use** – This pertains to the uses we make of water, and its contribution to the wider economy.
- **Environment** – This tries to capture the environmental impact of water management, attempting to ensure long-term ecological integrity.

The WPI can be used at a range of scales. Figure 4 shows the use of the WPI to compare Cambodia, Bangladesh, Paraguay, and Brazil. For Cambodia, the main problem is access, while for Bangladesh, resource is the main constraint because of its high population density. Given the multi-faceted nature of the WPI, it remains a work in progress, but the complexity also provides a valuable means of addressing the intricacies of the poverty-water nexus.

EMERGING CONCEPTS

In this section, I highlight several of the new concepts emerging on the research agenda.

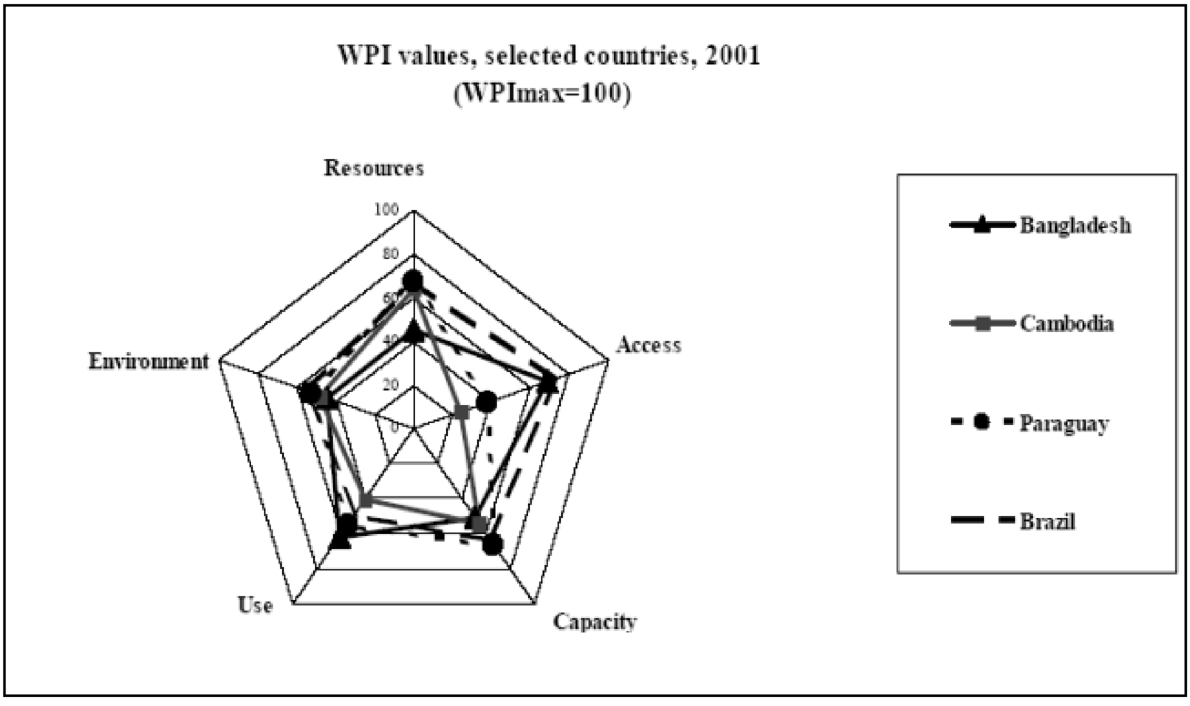


Figure 4. The use of the multi-dimensional water poverty index for comparison at the national level (Sullivan and Meagh, 2005)

Environmental flows

Freshwater ecosystems are losing biodiversity faster than marine and forest ecosystems. Human development appears to be the main culprit for these losses.

Recent assessments, such as those contained in the soon-to-be-published *Millennium Ecosystem Assessment,* are beginning to provide estimates of the value of natural systems to human society. Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions. Water provides goods and services that guarantee human health and life itself and is essential for the preservation of biodiversity.

Moreover, freshwater biodiversity itself provides an important service by helping to regulate aquatic ecosystems.

Turner et al. (2004) recently reviewed the issue of the economic valuation of water resources in light of the intensifying demand for water for agriculture and other sectors. They considered the role of 'raw' water in naturally occurring watercourses, lakes, wetlands, and soil and aquifers, taking an ecosystem function perspective at a catchment scale, and taking into account the demands from irrigated and rainfed agriculture.

The result is an 'advocacy' brief which sets out to bring together economic and ecological evidence and argumentation in support of the need to challenge and change the fundamentals of the prevailing technocentric water resources exploitation worldview. Their economic framework based on cost-benefit analysis provides a new approach to help further the important goal of feeding a burgeoning global population without destroying the planet's critical ecosystem services.

An important related concept is that of blue and green water (see Falkenmark 2005). *Green* water is water held in the soil and available to plants, and used *in situ* by plants. Groundwater and stream flow, dubbed *blue* water, can be used elsewhere – for drinking, irrigation, urban and industrial use, and environmental flows. Dent of the International Soil Reference and Information Centre (personal communication, 2005) has recently advocated a system of green water credits, by which payments in cash or kind are made to rural people for specified water management activities. Farmers and graziers produce crops and livestock, and manage the source of water for other users; they deliver the water in wells, streams and reservoirs. However this is not recognized, and currently not rewarded; in effect, water is delivered by default.

Recognition and payment for this service will deliver larger quantities of more secure, better quality water supplies. In the simplest case, the downstream users of water transfer pay the upstream producers, directly or indirectly. Beyond that, Dent is proposing a global facility to draw upon international and national public and private finance, for example through debt swaps, insurances, investment protection service fees, etc. Pilot studies of green water credits are currently in progress, financed by various donors.

Virtual Water

Virtual water is defined as the volume of water required to produce a commodity or service – e.g. one metric ton of paddy rice requires 2300 cubic meters (m^3) of water to produce. Within the global water system, the analysis of trends in virtual water trade in agricultural commodities provides a valuable means for studying the interactions and feedback between the global, regional, and national scales. Virtual water provides a tele-connection in the global water system, linking through global trade the water resources in different regions. Virtual water trade also illustrates the interactions in the coupled human-environment system, a key concept discussed above.

Virtual water has biophysical dimensions, such as climate-induced water scarcity as a driver, or water savings through production in more humid regions. It also has important governance and institutional policy dimensions, such as the allocations of water at different scales, and the opportunity costs of water used in export agriculture, among others.

There is a need to address questions of environmental or socioeconomic impacts of virtual water trade, and the usefulness of virtual water trade as a tool in an integrated water resources management context. There is also the need to consider the potential for compensation mechanisms for the water footprint that countries

Table 1. Water footprints of selected countries in the Asia-Pacific region. (adapted from Hoekstra and Chapagain, 2005)

		Use of domestic water resources					Use of foreign water resources			Water footprint	
ForTotal	Per capita	Country	Population	Domestic Crop evapotranspiration		*Industrial water withdrawal			For national consumption		
		water withdrawal	For national consumption	For export	For national consumption	For export	Agri-cultural goods	Industrial goods	reexport of imported products		
		Gm^3/yr	Gm^3/yr	Gm^3/yr	Gm^3/yr	Gm^3/yr	Gm^3/yr	Gm^3/yr	Gm^3/yr	Gm^3/yr	m^3/cap/yr
Australia	19,071,705	6.51	14.03	68.67	1.229	0.12	0.78	4.02	4.21	26.56	1393
China	1,257,521,250	33.32	711.10	21.55	81.531	45.73	49.99	7.45	5.69	883.39	702
India	1,007,369,125	38.62	913.70	35.29	19.065	6.04	13.75	2.24	1.24	987.38	980
Indonesia	204,920,450	5.67	236.22	22.62	0.404	0.06	26.09	1.58	2.74	269.96	1317
Japan	126,741,225	17.20	20.97	0.40	13.702	2.10	77.84	16.38	4.01	146.09	1153
Thailand	60,487,800	1.83	120.17	38.49	1.239	0.55	8.73	2.49	3.90	134.46	2223
Global total / avg.	5,994,251,631	344	5434	957	476	240	957	240	427	7452	1243

leave in other regions (Hoekstra and Chapagain 2005).

As Table 1 shows, two countries in Southeast Asia have a per capita water footprint higher than the global average. However, India and China have footprints lower than the global average, indicating a potential need to import virtual water. The future role of Southeast Asian nations in exporting virtual water to meet the food needs of neighboring countries is clearly an important option for consideration.

Another emerging issue related to virtual water is the environmental impact of the nutrients embodied in traded agricultural commodities. Craswell et al. (2004) have shown that annually up to 4 million metric tons of nitrogen, phosphorus and potassium in grain and livestock products are transported internationally in net trade. This total is likely to double by 2020, with serious consequences for the environment, particularly in feed-grain importing countries such as China; because up to 80% of nutrients fed to animals are excreted and must be disposed of, the nutrient load on surface and ground waters in livestock-producing areas around the big cities in Asia will become an even more serious problem than it is now.

The Interdisciplinary Discourse on Water

In all of the foregoing discussion, I have advocated an interdisciplinary approach to research on the global water system, and this is long overdue. However, integrating the natural science and social science approaches to the water systems research and development presents a major challenge. There is a need to bring together different perspectives on the global water system (for example, economic, political science, sociological, anthropological, biological, and geophysical) and to focus these perspectives on specific scientific themes designed to generate important new insights in the water sciences.

To achieve this alliance of perspectives, it will be necessary to bridge both the conceptual and practical gaps currently separating the disciplines. Gaps arise from differences in nomenclature, in quantitative and qualitative approaches, and in the scope and scale of typical studies.

To bridge these gaps, the GWSP plans to sponsor a "*Global Water System Discourse*". The purposes of the Discourse will be: a) to develop a joint terminology of the global water system; and b) to develop a common conceptual framework for understanding the global water system. A central and early focus of the Discourse will be the development of a lexicon of terminology to be shared by GWSP participating scientists, and users of its output. This early, the GWSP product is expected to help merge the knowledge gained from years of case study experience from human dimensions research, with a growing technical capacity to monitor the changing state of the hydrosphere from the Earth Systems sciences. Developing a GWSP Lexicon would encourage and facilitate the interdisciplinary discourse.

CONCLUSIONS

The research agenda to improve our understanding of the water resources in the context of poverty eradication is far from a closed book. The highest priority must be given to improving the understanding of how human development impacts the multi-dimensional water system, utilizing an interdisciplinary approach. Research on institutions, governance, and policy options lies at the heart of the global effort. The approach needs to consider global, regional, and local factors affecting water resources and the poverty nexus.

This paper has attempted to introduce some of the new concepts that are currently the focus of attention and discourses among water scientists in the international arena. More work is needed to train developing country scientists in these new approaches, so that their country's policy-makers can gain most effectively from the body of scientific knowledge on the global water system. In this way, both the urban and rural poor in Southeast Asia can benefit immensely.

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