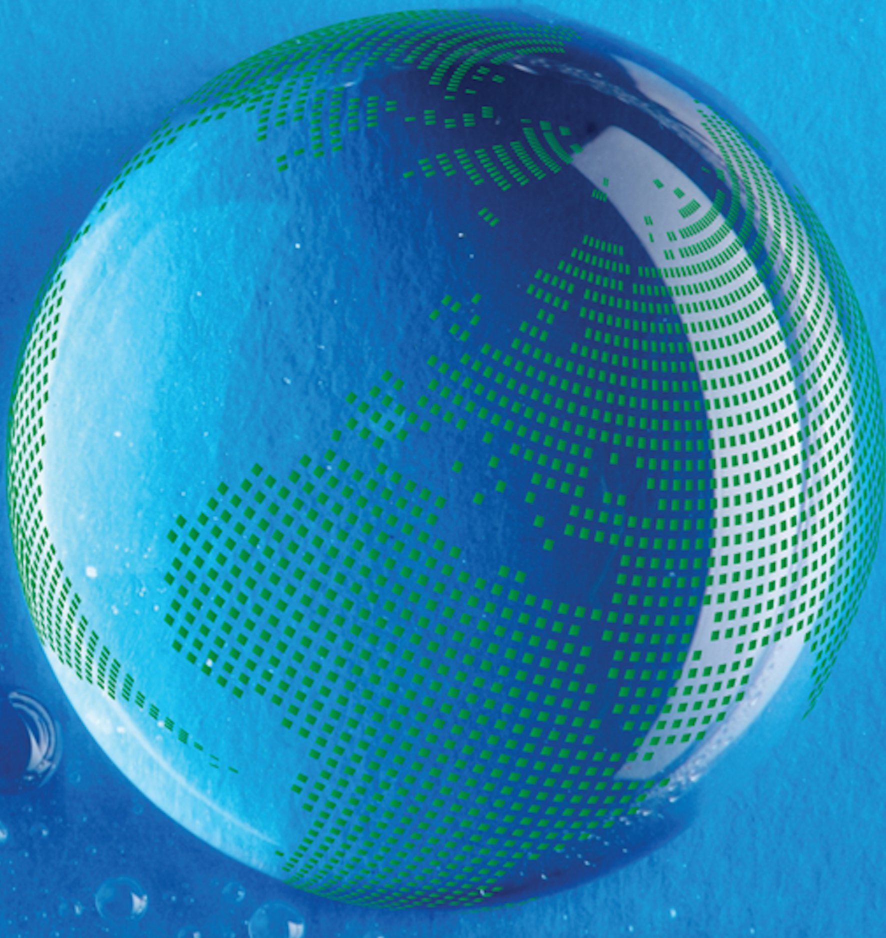
Global Water

Issues and Insights



Edited by R. Quentin Grafton, Paul Wyrwoll, Chris White and David Allendes

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1. Introduction

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Freshwater governance holds a prominent position in the global policy agenda. Burgeoning water demand due to population growth and rising incomes is combining with supply-side pressures, such as environmental pollution and climate change, to create acute conditions of global water scarcity. This is a major concern because water is a primary input for agriculture, manufacturing, environmental health, human health, energy production and just about every economic sector and ecosystem.

In addition to its importance, the management of freshwater resources is a complex, multidisciplinary topic. Encompassing a range of fields in the physical and social sciences, the task of sustainably meeting human and environmental water needs requires a depth and breadth of understanding unparalleled by most other policy problems.

Our objective in this volume is to provide knowledge and insights into major issues and concepts related to freshwater governance. The book is divided into five themed parts: Economics, Transboundary governance, Development, Energy and Water Concepts.

A part addresses each theme and opens with an introduction that provides an overview of key topics. For example, the introduction to the economics section presents two main foci: measuring the value of water and managing trade-offs between different water uses. The thematic case studies discuss issues such as water pricing in Organisation for Economic Co-operation and Development (OECD) countries, finance of water supply and irrigation infrastructure and improving agricultural production with enhanced water management.

The aim of the volume is to accessibly communicate academic research from the many fields of freshwater governance. Too often, academic research is paywalled and/or written in a style that caters to colleagues in the same field, rather than a broader audience from other disciplines, the policy-making community and the general public. This open-access book presents the research of a range of global experts on freshwater governance in brief, insightful chapters that do not presume a high level of pre-existing knowledge of their respective subjects. This format is intended to present knowledge on the key problems of and solutions to global freshwater challenges.

The final part presents research from several United Nations Educational, Social, and Cultural Organisation (UNESCO) supported water research Chairs and Centres. Support and coordination of the insititutions highlighted in this part of the book is provided by UNESCO. One water research Chair is The Australian National University – UNESCO Chair in Water Economics and Transboundary Governance, which was established in April 2010 and works with partners in southern Africa, UNESCO, the Global Water Partnership and other organisations to: (1) increase the skills, capacity, networks and potential of leaders and prospective water managers and policy-makers; (2) sustain and strengthen institutional capacity (especially in southern Africa) by providing a platform for collaboration and institutional development; and, (3) develop innovative research, tools, case-studies, and insights on water economics, water governance and equity.

Established by the ANU–UNESCO Chair, the Global Water Forum (GWF) seeks to disseminate knowledge regarding freshwater governance and build the capacity of students, policy-makers and the general public to respond to local and global water issues.[1] The GWF publishes accessible, subscription-free articles highlighing the latest research and practice concerning freshwater governance. A broad range of water-related topics are discussed in a non-technical manner, including water security, development, agriculture, energy and environment. In addition to publishing articles, reports and books, the GWF is engaged in a range of activities, such as the annual Emerging Scholars Award and hosting a portal to educational resources on freshwater.

We hope that you enjoy reading this book and, more importantly, gain an improved understanding of the complex freshwater-governance challenges facing us all on a global scale and at a local level.

1 The Global Water Forum can be accessed at: http://www.globalwaterforum.org.

Part 2: Economics

2. Economics

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The economics of water concerns the measurement and effective management of the trade-offs across its many competing uses (and non-uses) over time and in different locations. Measurement requires estimation of the costs, benefits and risks associated with alternative uses of water. For example, these alternatives could be: (i) keeping water in the river to support ecosystem services, (ii) extracting it for a town's water supply, or (iii) using water to irrigate a rice crop. Effective management ensures that society's objectives for water use (for example, environmental sustainability, sanitation and waste disposal, or food production) are achieved by supporting methods to allocate water that favours higher value uses (including non-uses) and ensures that basic water needs are met.

Measuring the value of water

The challenge of measuring the value of water across different settings is that it is used as an input or intermediate good in many production systems and, thus, has multiple and possibly competing values as a factor of production. But water can also be a final product, such as drinking water, washing, or waste disposal, and also has value *in situ*, such as when water is not extracted from a river to generate or retain ecosystem services and benefits. The market benefits of water in production processes or direct use can be determined from market transactions, such as the price at which water is traded in a market or water's derived demand in the production of a crop or product.

Typically, the greater challenge is to estimate water's value in a setting where markets, in general, do not exist and there is no direct production beyond ecosystem services. Non-market valuation techniques that can, and have, been employed include: (1) valuing recreational sites and rivers by the travel costs of those who make use of ecosystems services, such as catching fish or canoeing; and, (2) stated preference methods whereby people are asked direct questions about their willingness to pay for a change in the quantity and quality of a water resources. In both travel cost and stated preference approaches the values obtained from respondents are, in general, aggregated to obtain an aggregate valuation from water.

Managing trade-offs

Valuations and values of water provide the basis for allocating water efficiently and equitably across competing uses and users. Typically, economists use a cost-benefit analysis (CBA) framework that also accounts for risk and enables the comparison of alternative allocations across competing uses. The typical rule is that any allocation should generate a positive net present value such that the 'discounted benefits'[1] of the given allocation, less the discounted costs, is positive. Ideally, allocations with higher benefit-to-cost ratios are preferred. For this tool to be useful all costs and benefits must be accounted for, including the hard-to-measure non-market values for water and especially water *in situ*.

While CBA is a helpful economic tool to manage trade-offs, decisions about reallocating water across competing uses must also involve consideration of equity, or who gets what and when. Thus, an allocation that makes disadvantaged or vulnerable groups worse off, and without adequate compensation, may not be desirable from a societal or fairness perspective, even if the allocation has a high costs-benefit ratio for society as a whole.

Beyond the calculation of costs, benefits and compensation arising from changes in water allocations, effectively managing trade-offs also requires an understanding of water externalities. This is an economic term for spillovers, both positive and negative, that arise from the actions of water users or keeping water *in situ*, and which are not accounted for in the decision-making of an individual water user. For example, a farmer irrigating a crop may impose externalities on downstream irrigators if the upstream farmer's river extraction reduces water availability downstream. In the case of recreational users, the externality could be that the water returned to the river after irrigation use is of lower quality. If the upstream irrigator does not account for these downstream costs then too much water will be used in irrigation upstream. This is a common cause of environmental problems and is a major driver of the overuse of water.

Another challenge in water use is that water management can provide non-rival benefits or public good benefits. These benefits can be enjoyed by all, such as the aesthetic and ecosystem benefits of wild rivers, but can be underprovided because of 'free riders' who enjoy, but do not wish to pay for, these benefits. Typically, local, regional, or even national governments intervene to provide the public good benefits of water, but even so under-provision remains common.

1 The term 'discounted benefits' implies that benefits felt in the longer term receive a lower weighting in cost-benefit calculations. So longer term benefits are significantly 'discounted' when we think about them in terms of their 'present value'. This method for adding up costs and benefits over a period of time is a common technique in economics and, indeed, in the daily consumption and production decisions that we all make.

The key to managing trade-offs is to devise effective methods to overcome under-provision of the public benefits of water and prevent the overuse of water in cost-effective ways. These may include: cap and trade markets for water to reduce overuse, water emission taxes to reduce water pollution and user charges to recoup public benefits of use.

Overview of chapters

The economics section of this volume has six chapters covering a broad range of issues. The articles provide insights into the application of economics to the measurement and management challenges discussed above. Ward and White (Chapter 3) summarise the key findings of a paper published in *Water Resources Research* showing how and the level at which households in Organisation for Economic Co-operation and Development (OECD) countries are charged for their water effects their consumption and behaviour. Rodriguez and McMahon (Chapter 4), both of the World Bank, review the financing of water supply and sanitation in developing countries. Their key insight is that while financing is a critical issue, the management of water providers and the incentives that they operate under are equally as important to ensure delivery of cost effective water services, especially to the poor and vulnerable. Abramson and Gurin (Chapter 5) take a micro view of how farmers and households in poor countries can access adequate water given that they do not have access to centralised systems and must obtain water by their own means. While hand-operated water pumps are ubiquitous, they are insufficient for the needs of households and farmers, and powered pumps offer substantial benefits to the water-deprived. Katic's chapter on water use by West African rice farmers (Chapter 6) emphasises that simply increasing water supplies does not necessarily raise incomes. While greater water availability raises yields and revenues, these can be offset by higher costs. Importantly, she finds that there are other ways to boost farm revenues such as improvements in the quality of local produce. Kajisa (Chapter 7) examines the growing use of private pumps and wells in Tamil Nadu, India and its impact on community-based and managed irrigation systems. Lower cost pumps have allowed individual farmers to benefit from accessing groundwater in their own wells, but at a social cost. This has imposed a 'double tragedy': the depletion of groundwater systems and a reduction of investment and effectiveness in community-based systems, which leaves poorer farmers, who have been less able to build and use their own wells, much worse off. The last chapter in this section, by Grafton and Horne (Chapter 8), is based on work published in *Agricultural Water Management*. They describe the history, net benefits and limitations of water markets in the Murray-Darling Basin. Their contribution shows how water markets can in practice, and not just in theory, provide a means to improve outcomes for water users and a means to reallocate water from use to non-use purposes.

Dr R. Quentin Grafton FASSA is Professor of Economics, ANU Public Policy Fellow and Director of the Centre for Water Economics, Environment and Policy (CWEEP) at the Crawford School of Public Policy at The Australian National University. He is the Chairholder, the UNESCO Chair in Water Economics and Transboundary Water Governance and in August 2013 was appointed Executive Director at The Australian National Institute of Public Policy (ANIPP).

3. Managing residential water demand in the OECD

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Water scarcity is a growing concern in many cities due to rapid population growth, rising incomes and the associated increasing demand for water, and increasingly variable water supplies resulting from changes in the global climate.

Due to the economic and environmental costs of large-scale investments in water supply, together with the significant time required for planning and implementation, many urban areas are seeing increasing use of policy measures designed to regulate urban water demand. This research looks at the effectiveness of these demand-side policy measures on residential water demand in the countries of the Organisation for Economic Co-operation and Development (OECD).

According to standard economic theory, the most efficient way to regulate water demand is through volumetric prices (Grafton and Ward 2008). Under such a system, users pay a charge for each unit of water consumed, as opposed to water tariffs, which charge users a block rate depending on the level of their consumption. By using volumetric charges, the water price can be raised during times of scarcity so that users consume less water, thereby reducing demand when supplies are low (Ward et al. 2011).

Due, however, to concerns over the equity of using water prices to regulate demand, and claims that residential water use is unresponsive to changes in price, many water utilities focus on non-price approaches. These include requirements or subsidies for using water-saving devices, such as low-flow shower heads and dual-flush toilets, and the use of public information campaigns to promote water conservation attitudes, such as taking showers instead of baths.

Mandatory water restrictions are an additional non-price approach that is sometimes used to regulate water demand during times of water scarcity. While effective, they can generate significant welfare losses for water users and, as such, was not considered in this research (Ward et al. 2011).

In order to understand the impact of volumetric prices, water-saving devices, and water conservation attitudes on residential water use, data was analysed from an OECD survey of 1600 respondents across ten countries looking at the price and non-price determinants of residential water demand (Grafton et al. 2011). Respondents were asked a series of questions regarding the following factors: (1) household characteristics (such as age, income, household size); (2) environmental attitudes (such as whether they are members of an environmental organisation); (3) adoption of water-saving behaviours (such as whether they turn off the water while brushing their teeth); (4) use of water-saving devices (such as rainwater tanks); and, (5) domestic water use (such as water consumption, total water cost).

Once the surveys were completed the results were collected and analysed in order to answer three key questions:

(1) What are the impacts of price on household water consumption?

(2) What are the impacts of water-saving devices on household water consumption?

(3) What are the impacts of attitudinal characteristics and environmental concerns on household water consumption?

Impacts of price on household water consumption

The analysis of the survey data revealed that water demand was inelastic and statistically significant from zero across all ten OECD countries. The price elasticity of demand ranged from a low of –0.27 for Norway, to a high of –0.59 for Italy, while the average price elasticity across the entire sample was –0.43. A ten per cent increase in the average water price across households, therefore, lowers urban water use in the OECD by about 4.3 per cent. This finding supports the economic principal that the higher the average volumetric price of water, the lower household water consumption will be (see Figure 1).

The results also suggest that volumetric charges are the most important cause of respondents engaging in water-saving behaviours, such as turning off the water while brushing teeth, taking a shower instead of a bath, watering the garden in the coolest part of the day, and collecting rainwater and recycling wastewater. The estimated water savings for households facing volumetric water charges as a result of these water-saving behaviours was around 40 kilolitres each year, or a quarter of the average household water consumption in the OECD.

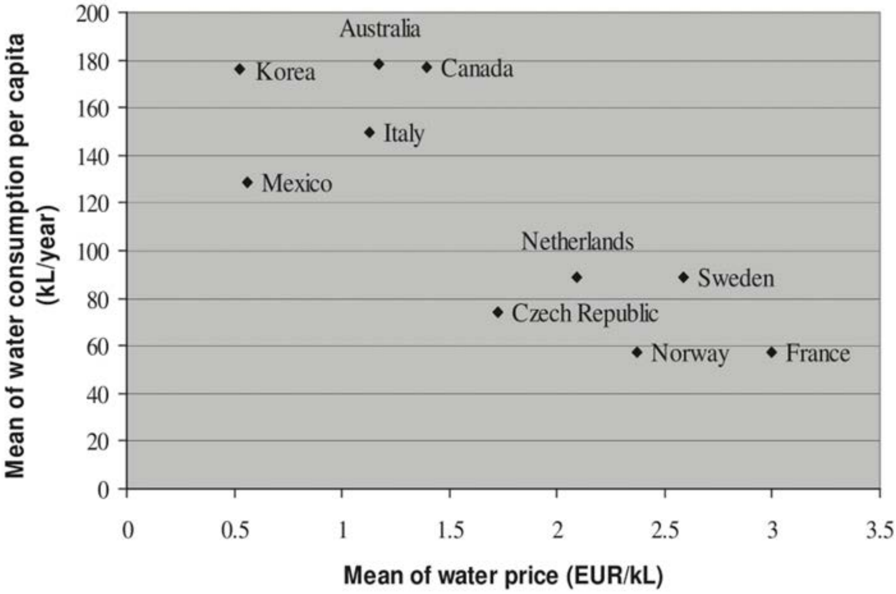

Figure 1: Average water consumption per capita and volumetric price across ten OECD countries

Source: Adapted from Grafton et al. 2011.

Impacts of water-saving devices on household water consumption

The analysis of the survey data revealed that only dual-flush toilets have a statistically significant and negative impact on water consumption. The coefficient on the dual-flush toilet variable was –0.25 and statistically significant at the one per cent level. This suggests that the use of water-efficient toilets reduces household water consumption by about 25 per cent. By contrast, low-flow shower heads and rainwater tanks did not have a statistically significant impact on household water consumption.

While it initially seems intuitive that water-saving devices should reduce household consumption, this may not necessarily be true in every case. This is because an increase in the water efficiency of a device effectively reduces the unit cost of using it and, as a result, can cause an increase in its use. Olmstead and Stavins provide a review and summary of several studies on water saving devices and also find that the impact of such devices on water consumption is mixed (Olmstead and Stavins 2009).

Impacts of attitudinal characteristics and environmental concerns on household water consumption

The analysis of the survey data did not reveal significant evidence of the influence of environmental concerns and behaviours on household water consumption. Attitudinal characteristics and environmental concerns were, however, found to increase the use of dual-flush toilets, which significantly reduces water consumption.

Some environmental behaviours were found to have a statistically significant and positive effect on the probability of undertaking water-saving behaviours. For example, being a member of an environmental organisation or a supporter of an environmental organisation increased the probability of turning off water while brushing teeth, plugging the sink when washing dishes, watering the garden in the coolest part of the day, and collecting rainwater/recycling wastewater. Higher levels of environmental concern were also found to be statistically significant in terms of increasing the probability of undertaking a range of water-saving behaviours.

Policy implications

Overall, the results suggest that volumetric water pricing is one of the most effective policy measures available to regulate household water consumption. The results also suggest that water-demand management policies, which combine a volumetric charge for water use and a higher average water price with campaigns to promote water-saving behaviours (such as taking showers instead of baths) and the use of water-saving devices (particularly dual-flush toilets) would further improve the regulation of residential water demand.

Michael Ward is Professor in Economics at Monash University, Australia. After receiving a PhD in Economics from the University of Washington, he has published across a number of economic disciplines in some of the world's leading journals. In 2008, his paper with Jay Shimshack and Tim Beaty was selected as the 'Best Economics Paper' by the Agricultural and Applied Economics Association for work in the area of food safety and nutrition. The article is based on an original piece of research published in *Water Resources Research*, 'Determinants of residential water consumption: evidence and analysis from a 10-country household survey'.

Chris White is Managing Editor of the Global Water Forum and also works as a Research Associate at The Australian National University and as an Environmental Economist at URS, London.

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4. Water finance: Preparing for the next critical juncture

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Water supply, sanitation and irrigation infrastructure provide the critical water services that make economies prosper. The costs of investments in these sectors are low compared to the benefits they provide. By 2025, global water-sector spending will be in the trillions (Organisation for Economic Co-operation and Development (OECD) 2006). By 2050, the pace of urbanisation will be such that achieving universal access to the supply of water and sanitation will cost the developing world an additional one per cent of gross domestic product (GDP) (US$7.6 billion) every year compared to current needs (Roehrl 2012). The poorest of these countries, despite their greater need, will have the fewest resources to invest.

The 2008 global financial crisis has introduced a new dilemma. As GDP growth slows, so does funding for water services. Credit for developing countries has dried up (World Bank 2013) and current private investment in water services is only about a third the size of development assistance to the sector. Within that slice, international and domestic investors are working with an increasingly narrow list of large, urban areas in middle income countries.

By and large, low-income countries are considered too risky for investment. But with water demand outpacing supply in several large cities, they could become the next growth market for international investors. In order to make private money work to their advantage, these countries will need a sturdy public sector that can promote efficiency and equity in water services and ensure a stable and enabling environment, including institutional, legal and regulatory structures.

It is estimated that more than 75 per cent of all sector funding is provided through public sources, coined by the OECD as the ‘3 Ts’, or tariffs, taxes, and transfers. While desirable for funding and maintaining infrastructure (because they don’t have to be repaid), each T has a set of drawbacks that make it less optimal (in many cases) than private sector funding.

Tariffs are collected directly from households in exchange for water services. If set too low, they risk putting service providers out of business and providing incentives for people to over consume. If set too high, they are not equitable and leave customers dissatisfied.

Tax revenues are provided annually from national or sub-national governments to local service providers. Water budgets change in line with changes to tax revenues, leaving service providers with short-term cash that does not promote long-term investment or incentives to improve performance. A recent study by WaterAid shows that many countries in Africa reduced their budget allocations to water between 2008 and 2010 (WaterAid 2011). Furthermore, most developing countries run their budgets on yearly cycles, creating uncertainty regarding the future tax revenue that will be allocated to water. This is a disincentive for operators to enter into long-term sector planning.

Transfers from donors are well-intentioned but less effective by the time they reach the local service provider. They are as subject to the same volatility as taxes and slower to deliver on promises: sector disbursements average only 70 per cent of commitments. Transfers are also rarely aligned with local capacity to spend the resources. In a 2011 UN-water global annual assessment of sanitation and drinking-water GLAAS survey of 38 countries, a meager 18 per cent of participating countries disbursed more than 75 per cent of donor capital commitments to sanitation (World Health Organization (WHO) 2012). This is also exacerbated by the (sometime) discrepancies between donor and country/ sector priorities.

Each of these '3 Ts' crystalises the status quo, whereby infrastructure is fixed in the short term without incentivising long-term efficiency improvements or thinking on investment. This arrangement has left poor countries at a critical juncture. Once the world economy starts accelerating again, both private and public funds will rush into the sector. Unless serious reforms are in place, more dollars will go to waste and the status quo could become irreversibly solidified.

Countries need to be ready to make the best use of all their resources by improving water's public sector framework (Rodriguez et al. 2012). First, to protect the public's interest, they need to heed lessons from the history of privatisation in water. This includes sound governance structures, enforced regulations and separation of powers among institutions. Whether the private sector is brought in to improve operations; provide technical assistance; invest in, manage, or own the water infrastructure is irrelevant. The key is having a public sector that is willing to counter-regulate at the same speed: share risk, protect water consumers and maintain control over performance and delivery of results. Second, governments need to drive service providers toward financial sustainability through two means: services that recover most, if not all, of their own costs and more efficient public spending.

In many developing countries, recovering operational costs will require cutting expenses (through efficiency improvements and reductions in unaccounted for water) and increasing revenues (higher tariffs and better collection rates). Four years of such efficiency improvements helped Uganda's National Water and Sewerage Corporation double its revenues. Reforms were realised through a private sector management structure whereby staff were paid to reach performance targets.

The other side of financial sustainability — government spending — can be improved by more transparent budgeting, long-term investment planning (that integrates the melting pot of funding sources), and hiring the right skill sets to manage spending. To do this requires serious consideration of operating costs and the subsidies that pay for them — where they are going and how they are impacting the daily decisions of consumers and service providers.

While such reforms would make current spending more efficient, governments and donors can do much more to help address the financing gap. They have the power to make service providers more self-sufficient by allowing tariffs to reflect the real cost of services, or providing guarantees and risk-pooling instruments that enable private borrowing. They can also remove the information asymmetries that block private finance from entering the water sector by inventorying assets, mapping out potential water markets, or showcasing creditworthy utilities. More transparency would reduce risks and entice the private sector to court a new market of poor people that is three billion strong and growing. Lastly, they can work together to ensure that grants are allocated based on country and sector needs. This will ensure full ownership of the process.

The Philippines is implementing such game-changing reforms, taking a holistic approach that supports private participation while at the same time strengthening local government capacity to design and implement projects. The government, as financial broker, is pioneering a way to pool the risk (the country is host to 6000 small utilities) and leverage resources toward a more sustainable public–private partnership in water. It is worth noting that these advances have been backed by top-level leadership, which is rare in many developing countries.

Whenever it comes, the next influx of cash (and the mechanisms through which it is loaned) will set the pace for a new generation of water infrastructure. Poor countries should take this time to get their financial house in order by designing a sector investment plan like Indonesia's or undertaking a Public Expenditure Review, like Malawi. Such instruments will help public and private interests see the goal, understand the limitations and budget and plan accordingly. They can also provide a framework under which donors and development institutions coordinate at the country level to provide longer budget cycles and more strategic support that aligns with their respective comparative advantages.

For most low-income countries, simply financing more water infrastructure and services — from public or private sources — will not solve the problem. Changing how the money is budgeted, targeted and executed is the proper place to start.

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5. Outlining a transition from cost-effective to productive rural water service improvements

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Although global trends indicate that the Millennium Development Goals for drinking water have been met, many developing countries still lag behind, including rural Sub-Saharan Africa (SSA) (United Nations Children's Fund (UNICEF)/World Health Organization (WHO) 2012). Despite a gradually emerging shift in policy from rights-based to market-based water development, and growing recognition of the importance of achieving full cost recovery of water improvements from users, market forces have remained sidelined from the rural water sector in SSA (United Nations Conference on Sustainable Development (UNCSD) 2012; United Nations (UN) 1992, 2002; Fonseca 2003). Instead, soft financing arrangements predominate, ranging from charity to, at most, user payment of operation and maintenance costs, with capital costs being met by donor funding or subsidies (Harvey 2007). As a result, the goal of minimising water costs to maximise aid effectiveness has been deeply entrenched in the sector, limiting the use of water technologies to only a few of all technologically feasible options for these areas.

According to the criteria of cost-effectiveness, most remote water interventions use the cheapest available means for providing improved water services. In many areas, this is the ubiquitous hand-pump-operated borehole — the most common water source in rural areas, with almost one billion rural users worldwide (UNICEF/WHO 2012). Hand-powered pumping is cheap, but limits the supply of water to exclusively domestic uses. Higher yielding water sources are common in many parts of Africa, suggesting that there is a widespread potential for small-scale productive or multiple-use groundwater sources (MacDonald et al. 2012). Yet higher yielding pumps, such as motorised pumps, are seldom considered, much less seen, in remote areas of SSA.

Such approaches may drastically reduce pumping costs in communities with grid electricity. For off-grid communities, solar photovoltaic (PV)-powered pumping is suitable for both productive irrigation and domestic uses, as its output aligns with the water needs of crops. It may also provide excess or 'free' electricity to off-grid communities and has minimal operation and maintenance costs (Burney et al. 2009). Diesel-powered pumping may be less sustainable and subject to volatile price fluctuations, but is one of the few alternatives available to off-grid communities.

Figure 1 presents a cost comparison between hand pumps and these other, higher yielding approaches for a new borehole that are typical of rural SSA: grid -, solar - and diesel-powered submersible pumps.

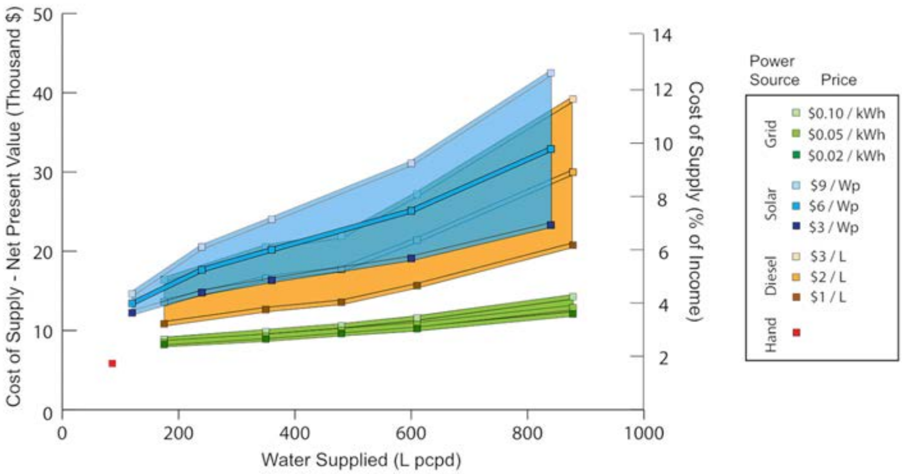

Figure 1: Cost comparison of water quantity improvements by pumping method for a village of 20 poverty-level households

Source: Author's research and sources referred to in the text. Cost comparison of a new community borehole across various pumping methods and yields for a village of 20 households living at the rural poverty line of $1.25 per capita per day (pcpd). A value of 20 metres total pumping head is used as an estimate of regional average groundwater depth for SSA (MacDonald et al. 2012). A financing timeframe of 15 years is considered at a discount rate of ten per cent. A range of costs for diesel ($1, $2 and $3 per litre), solar PV arrays ($3, $6 and $9 per Watt-peak) and grid electricity ($.02, $.05 and $.10 per kilowatt hour) are compared. Grundfos WebCAPS® software was used to determine appropriate pump sizing, with local prices and meterological data for Livingstone, Zambia (Grundfos). Borehole construction was assumed to cost $5000 (Author's fieldwork, 2009 –11).

Hand pumps are certainly the lowest cost and, for meeting minimal water supply standards, represent the most cost-effective approach. Only a small proportion (two per cent) of household income would be required to fully finance the investment (although this contribution is rarely made). The cost of transitioning from a hand pump to a higher yielding motorised pump is dependent on the source of power available, and the price of solar and diesel inputs. If grid electricity is available, there is only a marginal increase (between three to four per cent of income) in total cost across all yields investigated. If not, users would need to pay between four per cent and 12 per cent of their income for diesel-powered improvements, or between five per cent and 13 per cent for solar-powered improvements over 15 years.

Figure 2 presents the cost of water under these alternatives.

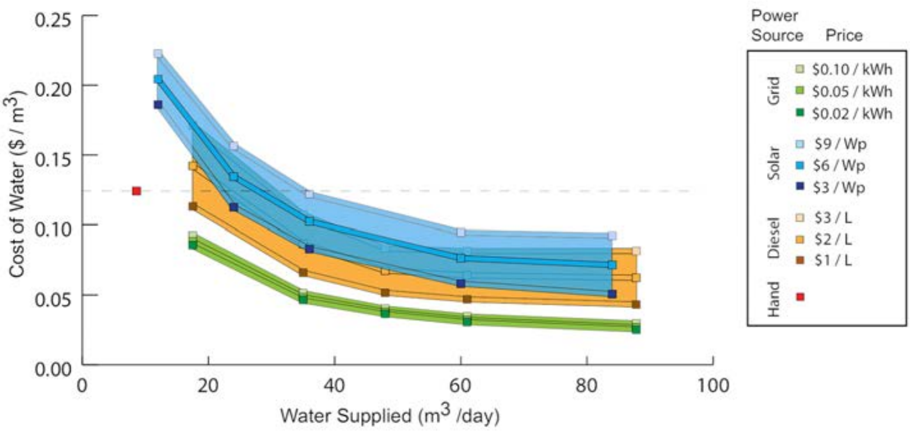

Figure 2: Cost of pumped water by pumping method

Source: Author's research. Water costs ($/cubic metre) across the same alternatives and scenario investigated in Figure 1, with a 15-year lifetime and ten per cent discount rate. The dotted line represents the price of water at any number of hand-operated borehole replications. Almost all higher yielding alternatives provide water at a lower cost per volume than handpumps. For shallower groundwater depths than 20 metres, these trends would be more acute, and vice versa.

While handpumps provide the lowest total cost per replication, a steady decrease in marginal water costs with yield exists for alternative pumping approaches. Thus, the requirement of cost-effectiveness only holds for minimum yields (up to 20–30 cubic metres/day per borehole, or 200–300 litres pcpd for a village of 20 households). At higher yields, hand pumps are the least cost-effective alternative. In other words, the effectiveness of every dollar spent pumping water increases with the amount of water pumped. This suggests that water-related productive activities would provide increasing returns on investment, at least within these parameter ranges and assuming water is a limiting production factor.

Hand pumps are ubiquitous in rural areas primarily because low density populations have low-yield requirements for meeting domestic water service standards. Under cost-effective criteria, alternative pumping approaches are excluded since additional water only creates additional cost. But if small-scale productive water uses could be coupled to project costs, additional revenue could be generated.

To demonstrate the impact of this policy shift in a realistic, field-based context, I investigate a potential market-based 'water-for-work' program, as outlined in a previous study (Abramson et al. 2011). Under this arrangement, multiple-use water improvements that are capable of meeting both domestic and productive water needs are designed for unreached villages. Community gardens drawing upon these water systems are developed, and households contribute their time cultivating high-value produce, which is sold and profits directed toward financing the system. This setup removes monetary limitations and may enable market-based cost recovery of water improvements where conventional cash payments fail.

I investigate this setup in the same typical village in which a multiple-use borehole is developed, and labour in the community garden is conducted over two years (Figure 3).

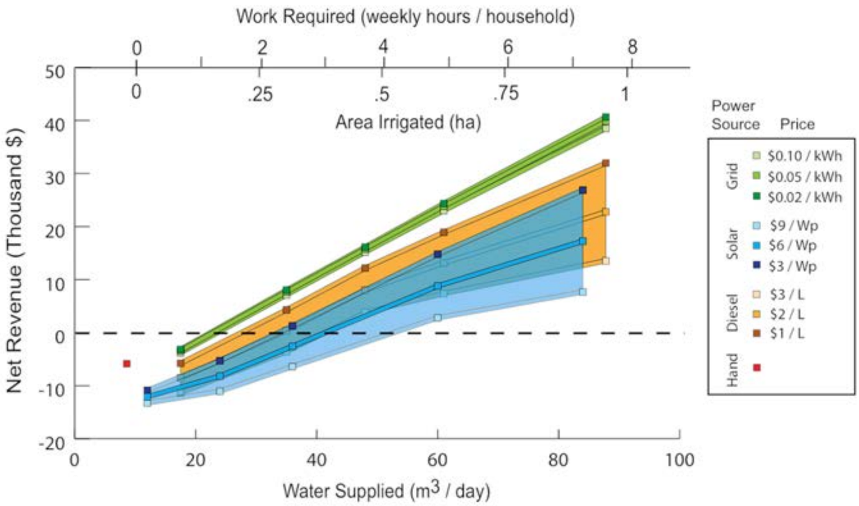

Figure 3: Net revenue of hypothetical 'Water-for-Work' program coupled to various pumping methods

Source: Author's research. Net revenue generated under a multiple-use, new community borehole and pump coupled to community drip irrigation of high-value, off-season produce. Where net revenue is above zero, full cost recovery is feasible within two years. While hand-powered pumps incur a relatively small amount of debt, the 15-year costs of higher output water supplies could be amortised with a small community work commitment in grid-connected areas, and with a larger, but still reasonable, community work investment for off-grid areas. The same scenarios described in Figure 1 are applied here, where each household is allowed 500 litres per day of domestic water. This comparison assumes that all excess water beyond that amount is used for drip irrigation of tomatoes over two seasons as part of a water-for-work approach as described by Abramson et al. (2011), who also describe the agronomic costs. A price of $1/kilogram and a maximum yield of 50 tons/hectare are assumed. The Hydrus® 1-D Soil-Plant modelling software was used to model transpiration under eight millimetres of PET, groundwater salinity of 0.5 deciSiemens per metre (dS / m), and a growing season of 120 days (Hydrus). The relative yield to relative transpiration relationship for tomatoes was taken from Ben-Gal, et al., and used to determine actual tomato yield (2003). Weekly work requirements for drip irrigation are taken from Woltering et al. (2011).

Under the alternative policy of incorporating water-based revenue, optimal technology outcomes and pumping schemes are drastically changed. Because hand pumps are the lowest yielding alternative and inhibit significant productive use, they provide no return on investment. Grid-powered motorised pumps provide significant net revenue, while the costs of solar- and diesel-powered improvements could both be recovered fully under alternative pump outputs. For context, even these expanded outputs require labour commitments less than what has been stated and revealed from a recent field study in rural Zambia, suggesting that demand for such a program would be sufficiently high (Abramson 2012).

These results suggest that in seeking to minimise costs of rural water improvements, a strategic opportunity for rural community development is being overlooked. Certainly, other models may exist for expanding water service provision. Microfinance, for instance, is already being implemented in the rural water sector, and may provide a suitable platform for scaling this policy shift.

Adam Abramson received his PhD from the Blaustein Institutes for Desert Research, Zuckerberg Institute for Water Research, Ben Gurion University of the Negev. His doctoral research focused on financing rural water improvements and resulted in his thesis 'Decision support system (DSS) for assessing the feasibility of cost recovery of rural water improvements in Africa'. This article is based on his work in developing a DSS, and his field experience in rural Zambia. He thanks the Grace & Hope Charitable Trust, United States for support for this research. He can be contacted at dr.adam.abramson@gmail.com and his website is www.outoftheground.org.

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6. Improving West African rice production with agricultural water management strategies

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The populations of West African countries continue to grow at rates exceeding three per cent per year. The international food price spike of 2008 focused attention on the risks to national security and livelihoods associated with importing significant quantities of food; and government and donor investment strategies now focus on ensuring national food security. Since rice is a key staple crop in the region, increasing rice production in a profitable way is critical to food security and sustained economic growth.

Over the last 20 years, increases in rice production have generally been obtained by putting more land under cultivation. As pressure on land intensifies, however, the results are a dramatic decline in soil fertility, increasingly degraded natural resources and increasing conflicts over land use. In this context and as observed worldwide, water-management interventions are key to the intensification of rice production. The importance of irrigation or water control in enabling a 'green revolution' has been underlined in many continental, regional and national strategic policy documents.

Diverse typologies of rice-irrigation systems exist in West Africa, which can be categorised into two broad classes: conventional systems and emerging systems. The conventional systems are mainly initiated and developed by governments and nongovernmental organisations (NGOs), or are developed by communities or individuals over a number of years. Conventional systems include public surface irrigation systems and small reservoirs. The emerging systems are those irrigation systems initiated and developed by private entrepreneurs and farmers, either autonomously or with little support from the government and/or NGOs. The emerging systems include river/stream lifting or pumping-based irrigation systems, public/private partnership-based systems, lowland/inland valley rice water capture systems, and private small-reservoir systems.

In order to understand the impact of alternative water-management options and policy interventions on the profitability of rice production, this study analysed farm household data from three donor-funded project surveys in three West African countries.[1] The data was collected in two sites in Ghana, one in Burkina Faso and one in Niger; and looked at detailed rice-production budgets of small-scale farmers. The farmers interviewed were classified into three water management systems: irrigation (public scheme), supplemented rain-fed (rainfall aided by autonomously sourced water supplies) and purely rain fed (Katic et al. 2013).

Once the surveys were completed, the results were collected and analysed with a policy analysis matrix (PAM)[2] in order to answer three key questions:

1. What is the impact of water management interventions on rice farmers' income?
2. Is local irrigated rice price competitive against imported rice without additional public policy interventions?
3. What are the major determinants of local rice profitability in West Africa?

Impact of water management interventions on rice farmers' income

The analysis revealed that water-management interventions may or may not increase rice farmers' income in the sites studied. Our result is in contrast to previous studies that have found (under different assumptions on labour costs and local prices) that rice production always breaks even, or earns positive profits in the region (Coronel and Lançon 2008; Seini 2002; Seini and Asante 1998).

On one hand, water management raises rice revenues by increasing yields. On the other hand, these farming systems require a higher amount of labour per unit of land, increasing production costs. While in the Ghanaian sites, the cost of implementing water management (both supplemented rain-fed and irrigated systems) outweighs modest increases in rice yields valued at low prices; in Burkina Faso, lower wage rates and a higher price for local rice mean that the value of greater yields is more than sufficient to cover the costs of irrigation.

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1 'Lowland paddy fields development/Disseminating lowland rice cultivation in inland valleys in West Africa' and 'Assessing the impact of Sawah development on rice farmers in the Ashanti region, Ghana' both funded by the Government of Japan, Ministry of Foreign Affairs; and WAIPRO (West African Irrigation Project) funded by USAID.

2 A PAM is an analytical framework that is frequently used to advise agricultural policy in the context of comparative advantage and private competitiveness. It consists of a two-way accounting matrix measuring revenues, costs and the derived profits at private (actual) and social (efficiency) prices.

Comparative advantage of local rice production

The data revealed that internationally traded rice varieties are higher quality than locally produced rice. Thus, with or without pricing policies, local rice cannot compete with imported rice on price because they are different products.

The main public policy in place in the region that affects the profitability of local rice production is an import tariff that inflates the price of competing Asian rice varieties. Although imported rice is more expensive than local rice, even if no tariff were imposed, most local consumers still buy it due to its non-price attributes (absence of stone, less broken rice, uniformity and appearance). Even the lowest quality imported rice (Thai 25 per cent broken) is still better than the rice produced in all study areas.

The price gap between imported and local rice confirms that the two categories of product are not considered as substitutes by consumers. Thus, there are two different markets and the popular import tariffs have a weak additional demand impact on the market for local rice. Just because local rice is cheaper, it does not mean it is more competitive because the two products are not directly substitutable. This result suggests that there is a huge opportunity for the local industry to upgrade rice quality via effective policies/investments. This opportunity is greater for irrigated rice farms because the higher yields realised imply that the quality upgrade is applied to a greater production level.

Determinants of local rice profitability

The analysis revealed that the major factors influencing rice profitability in West Africa are labour costs, world rice prices and local rice quality. In addition, exogenous or policy-induced changes in these factors have a greater impact on rice produced under some form of water management.

Labour costs

Results suggest that profits are sensitive to labour costs. The analysed sites comprised small-scale farms where most labour is family based, whose opportunity cost is likely to be lower than the market wage. Rice production becomes a profitable venture when labour is valued at a rate lower than two-thirds of the market wage (or the quantity of labour employed falls below two-thirds of its original value). When comparing rain-fed fields with those under some form of water management, profits are more responsive to labour costs in the latter, simply because these systems are currently more labour intensive. Thus, efforts to increase the mechanisation levels of rice production systems in the region are especially needed to reduce the intensity of on-farm labour use in irrigated farms and boost yields even further by diminishing harvesting and post-harvesting losses.

World prices

Sensitivity results reveal that large variations in world rice prices would substantially impact the local rice industry. A fall in the price of the higher quality international varieties would reduce demand for local production and, in turn, reduce the price local farmers receive. In fact, if prices fell to pre-2008 levels and technology was unchanged, rice production throughout the whole region would become unprofitable for farmers. What is more interesting, even if local rice is upgraded to a 25-per-cent-broken quality equivalent, it will be less costly to rely on imported rice than to produce it internally. In this case, however, irrigated systems would be much more resilient to the competition of cheaper imported rice than rain-fed production because they attain higher yields.

Rice quality

The data reveals rice quality is as key to farm profitability as yields. The low quality of rice obtained after milling is explained by a combination of factors that include poor seed variety, lack of soil and water management, low input use, inappropriate farming, harvesting and post-harvesting techniques, and milling technology. The study results show that there is potential to raise private profits with quality improvements (profits would be over US$400/hectare if local rice is upgraded to a 25-per-cent-broken quality equivalent). In particular, irrigated systems benefit more from rice-quality upgrades because the effect on profits is complemented with greater yields. As a result, policies to improve both physical and quality loss should be complementary to reap the greatest potential from this use of land.

Policy implications

Overall, the results suggest that while trade policies are not effective in boosting local rice production in West Africa, investment policies, such as irrigation developments, have potential to raise the returns to rice producers. The results also suggest that to simultaneously enhance farm incomes, contribute to national economic growth and increase food security, water management must be complemented with further farm interventions to reduce quantity and quality losses.

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7. An assessment of the replacement of traditional irrigation systems by private wells in Tamil Nadu, India

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In developing Asian countries, a major recent change in irrigation management is the rapid spread of private pumps and wells (modern irrigation systems). This process was accelerated by the introduction of the hydraulic drilling method in the 1980s and further by the development of the pump industry in China and India in the 1990s. The spread of modern systems is associated with the decline in traditional, communally managed irrigation systems.

An example of this trend can be found in Tamil Nadu, India. Traditional irrigation systems in this region are tank systems, which consist of a water storage area, sluices, and water supply channels. The water storage area is a small reservoir constructed across the slope of a valley to catch and store water. Water is controlled by the sluices, which are attached to the tank bank and is delivered to paddy fields through channels. This communal infrastructure has been collectively managed by informal local bodies. Although tank systems were the dominant source of irrigation until the early 1960s, in the last three decades a massive diffusion of private wells and pumps has occurred throughout India, including Tamil Nadu (Figure 1).

The dissemination of private wells provides more freedom for users to control irrigation water, in terms of the timing and amount of water delivered to their own fields, compared with collectively maintained tank systems and, thus, those who have access to wells can increase their yield and income (Palanisami 2000). This process has, however, been associated with the degradation of traditional tank systems as there are now less users to maintain them, which could negatively affect the agricultural production of remaining tank users. State statistics have aggregated these positive and negative effects of private wells, and show a net increase in the average yield of rice, a staple crop in the area, and an increase in the average income of farmers (Government of Tamil Nadu).

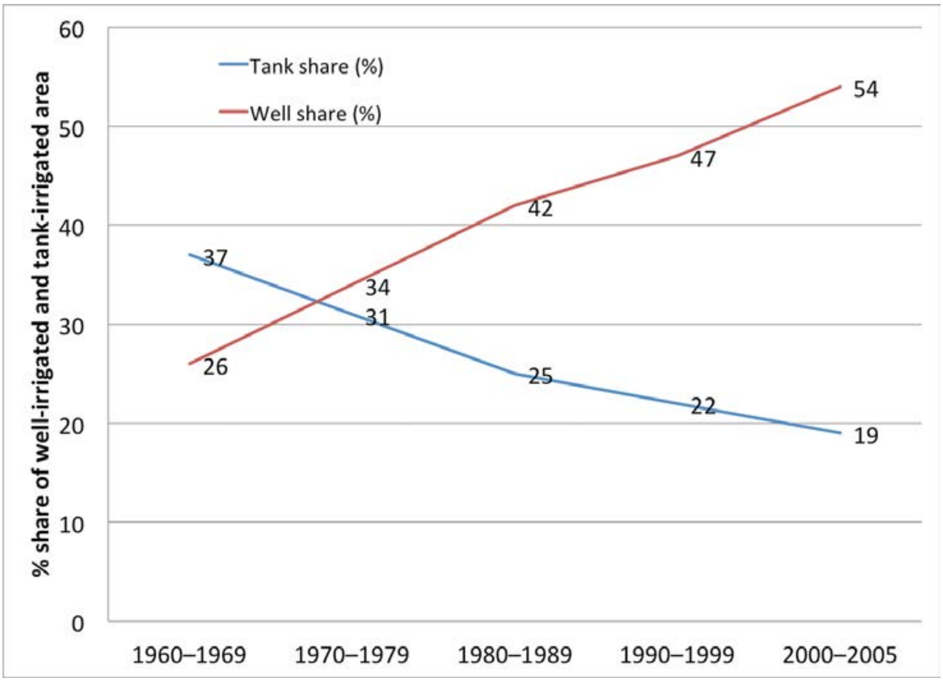

Figure 1: Percentage share of well-irrigated and tank-irrigated area in total irrigated area in Tamil Nadu from 1960 to 2005

Source: Author's research.

Double tragedy among tank users and well users

A closer look at the original data, however, suggests that the recent change to irrigation systems in Tamil Nadu is associated with increased poverty among a particular group of farmers: the tank users in high well-density areas. In principle, water from communal tanks is available to all farmers in the system command area. On the other hand, access to irrigation water from private wells is limited to owners and to those who can purchase water from the owners. Thus, with the decline in tank systems, farmers who are dependent solely on tanks will be disadvantaged, while farmers who have recourse to private wells can achieve higher levels of income and crop yield. Since this negative impact is large enough and the compensation of yield loss through income diversification is difficult, farmers without access to wells tend to fall into poverty. Table 1 summarises the rice yield, household income per capita, head count poverty ratio, and rice profit by irrigation status classified by the condition of tank (deteriorated or maintained) and by the access to wells (access or no-access). The worst situation across all indicators is that of farmers using deteriorated tanks without access to wells (column 1 of Table 1).

Table 1: Comparison of rice yield, income, poverty ratio, and rice profit by irrigation status

Irrigation status	(1)	(2)	(3)	(4)
Condition of tank	Deteriorated	Maintained	Deteriorated	Maintained
Access to wells	No-access	No-access	Access	Access
Rice yield (t/ha)	3.2	3.6	4.4	4.1
Household Income per capita (Rs./month) [a]	262	309	561	589
Head count poverty ratio [b]	0.67	0.59	0.30	0.24
Rice profit (Rs./ha)	-929	4,801	1,897	5,619

Source: Author's research. (a) The value is converted into a per capita base using the adult equivalent of household members. (b) The international poverty line of US$1 per day, adjusted for purchasing power parity, has been used. Use of the national poverty line of Rs. 324 (equivalent to US$36.40 at PPP exchange rate) monthly per capita for 1993–94 does not change the qualitative results.

The story does not end here. Since groundwater is a typical example of a common resource, under open access private users do not take into account the existence of a negative externality that their use imposes on other users. Hence, the likely outcome is the overexploitation of groundwater beyond a socially optimal level and, in the medium- to long-term, more costly irrigation as wells have to pump from deeper below the surface. Eventually, well users become unable to earn as much profit on rice as they did previously due to the higher electricity and infrastructure costs of pumping water from a depleted aquifer. Table 1 shows that among the well users (columns 3 and 4), the profit with the deteriorated tank is much lower than the other case, provided that the deterioration occurs in the high well-density areas (Kajisa et al. 2007). A detailed regression analysis supports this story, which can be found in the original piece of research assessing the introduction of the new irrigation systems in Tamil Nadu that this paper has summarised (Kajisa 2012). In this way, the replacement of tanks by private wells results in a double tragedy: increased poverty among non-users of wells and potentially no long-term profit among well users.

Toward a win-win solution

We call the above-mentioned story a tragedy because no individual currently has an incentive to change their actions. With regard to the first tragedy, the negative effect on the farmers with no access to wells has been created by the decline in collective management of tanks. Since well users do not suffer as much as non-users from this decline, they have little incentive to correct it. The second tragedy, related to the groundwater table, is a typical example of the 'tragedy of the commons'. Since the root of the problem is a negative externality transferred by each individual well user onto other well users, no incentive for correction exists. Without policy interventions, the correction of this double tragedy is difficult.

My simulation has shown that the revitalisation of collective tank management could effectively reduce poverty. In addition, revitalisation could supplement groundwater aquifers through percolation and thus alleviate the problem of overexploitation. Reducing the number of electric pumps could also be effective to avoid overexploitation. The first option for this purpose should be the abolition of the policy of free electricity for agricultural use, which may be politically difficult. Another strategy could be to charge a progressive sales tax on higher horsepower pump sets and deeper drilling of bore wells in order to deter over-dissemination and over-deepening of well irrigation systems. The government could then use the revenues from electricity, or from a tax, for tank revitalisation projects. This transfer could be considered legitimate because well users would receive an indirect benefit from the revitalised tanks, in that water from them permeates to re-supply groundwater aquifers.

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8. Water markets in the Murray-Darling Basin

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Introduction

Efficiently allocating water across competing demands and allowing for its reallocation as circumstances change and environmental concerns gain higher priority are challenges faced around the world (United Nations 2011; World Water Assessment Programme 2012; Grafton et al. 2012a, 2012b). This chapter assesses the development and implementation of water markets in the Murray-Darling Basin (MDB), which involves five states and territories (Queensland, New South Wales, Victoria, South Australia and the Australian Capital Territory) and the federal Australian Government.

In recent research (Grafton et al. 2014), we addressed the development and current status of water markets in the MDB, described what provisions were made to secure environmental flows, and identified lessons learned.

Review of water market development

The creation of statutory rights for water first occurred in Victoria in 1886 and in New South Wales in 1888. Originally, it was envisioned that state governments would allocate water to meet explicit policy objectives (Martin 2005). Throughout the 1960s and 1970s, however, these water licences were altered to specify the amount of water that could be diverted. Eventually, water licences became shares in a consumptive pool. The bundle of rights incorporated in a water licence was eventually unbundled to the extent that we see today.

Water entitlements are an ongoing claim to a share of a water resource while a water allocation is the volume of water assigned to a particular entitlement in a specific water year.

Reforms in 1994 separated water rights from land ownership and unbundled access and delivery rights, allowing for more trading flexibility. While allocation trade began in response to the 1982–3 drought and entitlement trade was permitted on a state-by-state basis starting in the late 1980s and early 1990s, the 1994 reforms allowed trade to increase significantly (Grafton et al. 2012a, 2012b). Their implementation came at the same time that a cap was placed on total surface water abstraction in the southern part of the basin; this cap not only limited withdrawals but also preserved the reliability of existing water entitlements by ruling out new claims on water resources.

Reforms continued into the 2000s, albeit at a slower pace (Horne 2012). As water trading helped users cope with increasing scarcity, government agencies also took action to secure flows for the environment: A$500 million was provided in 2004 as part of the National Water Initiative, and droughts encouraged another A$3 billion investment for environmental flow purchases in 2007. Equally important, the 2007 reforms established a Murray-Darling Basin Authority, and barriers to trade (such as interstate trade restrictions) were mitigated in order to improve competition within water markets and provide better information to buyers and sellers (Connell and Grafton 2011; Horne 2012).

Status of water trading in the Murray-Darling Basin

The trade in both entitlements and allocations within the MDB today represents about 80 per cent of all such trade in Australia. Entitlement trading in the southern part of the MDB peaked in 2008–9 (National Water Commission 2011:106). The allocation market, in contrast, has grown steadily over the past five years and, on average, represents 30 per cent of the total annual water allocation (National Water Commission 2011:74).

Government purchases of entitlements beginning in 2008 have made up a significant portion of entitlement trading (see Figure 1). Although entitlements are separated into several classes of reliability (the lowest of which suffers more severe cutbacks in allocations than the higher), prices for entitlements of each class have been relatively stable because they reflect future expectations and are therefore not influenced by short-term variations. In contrast, the price of allocations has tracked closely supply shocks. Figure 2 captures the price spikes; the impacts of widespread drought in 2008–9 saw the highest average prices (over A$400/megalitres(ML)), while 2010–11, a relatively wet year, saw prices drop to A$20/ML (National Water Commission 2011:34).

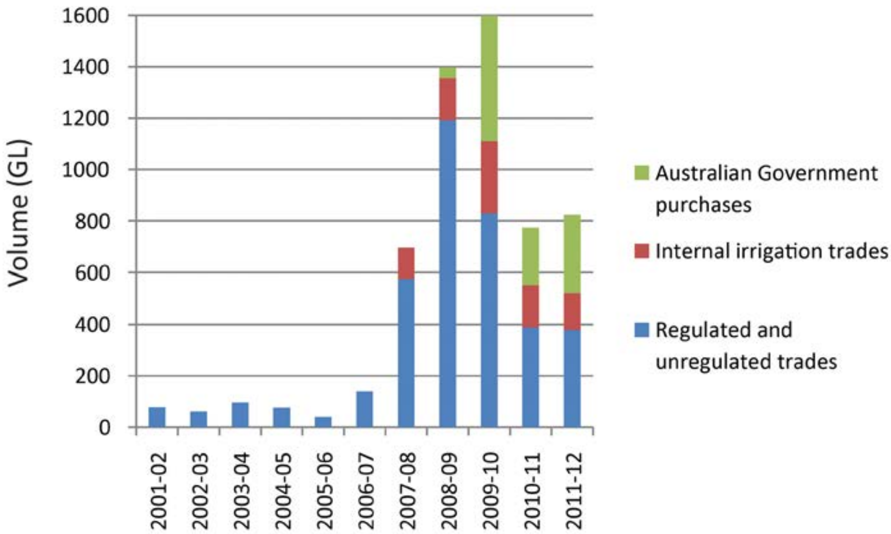

Figure 1: Water entitlement trade in the Southern Murrary-Darling Basin

Source: National Water Commission (2013).

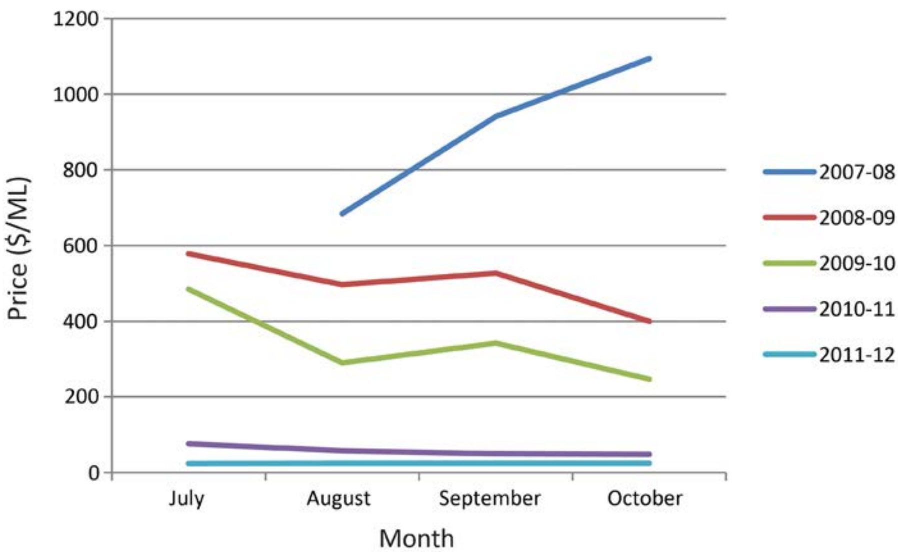

Figure 2: Average prices for water allocation trades in the Murray-Darling Basin ($/ML)

Source: National Water Commission (2013). July 2007-2008 figures not available.

One major trade barrier, termination charges levied by irrigation districts, was addressed in 2010. The Australian Competition and Consumer Commission imposed rules that prohibit districts from hindering the devolution of entitlements to individual members and their sale thereafter. As a result, individual irrigators can now sell entitlements outside of the irrigation district without paying an arbitrary termination fee. Concerns on the part of districts that entitlement trading would imperil their financial stability haven't materialised because entitlement sellers have chosen to maintain water delivery contracts for allocation purchases (Australian Competition and Consumer Commission 2013).

In addition, remaining trading restrictions are being eliminated or loosened. As an interim step, state water trading rules override the rules established as part of the Basin Plan (Minister for Sustainability, Environment, Water, Population and Communities 2012:122). The Basin Plan will take full force between 2014–19. Once that occurs, the unbundling of statutory rights will be complete and entitlement trades will no longer be restricted based on water volumes or the purpose of use; restrictions to protect the environment will be assessed when users apply for local use licenses. The states meanwhile continue to restrict water entitlement trading volumes. For example, the government of New South Wales has imposed a three per cent limit on water entitlement purchases for environmental purposes that would in practice preclude future government purchases and is incompatible with Basin Plan rules. We argue that the resolution to this conflict will showcase how much enforcement power the Basin Authority possesses.

Despite barriers, gains from trade across the basin have been substantial. One estimate indicates that reallocation of water rights has boosted the gross regional product of the southern part of the basin by A$370 million (National Water Commission 2010). Meanwhile, risks to towns and cities are mitigated because, in the event of drought or other supply shocks, they can purchase allocation water on the market.

The provision of timely and accurate market information is important to facilitate trading. For this reason, the national government is establishing, in cooperation with the states, a *National Water Market System* (2014) to convey this information to market participants. Its implementation has been slow and inconsistent, however: months to years have elapsed without critical updates being made to the information system.

Provisions for environmental flows

The cap on water extraction instituted in the 1990s was designed to limit adverse environmental impacts, but the timing and location of extraction could be altered by trading. Over the period from 1998–9 to 2007–8, some waterways within the basin experienced increased end-of-system flows as a result of trading, and these flows helped protect ecological assets during the prolonged Millenium Drought (National Water Commission 2010).

A distinction should be made between two types of environmental flows. 'Rules-based' flows are those that remain after all entitlement holders have extracted their allocations. Allocations vary based on hydrologic conditions and the interests of individual states, so these flows are not a fixed proportion of available water. These flows were reduced more severely than irrigation allocations during the Millenium Drought (Commonwealth Scientific and Industrial Research Organisation 2008:59). This was one factor that prompted the national government to invest in 'entitlement' flows, or flows derived from entitlements purchased by the government for the purpose of improving environmental outcomes. Using the funds mentioned above as part of the reform packages, the Australian Government has closed contracts for over ten per cent of total water entitlements in the basin at an approximate cost of A$2 billion (Department of Sustainability, Environment, Water, Population and Communities 2013). In addition, the government has funded water infrastructure projects designed to reduce water losses and subsequently direct the conserved water to the environment.

Lessons learned

Lessons learned can be summarised as follows:

- *Crisis can serve as a focusing event* — The severe droughts experienced in the basin prompted reform activity.
- *Markets strengthen regional resilience* — Trade-induced flexibility is improving outcomes for agricultural users, and entitlement portfolios for environmental flows are improving environmental outcomes.
- *Leadership is necessary in the political realm* — Basin-wide community support is indispensable, and political leadership is integral to implement market-based reforms.
- *Extraction caps are paramount* — Monitoring and enforcing surface water extraction caps strengthens water rights.
- *Water storage facilitates trading* — In addition to allowing downstream users to use allocation water on demand, water storage infrastructure extends the allocation trading season.
- *Timely and accurate information facilitates trading* — Participation can be encouraged by disseminating information on prices, which reduces uncertainty.
- *Statutory rights provide a flexibile framework* — Statutory rights allow for reform and reallocation without recourse to courts; one drawback is that

policy changes can alter the value of statutory rights, but these changes can be appropriately compensated.

- *Markets can secure environmental benefits* — While increased end-of-system flows depend on the direction of water trade, governments can always undertake water acquisition for the environment.
- *Water buybacks for the environment work* — Government purchases of water entitlements in the market have helped acquire water more cost-effectively than alternative subsidy schemes (Productivity Commssion 2010; Qureshi et al. 2008; Grafton and Hussey 2007).
- *Prices reflect scarcity and risk perceptions* — Allocation water prices have tracked supply shocks closely, and the disparity between the prices of different classes of entitlements reflects future expectations of water allocation to particular entitlements.
- *Inputs from local and basin-wide interests have different roles to play* — Local input is useful to develop site-specific environmental recovery plans, but it can hinder the development of basin-wide markets; regional markets may require support from higher levels of government to overcome local interests.
- *Monitoring and enforcement cannot be neglected* — The initial cap in 1995 didn't control extraction from groundwater aquifers and other diversions, and this resulted in an undesired shift toward unregulated water sources.

Conclusion

A long reform process has unbundled statutory water rights into access entitlements, rights to annual allocation volumes, tradable delivery shares and non-tradable water use licenses that regulate how water is used at certain locations. These changes have enabled a water market to emerge that has successfully reallocated water throughout the MDB. Meanwhile, entitlement acquisition largely by governments has secured significant additional environmental flows. The success of market-based platforms depends to a great extent on their design. Governments must work with all stakeholders to establish a fair and efficient system. Infrastructure systems play a critical role in regulating the supply side of the market, and accurate information on supply volumes and trading prices underpins the demand side. After two decades of improving the regulatory framework, markets have become an important element of water provision in the MDB. They are helping water users and governments manage trade-offs between water use and the environment, particularly in dry years.

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Part 3: Transboundary governance

9. Transboundary water governance

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The effective management of water across borders is central to overcoming the challenges of water scarcity. Transboundary management requires water managers to respond to outcomes that result from interactions beyond their borders. This can involve decisions on polluting activities positioned near downstream borders that have impacts experienced outside the jurisdiction, the consequences of a dam for cross-border flows, or how much water should be extracted for irrigation upstream.

To achieve the goal of better transboundary water management, governments need to understand the biophysical characteristics of water and the varying relationships that different people and interest groups have with it. The challenge for decision-makers is the uncertainty about the likely effects of policy choices when there are likely to be long-term benefits. Further, environmental systems are frequently subject to thresholds and cumulative impacts that result in significant loss when they occur, but which are hard to predict and difficult to reverse.

Role of national governments

National governments have a number of important and unique attributes. First, their capacity to make laws and enforce them. Second, their access to funds (including the capacity to tax), research and management. Third is the greater jurisdictional capacity to assess issues from a catchment-wide perspective (at least within their borders) and distribute costs and benefits between different stakeholders, particularly upstream and downstream. Finally, there is the potential for a higher degree of corporate consistency over the long term than is possible for most other institutions. To illustrate the issues of transboundary governance within a federal state we briefly review the history of water governance for the Colorado River.

The Colorado River

The role of the US federal government in the negotiation of the 1922 Colorado River Compact is a good example in coordination across multiple jurisdictions at the sub-national level. Bringing together the seven upper and lower Colorado Basin states, Hubert Hoover, the national government-appointed facilitator, brokered a water-sharing arrangement that has proved surprisingly resilient over the subsequent 90 years. One of the first products of the new compact (a voluntary agreement made under the implied threat of an externally imposed solution) was the Hoover Dam funded by the federal government and completed in 1935. The capacity of the dam to provide hydropower and regulate river flows has underpinned the development of the south-west of the United States since the 1930s.

The central government of the United States (defined in its wider sense so as to include national institutions, such as the Supreme Court) has subsequently shaped development in the region by funding strategic projects, such as the Central Arizona Project; influencing water-management plans through legislative requirements, such as the 1973 *Endangered Species Act*; and arbitrating disputes between the Colorado Basin states. More recently, using an approach that hints at how its role could evolve to deal with the predicted disruptive impacts of climate change, the central government pressured the lower Colorado states to negotiate between themselves an exceptional circumstances drought-management plan to share water that would protect key assets, such as the major cities. The four states acted in response to the threat by the national government that if they did not come to an agreement it would impose its own water sharing plans on them.

International transboundary water governance

National governments have significant coercive power to set water policy across sub-national jurisdictions. In theory, replicating the same structure at the next level up, international transboundary water governance, would require some form of international government with executive power to force negotiations and resolutions, as in the case of the Colordao River. But the collection of institutions that most nearly resembles an 'international government' is the United Nations (UN) and its various agencies. The UN is, by and large, a consensus-based organisation that is ill-equipped to solve contentious trade-offs. The sovereignty of nation states is a key principle of the UN and, in practice, the General Assembly and other UN bodies are not vested with the power to make or enforce decisions on how particular countries use transboundary waters.

In the absence of an overarching authority to further the collective interest by enforcing rules, making investments and distributing costs and benefits, a wide range of actors exert influence in the international sphere, such as the World Bank; powerful nongovernmental organisations, such as the World Wide Fund for Nature; large commercial companies; and, various UN agencies.

National governments are the foundation upon which international society is built and agreement on transboundary waters unavoidably requires agreement by sovereign governments. Nevertheless, the power and authority of national governments is circumscribed by multiple interests and other layers of government. Consequently, compared to the sub-national level governments, there is a more heterogeneous arrangement of frameworks within which national governments pursue their individual and collective interests related to transboundary waters. This chapter demonstrates the complex nature of these frameworks and provides examples of their components through five sections covering a range of different issues.

Overview of chapters

In this section Warner, Zeitoun and Mirumachi (Chapter 10) discuss the power dynamics underlying transboundary governance between nation-states. They argue that transboundary relations are typified by a mixture of cooperation and conflict. In contrast to common preoccupations concerning military and economic instruments of 'hard power' to resolve water disputes, they demonstrate the importance of nonviolent, co-optative instruments of 'soft power', from side payments and bribery to persuasion and inciting desire to emulating success. The long-held disagreement between Egypt and Ethiopia over the latter's plans to dam the upper Nile provides a demonstratation of these points, as well as the fact that, no matter how hegemonic or dominant a state, its hard and soft power are ultimately fluid.

A well-established means of achieving cooperation between nation states is the adoption of shared legal frameworks or agreements. Treaties, for example, may stipulate the rights and obligations of signatories in the joint management process and, importantly, place restrictions on actions that may harm other signatories. International water law advanced significantly during the twenty-first century and, although a proposed universal treaty (the 1997 Convention on the Law of Non-Navigational Uses of International Watercourses) has received insufficient support to come into force, there is a large and increasing number of legal agreements between states. In this chapter Gerlak, Lautze, and Giordano (Chapter 11) analyse an important aspect of such agreements: the sharing of data and information concerning the state of shared water resources. They find that states are engaging in greater data and information exchange, but uncover a reluctance on the part of many states to legalise formal schedules for exchange.

Another prominent method for governing international water resources, and one that can be a product of formal legal agreements, is river basin organisations (RBOs). These multilateral organisations provide a framework for states to make decisions, resolve disputes, share information and generate knowledge. In this chapter, Schmeier (Chapter 12) observes that success varies greatly between different RBOs and suggests that differences in institutional design and, in particular, the organisational set-up and water-governance mechanisms an RBO provides, can contribute to its success. Understanding which characteristics work, and in what context, sheds important light on how to achieve improved cooperation and collective outcomes in the reform of existing RBOs and design of new ones.

The legal and geopolitical context prompting states to sign an international transboundary water agreement is the subject of Villar and Ribeiro's (Chapter 13) contribution to this section. Notably, cooperation was achieved in the authors' example without prior conflict. The authors show how the process leading to the 2010 Agreement on the Guarani Aquifer, encompassing Argentina, Brazil, Paraguay and Uruguay, began with scientists recognising the shared nature of the aquifer and the need for its joint management and was supported by multilateral institutions, such as the World Bank. The essay is a valuable survey of the key passages in the agreement text, particularly those relevant to the main principles of the UN Law of Transboundary Aquifers: sovereignty, the equitable and reasonable use of water resources, the obligation not to cause harm, cooperation and the exchange of data and information.

The final chapter in this section is a case study in potential conflict. Wirsing (Chapter 14) details the plans of China and India to exploit the Brahmaputra River for hydropower and water diversions for agriculture and other uses. The author views the lack of existing agreements with concern, arguing that, even if water is not the issue at the centre of these emerging powers' difficult relationship, their respective water insecurity means that disputes over exploitation of the Brahmaputra could have much wider impacts.

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10. How 'soft' power shapes transboundary water interaction

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With monotonous regularity since the late 1980s nongovernmental organisations (NGOs), politicians or think tanks have predicted a water war. Recently, a UK minister predicted war in the coming decades (Harvey 2012). No such thing has happened, though, and prominent water scholars have argued a war fought strictly over water is unlikely in the future (Wolf 1996; Allan 2001).

That does not mean there is peace and harmony among co-riparians. Power differences and latent conflicts persist, usually under the radar of the basin hegemon (or dominant power), but in full view of those who live their effects. The state of affairs in many transboundary basins can be characterised as a mix of cooperation and conflict (Mirumachi and Allan 2007), with those benefitting from the status quo emphasising the former. Our first article on the subject called this the 'ugly' side of cooperation (Zeitoun and Mirumachi 2008).

A clue to understanding this situation, we argue in its sequel (Zeitoun et al. 2011), is to look at what lies beneath: how power is exercised. The 'water wars' discourse has simplistically focused on the exercise of hard power, predominantly violence and coercion. Both philosophical reasoning (Hannah Arendt) and empirically grounded hydropolitical work (Dinar 2009) has shown, however, that rule based on fear and brute power has little hope in the long term. Some kind of legitimacy and consent is needed to perpetuate any skewed transboundary water arrangement based on unequal power relations.

Empirically, we find relations between riparians to be governed by a wider spectrum of power instruments, from side payments and bribery to persuasion and inciting desire to emulating success. This wide range of nonviolent, co-optative power manifestations is collectively known as 'soft' power: getting others to want what you want. Nye (1990) sought to explain how relations can be peaceful through the power of attraction without the need for a threat of violence. We find, however, that soft power not only contains the positive power of attraction, but also its negative, repellence away from certain agendas and issues, and towards maintenance of a biased status quo.

Nye was reiterating Machiavelli's understanding of power as a centaur, half man (arguably rational), half horse (based on strength). He was far more optimistic than Machiavelli about human progress towards eternal peace, buttressed by freedom and trade. Fragmented evidence to support this hope exists in transboundary water contexts; many treaties never really came off the ground, and even in highly integrated Europe, diplomatic crises over water are not unheard of (Warner and van Buuren 2009).

A soft power perspective may not yet be sophisticated enough to explain power relations between riparians. Our analytical framework of 'hydro-hegemony' (Zeitoun and Warner 2006) highlights how conflict, even if it is not open and visible, can be structurally present between riparians (and groundwater users from transboundary aquifers). In an integrated transboundary water configuration, interests between dominant and subordinate are harmonious; in a distributed power configuration, they are fundamentally at odds. Cooperation by the non-hegemonic actor, or its compliance with certain states of affairs, does not necessarily mean consensus. Successful framing by the stronger party of the common good (soft power), however, can result in power differences going uncontested and countries signing treaties that bring highly differential benefits. Unqualified calls for and claims to transboundary cooperation 'of any sort, no matter how slight' (UNDP 2006) are therefore as wrongheaded as are alarms over water wars. Policy and programs promoting unqualified 'cooperation' were criticised on the grounds that negative forms of cooperation need reform or resolution, not management or encouragement.

The 'hydro-hegemony' framework is indebted to the Gramscian concept of hegemony as ingrained in material and ideational structures pervading social systems (Selby 2005; Davidson-Harden et al. 2007). River negotiations are multi-level power games (Warner 2008) in which state representatives are the lynchpin. Representatives of hydro-hegemons can deny there being conflict and appear magnanimous, while knowing full well that the odds are stacked in their favour. State representatives may frame their water interest in non-contestable security terms (Buzan et al. 1998). Whether picked up, amplified and given material support, or purposely backgrounded, such discursive framing of issues matters.

A useful example is that of Egypt's long claim of a veto on any upstream 'arrest' of Nile waters for consumptive use, through irrigation reservoirs, distribution systems and the like. Underpinned by one of the largest armies in the region, the national government has previously declared upstream dam-building to be a *casus belli* (a legitimate reason to start a war) should it lead to lower inflow into Egypt (Warner et al. 2012). It could be argued that this threat has prevented Ethiopia, the Blue Nile upstream power, from building dams in the past; alternatively there is also the material reality that the country could hardly fund and realise its own dam infrastructure. This penury is worsened by the stipulation of (once) key multilateral funders that they will not fund transboundary projects lacking the endorsement of all riparian sates. The balance of power in favour of Egypt relies on the moral and material support of the United States, to which it is one of the biggest allies in the region.

But it's not all about hard power. After Gamel Abdel Nasser's 1952 revolution, the nationalisation of the Suez Canal and the building of the Aswan Dam, Egypt became a respected southern leader. The government organised or condoned several cooperative, technical and political water fora about the river Nile (UNDUGU, TECCONILE, Nile 2002) on the unstated premise that these bodies would not tamper with Egypt's self-ascribed water rights, laid down in treaties agreed with Sudan, but none of the other Nile riparians, in 1929 and 1959. The government of Anwar Sadat signed a Camp David treaty with Israel, which anointed the country as a 'peacemaker' in the eyes of influential superpowers, and the country has seen prominent nationals (Boutros Boutros-Ghali, Mahmoud Abu-Zeid) ascend to leadership positions in multilateral institutions, bestowing upon Egypt an aura of authority and legitimacy in the United Nations (UN) world order. In everyday interaction, upstream states have for decades refrained from taking action against Egypt's interest without prodding.

A recent shift in the Nilotic water-sharing status quo over the past (half-) decade, however, seems to reflect a shift in the hegemonic power balance. Egypt is arguably not as important to American interests as it used to be, while its upstream neighbours do not appear to be as intimidated by Egypt as they once were. Opposition to Egypt's unilateral hegemony have been voiced by Tanzania and Uganda since the 1960s. It was not until 2010 that the upstream states signed their own agreement without Egypt (Nicol and Cascao 2011).

External direct investment, especially from China and the Gulf states, has dramatically improved the bargaining and economic position of upstream countries. China has used its own soft power through the provision of investment to these countries: buying oil in Sudan, supporting the giant Grand Ethiopian Renaissance (Millennium) Dam, and investing in land in several Nile states. China's non-interference in political relations and the persuasive example of its own economic success raises goodwill. Moreover, Egypt's relative international standing as an 'example' has also seen a slide, following allegations of human-rights violations, alienation from Israel, and failing megaprojects under Hosni Mubarak.

Nile politics telescoped in 2011. While Egypt was enmeshed in its February revolution, South Sudan gained independence and Ethiopia inaugurated its big dam. Ethiopia's 6000 megawatt hydropower dam, with an estimated cost of US$4.5 billion, is largely self-funded from bonds and taxes. Two Egyptian governments have since protested loudly, first using the language of casus belli, then calling for negotiation and finally, in 2013, proposing joint funding. As the dam is located only 20 kilometres from the Ethio-Sudanese border, a dam collapse would flood the Sudanese capital of Khartoum. Overall, however, Sudan stands to benefit from the dam in terms of better flood regulation, irrigation and a nearby source of hydropower, and would gain from approximation to Ethiopia. Sudan, however, has so far sided with Egypt in its refusal to sign the Nile treaty, at least officially, suggesting Egypt's soft power is still palpable if dwindling (Hamzawy 2010). Egypt currently has little realistic alternative to joining the new arena of Nile negotiations and no longer holds de-facto veto power over major upstream projects like Ethiopia's dam.

Power dynamics, such as those noted in the above example, show that no matter how hegemonic or even dominant a state, its hard and soft power are ultimately fluid. Examination of the soft-power subtext helps us understand what's going on in basins around the world. Similar analyses are not only applicable to the familiarly contentious Euphrates/Tigris, Jordan, Ganges, Brahmaputra and Colorado basins, but also to seemingly peaceful European transboundary streams such as the Rhine and Scheldt (Zeitoun and Warner 2006, Warner and van Buuren 2009). The incorporation of soft power into the analysis of conflicts in hegemonic contexts provides insight into the choices riparian states (can) make or avoid in their transboundary water interaction; and into how negotiations and treaties can lead towards conflict management but not necessarily to conflict resolution.

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11. Greater exchange, greater ambiguity: Water resources data and information exchange in transboundary water treaties

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Effective management of the world's water resources is considered to require access to credible and reliable data and information regarding the state of the resource, and how it is affected by water use and development, land use practices and climate change (Bernauer and Kalbhenn 2010; Rogers and Hall 2003; Timmerman and Langaas 2005; Wolf 2007; United Nations Educational, Scientific and Cultural Organization (UNESCO) 2009).

Water resources data and information exchange is a key principle of the growing global normative framework for transboundary waters that shapes international law (Conca et al. 2006). Data and information exchange is an important design principle associated with the effectiveness of institutionalised cooperation (Zawahri 2008; Stinnett and Tir 2009). Joint water resources data and information gathering can alleviate disputes over data and prevent broader conflict (Bernauer and Kalbhenn 2010). Increasingly, using data and information to understand complex problems is seen as a key component of the successful governance of common pool resources and adaptive management strategies (Dietz et al. 2003; Raadgever et al. 2008).

The issue of access to data and information on transboundary water resources, i.e. basins and aquifers that are shared by two or more states, is particularly important given the potential for conflict. Despite international calls for data and information exchange in transboundary waters and for exchange of basin-specific evidence to support cooperative management, no systematic research has been undertaken to understand where, how frequently, or what water resources data and information are exchanged.

Table 1: Select examples of water resources data and information exchange

Hydrologic data	1928 Convention between the German Reich and the Lithuanian Republic regarding the maintenance and administration of the frontier waterways, which states in article 10: ''The ordinary water-gauge observations at the usual observation posts shall be exchanged monthly immediately on receipt of the water-gauge lists''
Hydrologic information	1972 Agreement relating to the establishment of a Canada-United States committee on water quality in the St. John River and its tributary rivers and streams that cross the Canada-United States boundary in article 1 that the committee should ''exchange appropriate information about plans, programs, and actions which could affect water quality in the Basin''
Research, investigations, and assessments	1957 Agreement between Iran and the Soviet Union for the joint utilization of the frontier parts of the rivers Aras and Atrak for irrigation and power generation, which states that ''both parties hereto agree jointly to carry out exploration of the rivers Aras and Atrak all along the border common to the USSR and Iran and accumulate technical data related to their respective flows. They also agree to carry out necessary outdoor and indoor studies for the preparation of preliminary plans for irrigation and power generation from the strait of Ghis Ghalasi up to the end of the frontier of the river Aras and all frontier parts of the Atrak River''
Unspecified type as general reports	2004 Agreement on the Establishment of the Zambezi Watercourse Commission, which includes provision to ''collect, evaluate and disseminate all data and information on the Zambezi Watercourse as may be necessary for the implementation of this Agreement''
Prior notification	1994 OKACOM agreement on the Okavango basin in southern Africa. Article 1 addresses prior notification, calling for signatories to ''notify the Commission of any proposed development or other matter which falls within the function of the Commission''
Formalized communication	1994 OKACOM agreement on the Okavango basin in southern Africa. The agreement establishes ''a commission which will have formal meetings for sharing information and concern''

Source: Authors' research.

In a recent piece of research (Gerlak et al. 2011), we examined the content of all known and available transboundary water treaties signed between 1900 and 2007 in order to formally assess the sanctioned exchange of data and information in transboundary water settings.

For the purposes of the study, data are defined as 'hard' numbers relating to water resources, such as rates of river flow and levels of water quality. Information is defined more broadly as general qualitative information, such as communication that a flood is impending or other conclusions reached from the analysis of hard data. A third type of data and information exchange includes provisions to conduct joint research, investigations and assessments that include, or could be inferred to include, some aspects of data and information exchange.

In addition to these direct mechanisms for data and information exchange, we also examined more indirect mechanisms including prior notification provisions and formalised communication. Prior notification refers to treaty provisions for prior consultation, notification or consent of planned measures related to water. Formalised communication refers to provisions for joint management institutions, regular political consultations, consultations as conflict resolution measures and arbitration. Table 1 provides some examples of water resources data and information exchange identified in the study.

Table 2: Indirect and direct data and information exchange mechanisms (N = 287)

Direct water resources data and information exchange		37% (106)
Indirect water resources data and information exchange	Prior Notification	87% (248)
	Formalized Communication	90% (259)

Source: Adapted from Gerlak et al. 2011. N = number of total treaties investigated. Treaties may include more than one type of information exchange mechanism.

In cases where the exchange of hard data could not be specifically identified, agreements were classified as exchanging only information. As such, records of information exchange in the study may contain exchanges of data where data is not explicitly mentioned in the treaty. The frequency with which data and information are exchanged is divided into one of four categories: (a) regular, (b) event triggered, (c) on demand, or (d) unclear.

The findings of our research suggest that, while complete data and information exchange does not occur globally, most transboundary water treaties have some mechanism for exchanging water resources data or information. Interestingly, however, despite the importance of data and information exchange for transboundary water resources, the results also suggest that states continue to largely rely on indirect mechanisms to share and exchange data, including prior notification and formalised communication. As Table 2 indicates, for example, only 37 per cent, or 106 of the 287 treaties investigated include direct data and information exchange mechanisms.

Looking at how treaties have changed over time, we find that the use of direct mechanisms for exchange has increased from less than 20 per cent in the pre-World War II period to more than 50 per cent in the post-Cold War era. The most notable increases in the use of direct exchange mechanisms occurred during the 1930s to 1940s, and a consistent increase in their use was observed from the 1970s through to the present (Figure 1).

The latter of these two trends might suggest that the 1966 Helsinki Rules on the Uses of the Waters of International Rivers and 1997 UN Convention on the Law of Non-Navigational Uses of International Watercourses may play a role in influencing basin-level exchange.

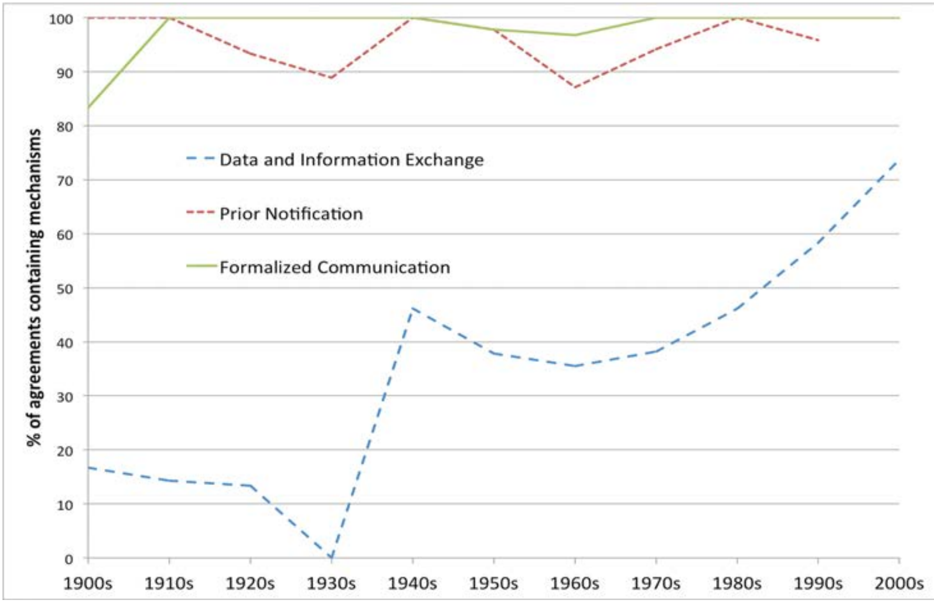

Figure 1: Direct and indirect mechanisms for water resources data and information exchange by decade (per cent of agreements)

Source: Adapted from Gerlak et al. 2011.

Looking at the different types and functions of transboundary water treaties, the results suggest that data and information exchange in procedural and generative treaties have seen the greatest rise. Procedural agreements are those that provide frameworks for regular, collective decision-making (e.g., joint water management committees) while generative agreements develop new social practices (e.g., establishing principles, such as 'no significant harm'). As such, we find that water resources data and information exchange is correlated with changes in the goals and nature of treaties themselves.

In addition, we observe exchanges occurring in all geographic regions of the world. While, however, exchange in transboundary settings is not unique to democracies, the results suggest that democracies have a greater frequency of exchange than autocracies or other types of regime. This suggests that common values do help to reduce transaction costs in seeking solutions to collective action problems (Agrawal 2002), and that democracies, which may be more attentive to demands from constituents for cooperation and transparency, are therefore more likely to agree to share information in the first place (Shanks et al. 1996).

Overall, our research suggests a convergence towards inclusion of water resources data and information exchange as a key component of water treaties. This movement towards a more formal, direct exchange of data and information represents a key principle of an emerging governing framework for shared river basins (Conca et al. 2006).

Table 3: Frequency of direct water resources data and information exchange

Frequency	Percent of frequencies of exchange (N = 111)
Regular exchange	29% (32)
Event-triggered	9% (10)
On request, as needed	16% (18)
Unclear	46% (51)

Source: Adapted from Gerlak et al. 2011.

While, however, we observe a growing trend for data and information exchange, we also find that only 29 per cent of agreements call for regular exchange of data or information; that is, with particular intervals defined, such as every six months or annually (Table 3). It appears, therefore, that states prefer unclear, event-triggered, and on-request exchange mechanisms to regular data exchange. This suggests a reluctance on the part of many states to formally legalise detailed schedules for exchange. Future research could therefore investigate the underlying causes or reasons for this hesitation around regular exchange and its implications for transboundary water management.

In conclusion, while our research suggests that states are increasingly engaging in data and information exchange in transboundary water agreements, we have uncovered a reluctance on the part of many states to legalise formal schedules for exchange. This ambiguity in terms of the frequency of exchange is consistent with earlier research on international water resources that suggests that states may intentionally design vague mechanisms related to data exchange in order to allow for greater flexibility in the face of resource uncertainty, or to serve domestic political purposes (Fischendler 2008). While it may have political benefits, this level of ambiguity may also trigger questions over the meaningfulness of irregular data and information exchange, and require closer examination from both academics and water policy decision-makers.

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12. Opening the black box of river basin organisations

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During the past decades, research on the governance of internationally shared river and lake basins provides ample evidence that cooperation can prevail over conflict (Wolf 2007; DeStefano et al. 2010). Scholars have also been able to provide comprehensive explanations for why and under which conditions agreements on shared watercourses are signed and river basin organisations (RBOs) emerge (Song and Whittington 2004; Dinar 2007).

The mere existence of RBOs does not, however, necessarily ensure that water-related problems in a shared basin will be solved, nor that the resources of the basin will be managed in a sustainable way. Instead, reality shows that some RBOs have been able to effectively govern their basin while others have failed, or have made limited contributions to the solution of water-related challenges.

In some river basins governed by RBOs, key problems of collective action have been addressed successfully. In the Danube and the Rhine river basins, for instance, the activities of the respective RBOs have significantly contributed to improving the water quality of the rivers. In other basins, however, challenges remain in spite of the existence of the RBO — such as in the Mekong River Basin, where the Mekong River Commission (MRC) is struggling to address conflicts over the use of the river and, in particular, the consequences of unilateral water use projects. And yet in other basins, the activities of an RBO might have addressed some water resources governance challenges, but also caused additional ones. A promiment example is the Senegal River Basin, where joint water resources development projects have been established in order to boost the economic development of the members of the Organisation pour la Mise en Valeur du Fleuve Sénégal (OMVS), but have led to unexpected environmental and social impacts.

While there are a number of potential explanations for such variation in the effectiveness of river basin governance, most often focusing on the nature of the basin itself as well as more general relations among riparian states (see, among others, Marty 2001; Hensel et al. 2006; Dinar 2009), I suggest that it might be the RBOs themselves that matter. That is, the way RBOs are designed and operate as institutionalised forms of cooperation can also be expected to have a major influence on water resources governance outcomes. Hence, it is time to open the black box of RBOs. Only understanding the design of RBOs and its effect on their capacity to respond to challenges of water resources governance will enable us to design institutions that will be able to effectively govern shared watercourses.

In order to understand the design of RBOs, and thus build a basis for the analysis of its influence on river basin governance, I propose to differentiate between two institutional design categories:

- the *organisational set-up of RBOs*, representing the RBO's infrastructure and consisting of its member states/its inclusiveness, its functional scope, its legal bases and water law commitments, its organisational bodies and the role of its secretariat or executive body as well as its financing sources, and
- the *water resources governance mechanisms* the RBO provides, including decision-making, information-sharing, monitoring or dispute-resolution mechanisms, as well as means for including non-state actors into its river basin governance activities.

Understanding the impact of RBO design on water resources governance requires, as a next step in analysis, a basic understanding of how existing RBOs encompass the aforementioned design characteristics. Since research on the design of RBOs is limited and rarely goes beyond comparative case studies, I have embarked upon establishing a baseline for the institutional design of all RBOs governing internationally shared watercourses (119 in total; see Schmeier 2013). This mapping exercise provides a comprehensive picture of institutionalised river basin governance.

Looking at the membership structure of RBOs — one of the most obvious institutional design features — reveals that the number of member states varies considerably across RBOs, ranging from bilateral RBOs, such as the International Boundary Commission between Canada and the United States, to RBOs with a large number of members — up to 14 in the case of the International Commission for the Protection of the Danube River, or 11 in the cases of the Niger Basin Authority and the Nile Basin Initiative respectively. Even more importantly, RBOs also vary with regard to their inclusiveness; that is, whether they include all riparian states to a basin or a subset of them only.

Similarly, RBOs vary with regard to their functional scope and the issues they cover. While water quantity and quality are the issues addressed most often by RBOs, other issues such as hydropower management, irrigation, or river-based tourism are less commonly tackled by RBOs. In addition to issue coverage, the baseline scoping exercise has also indicated that RBOs tend to adjust and often expand their functional scope in order to integrate into their work newly arising exogenous challenges, such as climate change. Several RBOs, including the International Lake Constance Conference, the International Commission for the Protection of the Rhine, and the MRC, have recently included climate change in their functional scope and initiated a number of related river basin governance activities.

For the second category of institutional design features, the river basin governance mechanisms of an RBO, the analysis has shown that dispute-resolution mechanisms vary considerably. While some RBOs lack pre-defined mechanisms for solving emerging disputes among their members, others rely on mechanisms that are outdated (such as the reference to the Commission of Mediation, Conciliation and Arbitration of the Organization of African Unity which ceased to exist after the replacement of the organization by the African Union), leaving few RBOs with readily available mechanisms for addressing disputes among their members.

As indicated by the aforementioned examples, the baseline analysis has shown that RBOs vary considerably in their design. Accordingly, we can expect that such design features will have an influence on whether and to what extent an RBO can govern a river basin sustainably and effectively.

The baseline analysis on the institutional design of RBOs provides an important starting point for future research that investigates the relationship between their design and their performance governing the river basin with which they have been entrusted — especially in light of exogenous conditions, which are often expected to determine whether and to what extent RBOs can be successful in river basin governance. Most importantly, such further research and the detailed investigation of how institutional design matters and which features are most likely to make a difference can also inform policy makers about how to reform existing RBOs and design newly emerging ones. Opening the black box of RBOs can thus contribute to sustainably governing internationally shared water resources — even under adverse exogenous conditions — by providing concrete advice for policy action and thus the pro-active governance of water resources in shared basins through institutionalised cooperation among riparian states.

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13. The agreement on the Guarani Aquifer: Cooperation without conflict

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The Guarani Aquifer System (GAS) is a transboundary aquifer that encompasses Argentina, Brazil, Paraguay and Uruguay (Figure 1). It covers an area of 1,100,000 square kilometres within the Paraná Sedimentary Basin. In August 2010, the four states signed the Agreement on the Guarani Aquifer, which is the first shared-management agreement for a transboundary aquifer in Latin America.

The agreement on the Guarani Aquifer is unique in many ways:

- it was the first signed under the influence of the United Nations General Assembly (UNGA) Resolution A/RES/63/124 (2008): the Law of Transboundary Acquifers
- there are no regional conflicts over the use of its waters because the aquifer has been the subject of cooperation initiatives since the 1990s
- a range of actors have participated in these initiatives, including regional academic research networks, governments, international organisations and private companies.

This paper analyses the legal and geopolitical context that prompted the signing of the agreement on the Guarani Aquifer and evaluates its potential for preventing future conflicts and deepening cooperation between states. The research used qualitative analyses of results from the GAS Project (IW-Learn 2013), Southern Common Market (MERCOSUR) documents (MERCOSUR 2001, 2004, 2009), international rules related to water resources (UN 1997, 2011), the agreement on the Guarani Aquifer (GAA 2010), and relevant literature (Eckstein and Eckstein 2003; Jarvis et al. 2005; Feitelson 2006; Zeitoun and Mirumachi 2008; Laborde 2010; Sindico 2010; McCaffrey 2011; Villar and Ribeiro 2011).

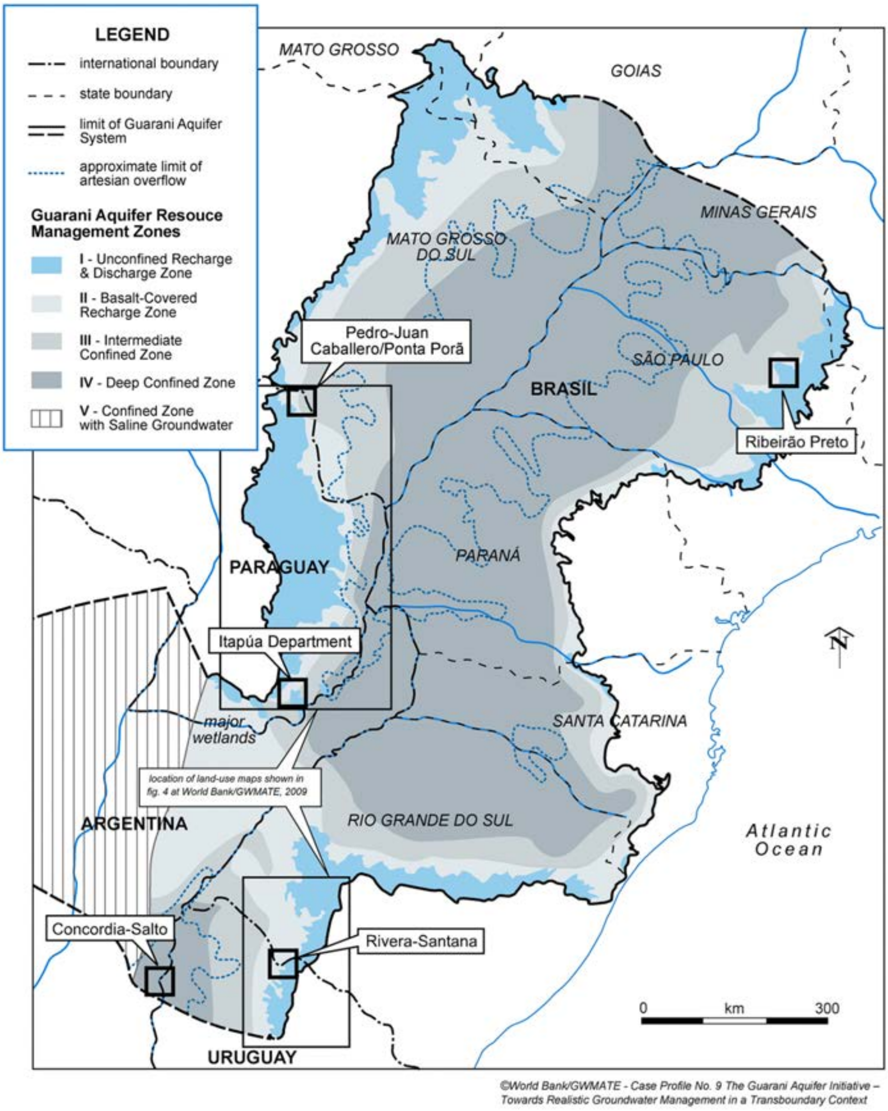

Figure 1: Guarani Aquifer

Source: World Bank/GWMATE.

The construction of the GAS cooperation process

Science played an important role in the cooperation process. The regional research community was responsible for recognising the transboundary character of the aquifer and the need to promote awareness regarding the matter. Indeed, academic researchers organised the first international meetings and projects concerning the aquifer. These efforts to gather funds for more ambitious projects attracted the involvement of national governments and a range of international organisations, such as the World Bank and the Organization of American States.

The alliance of these actors enabled the Environmental Protection and Sustainable Development of the GAS Project. This project was the most ambitious groundwater initiative in South America. The six-year project (2003–9) increased awareness of the GAS's characteristics and stimulated debate on groundwater management within the four countries at national, provincial, and community levels.

Parallel to the execution of this project, the MERCOSUR, included the Guarani Aquifer in its agenda. An Ad-Hoc High-Level Group was created in 2004 with the objective of drafting a shared aquifer-management agreement between the parties (World Bank/GW MATE 2009). The MERCOSUR Parliament also proposed: (i) the formation of a commission to study, analyse and compare each country's water-resource legislation; (ii) an agreement for the common management of the GAS and a transitional project assuring the continuity of the GAS Project structure; and, (iii) the establishment of a regional Research and Development Institute for the Guarani Aquifer and other aquifers shared by the states (Villar 2010).

Unfortunately, none of the MERCOSUR proposals were realised. Many factors contributed to this: the institutional fragility of the Mercosur Parliament, constant tensions within the bloc over trade relations, disagreements over the acceptance of new members, and the failure of the regional trade architecture to address conflicts over the construction of pulp mills on the Uruguay River. In this context, states decided to follow a more traditional approach and establish an international agreement.

The agreement on the Guarani Aquifer

The agreement on the Guarani Aquifer (see Amore 2010; República Argentina, República Federativa del Brasil, República del Paraguay and República Oriental del Uruguay 2010a, 2010b) follows the main guidelines of the UNGA Resolution A/RES/63/124 (the Law of Transboundary Acquifers), especially in relation to the following principles: sovereignty, the equitable and reasonable use of water resources, the obligation not to cause harm, cooperation, and the exchange of data and information.

Mention of the sovereignty principle in the UNGA Resolution A/RES/63/124 and the subsequent emphasis in the Guarani agreement (preamble and articles 1, 2 and 3) were much criticised. McCaffrey (2009, 2011) and McIntyre (2010) point out that the reaffirmation of this principle is inconsistent with the spirit of cooperation and equitable use, since states can appeal to sovereignty as a protective shield for imprudent, inadequate, or illegal actions. Improving cooperation, however, requires the promotition of dialogue between sovereign states. An important starting point is for all parties to feel secure in their rights. As Laborde (2010) explains, the sovereignty principle merely restates the well-established principles of international law and ensures safeguards for the aquifers, thus preventing the aquifer from being considered a 'common good of mankind'.

Equitable and reasonable use of water was included in Article 4 of the Guarani agreement which determines that states:

> shall promote the conservation and environmental protection of the Guarani Aquifer System so as to ensure multiple, reasonable, sustainable, and equitable use of its water resources.

The obligation not to cause harm is stated in Article 6:

> Parties that perform activities or work for utilizing the water resources of the Guarani Aquifer System, in their respective territories, shall adopt all the necessary measures to avoid causing significant harm to the other Parties or the environment.

By these means the agreement reaffirms the two major principles of international water law (i.e., equitable and reasonable use, and the obligation not to cause harm).

Cooperation is one of the strong points of the agreement and appears in many articles, such as 8, 9, 10, 12, 13, and 14. These statements foresee the need to exchange information on water resources and the right to seek additional information. Notably, articles 8 and 12 seek to build on the foundation provided by the GAS Project:

> The Parties shall proceed to adequately exchange technical information about studies, activities and works that contemplate the sustainable utilization of the Guarani Aquifer System water resources. (Article 8)

> The Parties shall establish cooperation programs with the purpose of extending the technical and scientific knowledge on the Guarani Aquifer System [...]. (Article 12)

Article 12 also reaffirms the obligation to provide information in the case of activities or works which could have transboundary impacts. Articles 9 and 10 further codify this issue:

> [...] information shall be accompanied with technical data available, including results from an evaluation of environmental effects; so that, the Parties receiving the information could evaluate the potential effects of the activities and work. (Article 9)
>
> Each Party shall provide the appropriate data and information required by other Party, or Parties with respect to the projected activities and work in their respective territory that may have effects beyond their boundaries. (Article 10, 2)

Finally, Article 15 states that a dedicated multilateral Commission will oversee the cooperation process. Unfortunately, the countries have yet to establish it and determine its statutes, competences, members and budget. Desirable objectives for the Commission would be: leadership in disseminating and producing knowledge about the aquifer; harmonisation of legal instruments, such as wellhead protection areas and groundwater permits; establishment of methodological guidelines for a groundwater database; and, coordination of a common groundwater informational system.

As the agreement makes no mention of the recharge areas of the aquifer with higher natural vulnerability that are more likely to create conflicts, the Commission could take the lead in designing a common strategy to manage these areas, especially the ones within or very near the frontier zone.

In case of conflicts over the use of the Guarani Aquifer, the Commission would be in a position to present recommendations. Article 17 affirms:

> If through direct negotiations an agreement is not reached within a reasonable period, or if the dispute is only partially resolved, the Parties in the controversy shall, through mutual agreement, solicit the Commission related in Article 15 to, upon a presentation of the respective positions, evaluate the situation and, if appropriate, formulate recommendations.

According to this Article, however, the Commission will still have a restricted role because its participation has to be evoked by the Parties through mutual consent and its intervention has no binding consequences. If the countries can't reach an agreement after this procedure, Article 19 mentions the possibility of an arbitration procedure which would be defined by a future protocol.

Despite the progress in developing the Guarani Agreement, its power remains limited and further action is required. At the international level, states have to yet ratify the agreement, establish the Commission and its powers, and propose an additional protocol setting the dispute resolution mechanism. At the national level, all Parties need to improve groundwater management and monitoring.

Although much work remains, considering the absence of conflicts over the GAS, the fact that four countries managed to structure a common base for groundwater management is a considerable achievement. As Delli et al. (2009) explained, preventative diplomacy is usually the best way to prevent disputes, but it is hard to prove this statement due to the lack of practical initiatives. Without tensions it is hard to mobilise actors, interests and resources.

Literature highlights the value of conflicts to create cooperation. But the GAS case calls attention to the role of scientific and international organisations in promoting conditions to create common arrangements based on a precautionary approach, since there are no transboundary conflicts over the use of the aquifer or water scarcity. The mobilisation of different stakeholders over the Guarani Aquifer, the end of the GAS Project, and the approval of the UN Law of Transboundary Aquifers created positive pressure to deepen the cooperation process over the GAS and sign this unique regional agreement. The challenge now is to continue this process beyond the initial momentum and ratify and implement the treaty, particularly through the creation of an effective and empowered Guarani Aquifer Commission.

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14. The Brahmaputra: Water hotspot in Himalayan Asia

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Analysts around the world increasingly have their eyes on the Brahmaputra River, a transboundary watercourse with headwaters in the Tibetan Plateau of the Himalayan mountain range. The three riparian states sharing the Brahmaputra — China, India and Bangladesh — are the world's first, second and seventh most populous countries. All three face severe problems of water scarcity and steeply rising demand for power generation. The possibility of serious resource conflict involving these demographic giants stems from plans, some already being implemented, to put the river's thus-far relatively unexploited waters to greater use.

The combination of burgeoning populations, rapid economic growth and intensified global competition for energy resources is putting increasing emphasis on hydropower. India, already the world's sixth largest energy consumer, ranks seventh globally (2008) in current hydropower generation. Only about 20 per cent, however, of India's hydropower potential has been developed thus far. With its untapped potential standing at 95 per cent, the importance of the Brahmaputra is clear.

In 2010 China consumed 20 per cent of the world's primary energy supplies, overtaking the United States to become the world's largest energy consumer. With its installed hydropower capacity reportedly having reached 213,000 megawatts by the end of 2010, it was by far the world's leading producer of hydroelectricity. It plans to lift the proportion of non-fossil fuel use in the country's energy sector to 15 per cent by 2020, and half of that is expected to come from hydropower. That means that China aims to have 430,000 megawatts of hydropower capacity hardly a decade hence, the equivalent of one new Three Gorges Dam each year over the current decade. Given the overall vast leap in anticipated energy consumption, this converts to a major surge in hydroelectric dam building.

China is now predictably casting its eyes on the Brahmaputra's hydropower potential on China's side of the border. According to Tibet researcher Tashi Tsering, China has already constructed ten dams on tributaries of the upper Brahmaputra, with three more under construction, seven more under consideration, and yet eight more proposed (Tsering 2010). Those dams already built are small in scale and, since none are on the Brahmaputra itself, have stirred little interest outside China. China's plans, however, apparently include building five major dams directly on the Brahmaputra mainstream. Completion of construction on the first of them, the US$1.18 billion 510 megawatt Zangmu hydropower project in the middle reaches of the river, is expected by 2014.

More worrying yet, from the the perspective of India, is the possibility that China's aggressive search for promising hydropower dam sites in Tibet might ultimately drive Beijing to focus on the so-called Great Bend in the Brahmaputra, the point in the Himalayas where the river curves south onto India's Assamese plain. It was reported in May 2010 that research had indeed been carried out for a massive project at the bend (Watts 2010). Tsering (2010) predicts that China is likely to construct a 38,000 megawatt hydropower station and large storage dam near Motuo and, if built, 'China will gain significant capacity to control the Brahmaputra's flow. Basically, India will become dependent on China for flow of what is now a free-flowing international river' (*Hindustan Times* 2010; see also Rafferty 2010).

Diversion of the Brahmaputra's waters is another — and much more portentous — potential use. Planned diversion of this river's waters from India's water-surplus north-east to drought-stricken western and southern states, though at least temporarily on hold, is the key to India's River Linking Project (RLP). China's diversion plans, on the other hand, are lodged in the mammoth and already underway South-North Water Diversion Project (SNWDP). If proposals to include the Brahmaputra in an extended version of the still pending western route of the SNWDP were implemented, the consequences for downstream India and, even more so Bangladesh, might be disastrous.

China's southern belt has historically been a water surplus region while its north and north-west have been increasingly water scarce. According to a recent article in the *Economist*, this disparity has become alarming. 'Four-fifths of China's water is in the south', it reports, but 'half the people and two-thirds of the farmland are in the north … .' At least as alarming, it says, is the problem of water pollution: a recent study of the Yellow River and its tributaries, for instance, concluded that a third of the water, with about 4000 petrochemical plants feeding into it, was unfit even for agriculture. In fact, many of China's rivers are simply disappearing: since the 1950s, overexploitation by farms or factories has driven down the number of rivers by nearly half — from about 50,000 to 23,000 (*Economist* 2013).

A similar pattern of spatial variability in water supply also exists in India, where the north and north-east regions have been water surplus, while large portions of its west and south are water scarce. About 62 per cent of annual freshwater availability in India is found in the river basins of India's north leaving about 67 per cent of the country — mainly its west and south — with water availability of about 38 per cent (Kumar 2005).

Chinese and Indian hydrologists have naturally been giving attention to the prospects for water diversion — for transferring major quantities of river water from south to north in China, from north to south in India. China launched the massive SNWDP in 2001; India gave official sanction to its equally massive RLP in 2002.

It is, of course, where Indian water-diversion plans meet up with China's that transboundary concerns emerge; and it is the distinct possibility that they may meet up on the Brahmaputra that is currently exercising the imaginations of the region's strategic analysts.

Unknown presently is whether India's RLP will ever get off the ground. Also unknown is whether the RLP, if fully implemented, will include the Brahmaputra in its Himalayan component. Clearly, however, India's future diversion of the Brahmaputra's waters remains a live possibility — even a probability should the more threatening projections of the country's coming water scarcity prove correct. Moreover, should China move towards the Brahmaputra in coming years with an eye not just on hydropower but also on diversion, pressure on New Delhi to match Beijing's with an aggressive plan of its own would likely become irresistible.

There is uncertainty with regard to Beijing's plans. Official denials of Chinese plans to divert the Brahmaputra's waters are common. Of late, however, there have been a number of proposals floated indicating China's interest in diverting massive amounts of water to China's arid north-east from the Brahmaputra's middle reaches.

Brahma Chellaney, one of India's foremost strategic thinkers, has argued that it is not a question of if, but when, China will go ahead with the proposed diversion of Brahmaputra waters to its parched north. And such a diversion, he warns, 'would constitute the declaration of a water war on lower-riparian India and Bangladesh' (Chellaney 2011).

The relations between India and China are driven, of course, by much more than water; and even water cannot be confidently said to be driving things relentlessly and unalterably in the direction of violent conflict between them. Still, China's dire water circumstances, combined with its impressive economic strength, military power and uniquely advantageous upper riparian position, give us little reason for optimism when it comes to river-sharing agreements with lower riparian countries. India and China have recently signed an accord, updating earlier agreements, in which the Chinese consented to increase the supply to India of flood data of the Brahmaputra River (*Hindu* 2013). And the joint statement accompanying the accord did promise some greater transparency in regard to dams and water sharing on the Brahmaputra (*Hindustan Times* 2013). Aside from that, however, no major agreements currently exist between China and India in regard to water sharing of the transboundary Brahmaputra; and one should not expect any grand cooperative interstate scheme to develop soon in regard to that river. On the contrary, mounting tensions and at least verbal skirmishing between China and India over the Brahmaputra's contested waters seem more likely. There will surely be water woes impacting their relationship, in other words, even if water wars never materialise.

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Part 4: Development

15. Development

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The inclusion of targets for access to improved water and sanitation in the Millenium Development Goals (MDGs) reflected a clear appreciation in developing countries and their partners of the critical role that water and sanitation services play in people's wellbeing. The costs incurred when people cannot acquire safe drinking water, or do not use hygenic sanitation practices are large: a recent World Health Organization (WHO) study estimated the global economic losses associated with inadequate water supply and sanitation to be US$260 billion a year, or 1.5 per cent of the GDP of the countries included in the study (WHO 2012).

Typically, although not exclusively, it is the poor who have limited access and bear the bulk of these costs. Further, the majority of those without access live in rural areas — 89 per cent of those without access to improved water, and 70 per cent of those without improved sanitation (Sy et al. 2014). These factors mean that capacity to manage costs, and to take action to reduce the risk of incurring them, is limited.

The distillation of the water and sanitation challenge into two measurable targets has helped focus attention and attract commitment of financial resources to dealing with the issue. But it also risks masking the complexity of the problems associated with reducing the costs of using unsafe water and unhygenic sanitation.

For water, some of the complexities arise because of the nature of water as an economic good and the need for societies to find ways of managing trade-offs between alternative uses, as well as to address strong social expectations concerning access to a necessity of life. A further level of complexity arises because of the need for robust institutions: to devise and implement policy, to manage water resources, and to provide water-supply services to households.

These complexities can be challenging in developed countries, but they are exacerbated in developing countries by the constrained functionality of formal institutions that would underpin market solutions, and limited capacity of public sectors to provide water or to regulate provision. Property rights in general, not just with respect to water, are hard to define and protect, and the means to resolve disputes that cross communal boundaries are often absent or dysfunctional. This can constrain adoption of private and communal solutions that require scale to be viable (for example, where water needs treatment and transmission and distribution structures). And in most developing countries, governments do not have the financial and managerial capacity (and in some cases the interest) to provide public sector solutions, or to implement policies to manage externalities associated with use of water resources.

Typically, the majority of households in developing countries rely on private (including self-provision) and community initiative to meet their water needs. (A recent study of private water provision in Bangladesh, Benin and Cambodia, for example, estimated that only 11 per cent of the total population of these countries get their water from state-run systems, Sy et al 2014.) In the foreseeable future, this pattern is unlikely to change, especially for poor and rural households. Policy makers — and their development partners — are thus increasingly focusing on what is required to help ensure that private and communal provision delivers safe water, and that households are able to pay for it. Among other things, this requires understanding the market for water and the drivers of household demand, calibrating the enabling environment for private sector investment in water supply, and developing policies that address the ability to pay of poor households that often have seasonal or volatile cash incomes.

Overview of chapters

In the development section of this volume there are six contributions that illustrate a selection of the complexities involved in addressing the water needs of poor people in developing countries, and ways in which new solutions may be emerging. Bain et al. (Chapter 16) show how the indicator used in the MDGs — which measures access to a water source that is likely to be protected from outside contamination — may give a misleading impression of the extent to which people are using water that is safe to drink. They argue that if the data are adjusted for water quality, a much higher proportion of the world's population still lacks access to safe water than progress towards the MDG target implies. In a similar vein, Vedachalam (Chapter 17) provides evidence from urban centres in India that access to improved water sources does not necessarily translate into regular availability of safe water: constrained supply from improved sources drives households to augment piped supplies with other, less reliable water. He also argues that the sustainability of some improved water sources is under threat from depletion and contamination. Karim et al. (Chapter 20) examine the complex social effects that can arise if development projects and technology alter the balance between competing uses of water sources. Their paper explores the impact on within-household gender violence of the installation of deep tube wells for irrigation that reduce the ability of hand pumps to provide water for domestic purposes. Berg (Chapter 19) considers the challenges of regulating state-owned water utilities, and the fact that regulation alone cannot sustain service delivery unless supporting insitutions and structures are in place. He proposes elements of governance and utility organisation that are pre-conditions for good performance, without which external regulation is unlikely to achieve traction. And finally, Foster et al. (Chapter 18) look at the impact of the revolution in mobile communications in helping to solve one of the great challenges of water supply: facilitating payment and redressing the problem of cost recovery for both public and private water-service providers. Their analysis shows the importance of the opportunity cost of time to customers, and the costs to utilities of operating physical payment offices, and how the introduction of mobile bill payment services offer savings to both sides of the water service market.

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16. Improved but not necessarily safe: Water access and the Millennium Development Goals

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In early 2012 the United Nations announced that the drinking water target of the Millennium Development Goals (MDGs) had been reached in 2010: in two decades, and five years ahead of schedule, the proportion of people without sustainable access to safe drinking water had been halved (World Health Organization (WHO)/United Nations Children's Fund (UNICEF) 2012a). Whilst this undoubtedly represents a major achievement, fundamental concerns regarding the monitoring of safe water have been gaining prominence (Harmon 2012).

The measure used to assess progress towards the MDG target is use of an *improved* source; these are water sources that were considered likely to provide safe drinking water (Table 1). Consequently, this approach is an assessment of specific types of water sources, rather than the quality of the water they provide. Improved sources do not always supply safe water due to the presence of microbial or chemical contamination. In order to explore the scale of this discrepancy and how it might be addressed in monitoring, the Joint Monitoring Programme (JMP) for Water Supply and Sanitation of WHO and UNICEF commissioned a number of nationally representative studies. These Rapid Assessment of Drinking-Water Quality (RADWQ) studies were conducted in Ethiopia, Jordan, Nicaragua, Nigeria and Tajikistan between 2004 and 2005.

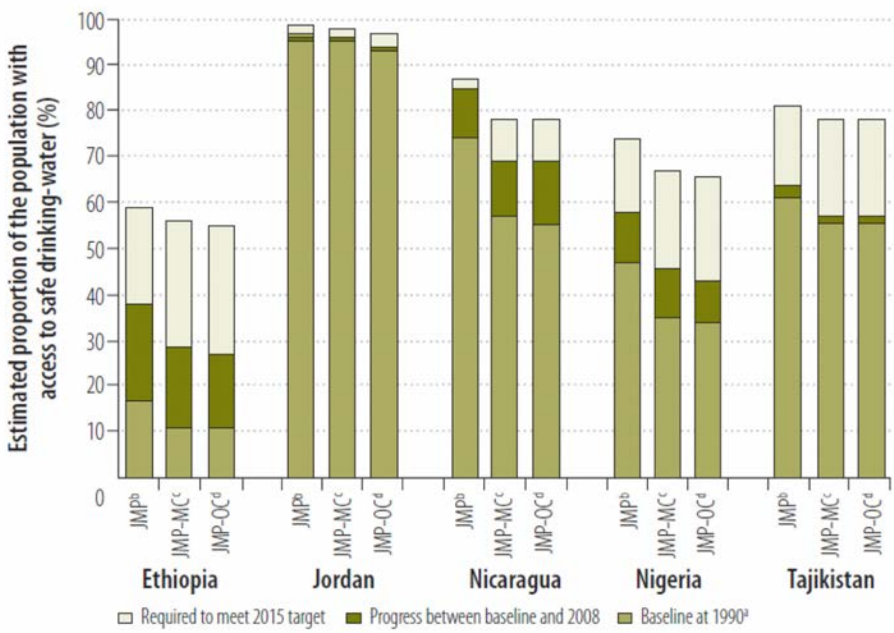
Table 1: The Joint Monitoring Programme (JMP) classification of source types into improved and unimproved

Source class	Types of source included
Unimproved drinking water sources	Unprotected dug well, unprotected spring, cart with small tank/drum, surface water (river, dam, lake, pond, stream, canal, irrigation channels), and bottled water.
Improved: Piped into dwelling, plot, or yard	Piped water connection located inside the user's dwelling, plot, or yard.
Improved: other sources	Public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, or rainwater collection.

Source: WHO/UNICEF 2012b.

In recent work (Bain et al. 2012), we sought to determine how these data on water-source quality would affect assessments of progress towards the 2015 MDG target in these countries. We adjusted reported coverage estimates for the following water quality parameters: thermotolerant coliform bacteria, arsenic, fluoride and nitrates. Accounting for compliance with the WHO *Guidelines for Drinking-Water Quality* for these parameters substantially lowers estimates of 'safe' water use in four of the five countries (see Figure 1). In Ethiopia and Nigeria, the countries with the largest populations, the adjustment represents an additional 8.9 and 22 million people without safe water in 2008. Across the five countries, the adjustment reduces reported access by 32 million people — a sizeable difference when compared to the 70 million that have begun to use improved water sources in these countries between 1990 and 2008.

The RADWQ studies show marked differences between countries, not only in the extent of the adjustment, but also in the likelihood of particular supply types being contaminated. Although there are some general trends in water quality between supply types, this is not consisent between countries. For example, in Nigeria boreholes were more likely to be compliant (86 per cent) than piped supplies (77 per cent), whereas in Ethiopia the reverse was the case (66 per cent versus 80 per cent respectively). As these data highlight, there remains a need for substantial improvement of 'improved sources'.



JMP, Joint Monitoring Programme for Water Supply and Sanitation; RADWQ, Rapid Assessment of Drinking-Water Quality; WHO, World Health Organization.

[a] For Tajikistan, the baseline year was 1995.

[b] JMP: the percentage with access to safe drinking-water was estimated using the original JMP figures.

[c] JMP-MC: the percentage with access to safe drinking-water was estimated using the original JMP figures adjusted for the percentage microbial compliance (MC) with WHO guidelines on drinking-water contamination with thermotolerant coliform bacteria derived during the RADWQ project.

[d] JMP-OC: the percentage with access to safe drinking-water was estimated using the original JMP figures adjusted for the percentage overall compliance (OC) with WHO guidelines on drinking-water contamination with thermotolerant coliforms, arsenic, fluoride and nitrates derived during the RADWQ project.

Figure 1: Estimated percentage of the population using safe drinking water in 1990 and 2008 in five countries and the MDG target for 2015, by indicator

Source: Bain et al. 2012. Reproduced with permission of the World Health Organisation (ID: 125807).

Studies in a number of other countries also highlight the discrepancy between improved water sources and the provision of water that is free of chemical and microbial contamination. For example, a preliminary study shows the Chinese population that gained access to safe water between 1990 and 2010 is at most 330 million, whereas 457 million people are reported by the JMP as having gained access to an improved source during the same period (Yang et al. 2012).

The compliance rate of improved sources is also known to vary considerably within countries; for example, between urban and rural areas or socio-economic groups. In related work (Yang et al. 2013) we combined data from the RADWQ studies with contemporary information from household surveys in the five countries to investigate socio-economic disparities in access to safe water. We found statistically significant differences in water quality between the poorest and richest households in Ethiopia, Nicaragua and Nigeria, even though we were unable to account for differential safety of sources of the same type. We also investigated differences in access to safe water by wealth quintile for users of the same type of supply using two household surveys that included measures of water quality. Whereas data from Bangladesh showed little difference in arsenic contamination between poor and rich borehole users, piped supplies used by the richest in Peru were considerably more likely to have adequate levels of chlorine residual (>0.1 parts per million) than those used by the poorest. Although this provides only a partial and indirect indication of microbial contamination, the results are consistent with a more recent study in Peru (Miranda et al. 2010) that found the absence of an adequate chlorine residual to be more common in drinking water used by low-income households and in rural areas. The study also found similar patterns in the presence of total coliform or *E. coli* and provides compelling evidence of persistent disparities in water quality between urban and rural areas as well as income quintiles.

The magnitude of the problem globally has also been estimated. Given that nationally representative water quality data are only available through RADWQ for five countries, and that results vary greatly between countries, this exercise requires a range of assumptions and may be imprecise. When water quality is incorporated, however, global estimates of those without safe water range from 1.8 to 1.9 billion (Payen 2011; Onda et al. 2012; Wolf et al. 2013) — over a quarter of the 2010 world population and more than double the reported population not using improved sources.

The majority of the studies described above, including the RADWQ studies, have assessed water quality as the point of collection and have been based on sampling at a single timepoint rather than regular monitoring. They may not, therefore, reflect the quality of the water at the point of use; water quality can deteriorate due to handling practices during transport and storage, but may also be improved by treatment in the home (Wright et al. 2004). One-off sampling may overestimate yearlong safety since water quality can vary seasonally (Wright et al. 1986) and infrequent sampling may miss contamination events. Further research is required to understand how the safety of supplies varies throughout the year and what factors are the most important determinants of safety.

There is a great need to improve sector monitoring, including safety. Proposals prepared by expert working groups for the JMP recommend monitoring an ‘intermediate’ service level after the exprity of the MDGs (UNICEF/WHO 2013). The intermediate service level would include accessibility, continuity of supply as well as accounting for water safety (provisionally defined as <10 *E. coli* per 100 millilitres throughout the year). This would represent a substantial improvement on the current practice of monitoring 'haves' and 'have nots' (Bartram 2008). There are, however, many challenges that need to be overcome, not least of which is establishing the feasibility and cost-effectiveness of water quality surveys in countries with limited data.

This work shows that interpretation of the MDG indicator as a surrogate for safe water can lead to substantial overestimates of the population using safe drinking water and, consequently, may also overestimate the progress made towards the 2015 MDG target. The current indicator does not adequately capture differences in safety between countries and does not reflect disparities in safety within countries. Whilst progress has been made, adjusting for water quality shows that much of the world's population still lacks access to safe water.

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17. Water supply and sanitation in India: Meeting targets and beyond

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Target 7C of the Millennium Development Goals (MDG) calls for halving the proportion of the population (baseline 1990) without sustainable access to safe drinking water and basic sanitation by 2015 (United Nations (UN) 2000). A large developing country like India is critical to meeting this target. Even though the MDGs set out to measure and reduce the population without sustainable access to safe water and sanitation, difficulties have been encountered in measuring 'safe' and 'sustainable', which have led to a revision of the target to achieving access to *improved* sources of water and sanitation (Zetland 2008). It has been argued that the revised goals grossly overestimate the access to safe water and sanitation (Bain et al. 2012; Satterthwaite 2009).

Table 1: Population (per cent) of India with access to improved sources of water

Year	Urban	Rural	Total
1990	88	63	69
1995	90	70	75
2000	93	77	81
2005	95	83	86
2010	97	90	92

Source: World Health Organization (WHO) and United Nations Children's Fund (UNICEF) 2012a.

Table 1 shows the distribution of India's population with access to an improved drinking water source. By 2010, 92 per cent of the population had access to an improved source of water, which brought down the proportion of the population without such access from 31 per cent in 1990 to eight per cent in 2010 (WHO/UNICEF 2012a). If Target 7C of the MDG (improved water access) were to be applied on a country-level basis, India has already surpassed the target well before 2015.

Table 2: Population (in percent) of India with access to improved sources of sanitation, and no sanitation

Year	Improved			No sanitation		
	Urban	Rural	Total	Urban	Rural	Total
1990	51	7	18	28	91	75
1995	53	10	21	25	86	70
2000	55	14	25	22	79	63
2005	56	19	30	18	73	57
2010	58	23	34	14	67	51

Source: WHO/UNICEF 2012b. The proportions of the population with access to improved sources and no sanitation do not add up to 100 percent. The remaining population has access to unimproved sources.

It is a somewhat different story, however, on the sanitation front. Table 2 shows the proportion of the population with access to an improved source of sanitation, and those that lack any source of sanitation and have to use open defecation. Though the proportion of the population with access to improved sanitation nearly doubled in the last 20 years, a majority of the population still does not have access to any sanitation and has to resort to open defecation (WHO/UNICEF 2012b). The five states of Chhattisgarh, Madhya Pradesh, Bihar, Jharkhand and Odisha — largely rural and located in the central and eastern parts of the country — have less than 30 per cent access to a sanitation source (International Institute for Population Sciences and Macro International (IIPS) 2007). It appears that India is likely to miss Target 7C of the MDG (improved sanitation access), and any hope of achieving the target by 2015 rests on the progress made in these five large states.

Access to water and sanitation also involves issues of gender and caste. In 2005, only half the population had access to water on the household premises, and 12 per cent spend 30 minutes or longer daily to get water for the household (IIPS 2007). Of the households that don't get water on premises, adult females are responsible for fetching water in 81 per cent of the families. Even among children below 15 years of age, girls are four times more likely than boys to be responsible for collecting water (IIPS 2007). Beyond gender, Indian society also has an uncomfortable history with caste discrimination that is relevant to sanitation access: lower castes have been traditionally entrusted with occupations such as collecting human/livestock waste.

These underlying traditions show up in the data as well. The states with the highest rates of access to sanitation (except the capital region of Delhi) are the eight north-eastern states and the southern state of Kerala, all of which are known for an egalitarian society (Milner 2009; Subramanyam and Subramaniam 2011). Additional analysis of the sanitation data by income quintiles reveals that the poorest 40 per cent in India have hardly benefited from improvements in sanitation. The poorest quintile is 47 times more likely than their richest counterpart to practice open defecation, a disparity three times greater than that observed in Africa (Brocklehorst 2010).

Table 3: Status of water supply and wastewater treatment in the six largest cities of India

City	Water supply				Wastewater	
	Capacity (MLD)	Hours per day	Consumption (LPCD)	Unaccounted (%)	Generated (MLD)	Treatment capacity (MLD)
Bangalore	965	4		34-44	772	
Chennai	198	4		20	158	264
Delhi	4346	4	78	26	3800	2330
Hyderabad	578	0.5-4	96	33	462	593
Kolkata	1625	9	116	30-40	706	172
Mumbai	3000	5	90	18	2400	2130

Source: McKenzie and Ray 2009; Shaban and Sharma 2007; Central Pollution Control Board 2009.

Although urban areas of the country fare better than their rural counterparts on water and sanitation access, a larger and denser population, coupled with dwindling natural sources of freshwater pose unique challenges to large cities, such as Bangalore, Mumbai and New Delhi. Table 3 shows the status of water and wastewater infrastructure in the six largest cities in India. Though the major cities reported an increase in the service coverage between 1991 and 1997 (Ruet et al. 2002), the availability of water supply ranges from four hours or less per day in Delhi, Bangalore and Hyderabad to nine hours in Kolkata; and 18 per cent (Mumbai) to 50 per cent (Kolkata) of the urban water is unaccounted for (McKenzie and Ray 2009). A household study conducted in seven cities in India found the average per capita consumption of water to be 92 litres per capita per day (LPCD), below the World Health Organization (WHO) guideline of 100 LPCD for optimal access (Shaban and Sharma 2007). Further analysis of the data by socio-economic quintiles shows that water consumption increases with a rise in socio-economic status, although the inter-quintile differences are not significant. The near-uniform water consumption across different income groups is largely a result of supply constraints and is not impacted by varying economic abilities (Shaban and Sharma 2007).

These numbers raise doubts about whether access to improved water sources translates to regular availability of safe water. Residents in several Indian cities augment their piped supplies with private wells and other informal methods, such as private tankers (Srinivasan et al. 2010). The use of groundwater for residential as well agricultural consumption is driving down water tables in many parts of the country, especially the agricultural bread-baskets of Punjab and Haryana (Rodell et al. 2009). Continued groundwater depletion can result in an inability to meet residential needs, reduced agricultural productivity and increased conflict over water rights.

Additionally, the lack of wastewater treatment capacity in cities like Delhi and Kolkata (Central Pollution Control Board 2009) threatens public health and the safety of already-scarce freshwater resources. A discussion on water security is incomplete without planning for adequate infrastructure for wastewater treatment. Not only does it allow for better management of available water resources, treated wastewater can be an additional source of freshwater in water-deficient regions (Vedachalam 2012).

Even though India has reported tremendous progress towards achieving the MDGs for access to water, the revised targets do not necessarily mean continuous and safe access to water, not to mention economically affordable water. Even large cities that boast higher rates of access are able to guarantee little water for a few hours a day, imposing health, economic and social costs on the residents. The Indian economy loses 73 million working days a year due to waterborne diseases, caused by a combination of lack of clean water and inadequate sanitation (DFID 2010). Access to sanitation, even more so than water, is a robust indicator of human development due to the complex role played by social, institutional and cultural factors (Vedachalam 2011). Low rates of access to sanitation underscore lack of action on several fronts, only some of which are due to lack of financial resources. Targeted investments in communities and individuals (Gupta 2012), along with institutions, will allow India to expand and ensure safe access to water and sanitation to all its residents well beyond 2015.

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18. Mobile water payments in urban Africa: Adoption, implications and opportunities

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The revolution in Africa's mobile communications sector offers new opportunities to address the continent's enduring water service challenges. Over the past decade, mobile phone subscriptions in Africa have grown to over 620 million and, by 2013, more Africans will have a mobile phone subscription than access to an improved water source.

Juxtaposing the rapid upsurge in mobile phone ownership is the slow progress being made towards the water access Millenium Development Goal (MDG). Between 1990 and 2008, the number of urban Africans lacking access to safe water more than doubled from 25 million to 52 million (World Health Organization (WHO)/United Nations Children's Fund (UNICEF) 2010). Many water service providers (WSPs) are unable to meet the needs of a rapidly growing population as they remain trapped in a vicious cycle of poor operational performance and low cost recovery.

A key contributor to this spiral of decline is under-collection of water bills, which costs the urban water sector in Africa almost US$500 million a year — equivalent to 0.07 per cent of the continent's GDP. Around one in five urban households with a piped connection fails to pay for water, while recent World Bank analysis suggests more than half of African utilities collect revenue from fewer than 50 per cent of their customers (Bannerjee and Morella 2011).

Figure 1: Opportunities for expansion of mobile water payments: mobile money deployments in Africa to 2011

Source: Authors' research.

In an effort to turn around their ailing financial positions, many WSPs are teaming up with mobile network operators (MNOs) to enable customers to pay their water bills using 'mobile money'.[1] Since 2009, at least 35 WSPs in east and southern Africa have launched a mobile bill payment service in concert with global MNOs including Safaricom/Vodacom, Airtel and MTN. In order

1 Mobile money is an electronic payment system that enables money transfers to and from an electronic account that can be accessed via an ordinary mobile phone. Each customer's account is linked to their mobile phone number by means of an in-built SIM-card application. Physical cash withdrawals and deposits are facilitated by a network of retail agents. While configurations vary across providers, the viability of mobile money is premised upon the cost base associated with an agent network, which is lower and more flexible than establishing 'bricks and mortar' bank branches. Mobile money can therefore profitably extend the reach of financial services to those who have traditionally been unbanked, such as low-income or remote households. The scale and growth of the opportunities for mobile water payments is demonstrated by Figure 1, which displays mobile money deployments in Africa to 2011.

to ascertain the implications of this trend, our team conducted a four-country study that examined mobile water payment deployments across Kenya, Tanzania, Uganda and Zambia (Hope et al. 2011).

For the WSPs that we investigated, mobile payment adoption rates range between one and ten per cent of customers (Table 2). In terms of transaction volumes, the National Water and Sewerage Corporation (NWSC) in Uganda leads the way with 23,000 customers transferring US$300,000 worth of revenue via mobile phone each month. The notable exception to the otherwise low levels of uptake is Kiamumbi, a small peri-urban community on the outskirts of Nairobi, where three quarters of the customer base have switched to the mobile payment option.

Table 1: Mobile water payment adoption rates for studied WSPs

Country	WSP	Mobile network operator	Served population	Mobile payment adoption	Months since launch
Kenya	Nairobi City WSC	Safaricom	2,250,607	4%	13
	Kisumu WASCO	Safaricom	181,512	8%	-
	Nanyuki WSC	Safaricom	57,252	1%	1
	Kiamumbi WT	Safaricom	2,922	76%	11
Tanzania	Dar es Salaam WASCO	Airtel Vodacom	2,380,000	1%	27
Uganda	National WSC	MTN UTL	2,426,502	10%	7
Zambia	Lusaka WSC	Airtel	1,285,270	-	-

Source: Hope et al. 2011.

In order to ascertain the benefits, motivations and barriers relating to customer adoption of mobile water bill payments, we conducted a household survey of water users in Kiamumbi. Time savings (98 per cent) and cost savings (63 per cent) emerged as the key reasons why customers opt to pay bills by mobile phone (Figure 2). On average customers switching to mobile payments save 80 minutes a month, with women being the main beneficiaries. Of the numerous socio-demographic, wealth and water-service satisfaction indicators we subjected to logistic regression analysis, full-time work status emerged as a statistically significant predictor of mobile payment usage. This finding points to the importance adopters place on being able to pay bills outside of business hours.[2]

2 The results from the survey however fail to unravel why Kiamumbi adoption rates are so much higher than elsewhere in east Africa. Some possible explanations include: (a) a longer than average trip to the alternative pay point; (b) a wealthier than average community placing a high value on their time; (c) a high degree of trust in the operators due to the scheme's strong operational performance, small size and community-orientation; and, (d) the high water tariffs which reduce the relative size of the mobile payment fee as a percentage of the overall bill.

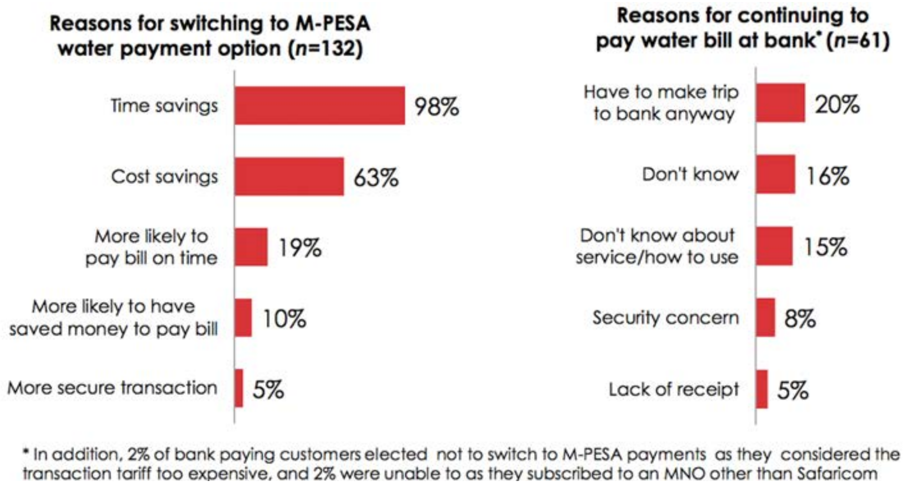

Figure 2: Time and cost associated with bank trips are keys drivers behind the adoption of mobile water payments in Kiamumbi

Source: Hope et al. 2011.

Across other large east African WSPs we examined, it is clear there are systemic obstacles hindering large-scale use of the mobile payment option. The first relates to customer perceptions of the integrity and trustworthiness of an electronic billing system. Deployments in Kenya, for example, lack a mechanism for automatically updating the WSPs billing system immediately upon receipt of a mobile payment, fuelling customer fears that last minute payments will not be recognised until after the generation of disconnection lists. Similarly, across all four countries, we noted a general unease associated with conducting a transaction that fails to produce a physical receipt, which has traditionally been an unambiguous proof of payment and defence against disconnection. In a number of the study locations there was a lack of awareness of the mobile payment option, suggesting greater marketing and promotional efforts are needed. Finally, transaction tariffs levied by MNOs on customers (which can be as high as US$0.30 per payment) are in some cases prohibitive, particularly those tariff structures that penalise low-income households for paying bills in many small instalments.

Where the above-mentioned constraints are released, mobile payments offer considerable benefits for both water users and service providers. For WSPs, operating physical payment offices is costly — utilities need to cover ongoing expenditure relating to rent, labour, insurance and cash transportation. The NWSC estimates its new electronic billing system will save US$420,000 per year as a result of pay point closures. Moreover, electronic billing will lower the risk of administrative error and misappropriation, in turn building greater consumer trust and willingness to pay. Perhaps most importantly, the increased convenience of bill payment is likely to drive an increase in revenue collection ratios. In Kiamumbi, for example, those using mobile payments are now ten per cent more likely to pay by the bill payment deadline than their counterparts paying at the bank. Results from Kiamumbi also illustrated the time and cost savings that mobile bill payments can generate for customers (Figure 3). Replicating these productivity gains across other urban centres in Africa will lead to significant social and economic benefits.

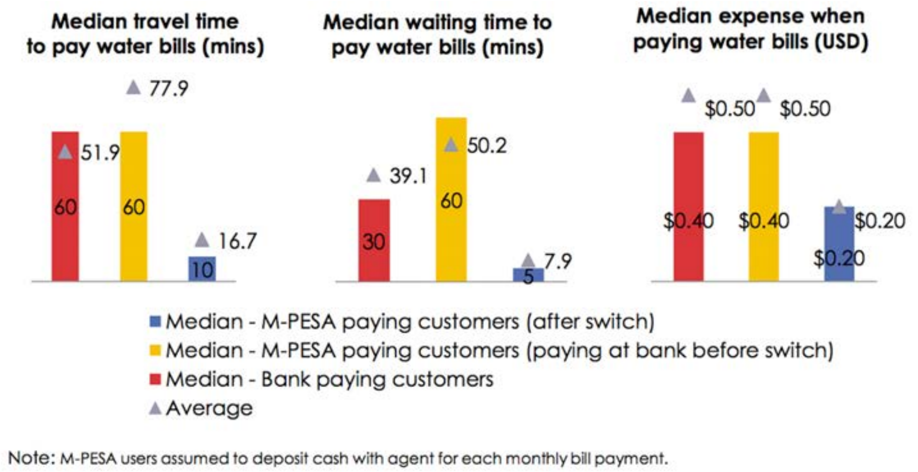

Figure 3: Indicative transaction costs for those taking a trip by public transport to pay water bills

Source: Hope et al. 2011.

With the mutual benefits that mobile water payments afford, this revenue collection mechanism can help provide the circuit-breaker that many African utilities seek to escape the vicious cycle of low cost recovery and poor operational performance. Ultimately, it is hoped this will translate into more reliable water services for customers and network expansions for the unserved. Technical and pricing innovations could also unlock mobile payment solutions that can directly benefit low-income, unconnected water users by eliminating profiteering operators from standpipes and providing a more secure and transparent mechanism in which rural communities can store funds for waterpoint maintenance. Yet, despite the significant potential, mobile water payments are only an instrument for transferring and storing money. Ultimately, the scale of the impact will depend upon the institutional, financial, operational, and regulatory responses that put this tool to good effect.

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19. Good governance for state-owned water utilities

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Two decades ago, many industry observors thought that private investment in water utilities would re-mediate and expand water systems in the developing world. Many (if not most) utilities are, however, still owned by nations, states, or municipalities. In many nations, water regulators were established to provide some 'comfort' to capital markets that pricing decisions would be based on financial sustainability rather than short-term political needs. Those oversight agencies are now, however, faced with the challenge of regulating another government entity: a publicly owned water utility that often depends on infusions of funds from the national treasury, donors, or a municipal government.

A fundamental lesson that emerges from a recent survey (Berg 2013) of developing countries is that sector regulation must be embedded in an adequate and consistent institutional framework in order to have a positive impact on performance. Sector regulation, by itself, is no guarantee of performance improvements in the drinking water supply and sanitation sector. Case studies and empirical analyses suggest that, without significant changes in the supporting institutions, the standard tools of regulation will not be effective. This conclusion is disturbing, especially for developing countries, since it means that the establishment of a regulatory agency might raise hopes, but ultimately, the agency's rules are unlikely to improve performance without additional, politically difficult initiatives.

As stated by an industry observer, 'to have effective regulation, you must have utilities that can, in fact, be regulated'. The problem boils down to getting a broader set of institutions to support regulatory and managerial actions that promote good sector performance (Body of Knowledge on Infrastructure Regulation (BoKIR) 2012). This means getting the governance structures right (rules of the game) and the substantive actions right (play of the game). For example, Uganda's successful performance was embedded in a reform process that involved 'regulation by contract', not external regulation by an autonomous agency (Mugisha and Berg 2008). The United Nations Economic Commission for Latin America and the Caribbean (ECLAC) report (Berg 2013) identified the following elements that promote success for state-owned and municipal utilities:

- Independent directors: The role of the utility's board of directors is a topic that is under-studied, yet it surely belongs on the list of issues warranting greater attention. If those monitoring and evaluating management (on behalf of the owners; i.e., the nation or the municipality) are driven by political concerns, they will tend to have a short-term view of outcomes: keep tariffs low, 'do not rock the boat' and leave technical management alone since 'they know best'. Certainly, regular interference by directors is to be avoided: let managers do their job. If business plans and executive performance are not monitored, however, then the board's governance responsibilities are abrogated. Little is known about the selection process, retention and other aspects of the boards of state-owned water utilities (assuming that they are, indeed, corporatised). Best practice suggests, however, that having respected representatives of different professions (for example, law, engineering, business and accounting) can promote healthy discussions and more careful reviews of management performance (Vagliasindi 2008). Note that if board members primarily come from (and return to) the realm of politics, they are likely to be more concerned with future political opportunities (and so will tend to be 'captured' by those making the appointments).
- Managerial commercial orientation: If the utility is fully embedded in a ministry or within a municipality, the likelihood that its managers will have a commercial orientation is reduced. A focus on cost-containment requires that financial sustainability be emphasised rather than (current) social concerns, since future performance will be weak if the utility acts like a charitable organisation. This point runs counter to the orientation of many water utilities. Yet waving the flag of 'social needs' over utility operations does not justify the inefficiencies that characterise many state-owned enterprises and municipal water utilities. In fact, those who speak loudest on behalf of a 'social orientation' are often the same ones who appoint politically connected individuals to positions of responsibility in utilities: managers who lack the expertise and professionalism required for making sound business decisions.
- Clarity of roles: Within the utility, each job description requires careful consideration. An organisational chart is only useful to the extent that it reflects actual interactions. If the enterprise consists of silos that hardly interact (for example, engineering and sales) then customer orientation becomes subservient to political infighting. Promoting interactions and learning among different units contributes to improved performance.
- Coherence among objectives: If managers have not prioritised objectives, there is likely to be inconsistency in decision-making. Keeping tariffs low is one popular objective, but it is inconsistent with expanding service coverage to the poor (unless a donor or government provides funds consistently over time). Thus, there is a clear need for a business plan that reflects reality. Similarly, a customer orientation promotes community and trust and supports the legitimacy of the water utility activities.

- Internal performance incentives: Uganda's National Water and Sewerage Company utilised incentives to meet targets (Muhairwe 2009). A strong case can be made that incentives and information are the cornerstones of good performance — both require that governance systems monitor trends over time and that boards take action when there is weak performance. Executives manage what they measure. One objective of a benchmarking study is to measure productivity and efficiency so that the analyst can make comparisons: productivity considers the link between utility inputs and outputs. Efficiency is related to productivity, but it involves establishing a standard and determining how close the firm comes to meeting that standard: how far is the utility from 'efficient practice'?
- Integrated information system: Data represent the raw material for decision-making. Investment decisions cannot be made in a vacuum. Maintenance requires an asset registry and information about reported leaks and customer complaints. Multi-period information on operations and financial conditions is essential for sound decision-making. Retaining historical data provides analysts with the opportunity to identify trends and conduct more robust statistical analyses. When managers make investment and operational decisions, they need to be clear about the objectives of the project, the techniques being used and the level of detail required for the dataset. The absence of such specificity limits accountability and diminishes organisational learning.
- Business plan: The combination of objectives, past outcomes and expected revenues, costs and other outlays serves as the basis for a business plan. Customer usage data and population growth can be used for forecasting likely future demand. Business plans serve as reality checks for decision-makers: are the cash flows reasonable and will the operational and expansion targets be met under current financial constraints? Will quality of service be improved under the business plan? This element of utility governance reinforces the need for a commercial orientation and for trained engineers and managers who can develop a sound business plan.
- Staff participation: Staff engagement is important for setting goals and developing incentives. Staff support requires that they have input into the business plan, performance incentives, and other aspects of utility operations. A top-down approach is not an effective way to run a complex organisation where information is widely diffused, and those in closest contact with customers and operations need to have a voice in how things are done. Given the potential importance of political appointments to the management of an organisation, there can be a lack of continuity within the regulatory agency. Also, staff training and capacity building may be given inadequate attention by top management.

These elements of governance and utility organisation lead to decisions that improve a utility's performance. Advocates (and incentives) for efficiency are crucial. Sound engineering is necessary, but not sufficient for improved utility performance. That means that governance within water utilities must be addressed (including selection of CEOs and boards of directors via non-patronage routes), just as external oversight of water utilities (sector regulators and government ministries) needs to be improved. Institutions matter — perhaps even more than money. As Rodriguez et al. (2013) emphasise, 'simply financing more water infrastructure and services — from public or private sources — will not solve the problem. Changing how the money is budgeted, targeted and executed is the proper place to start.'

Dr Sanford Berg earned his PhD in Economics from Yale University. His research has focused on infrastructure industries: the role of research and development in determining the basic industry conditions and the role of public policy in determining sector performance. Berg has examined the role of network industries in economic growth and the promotion of innovative approaches to improving water sector performance. He is the co-author of *Natural Monopoly Regulation: Principles and practice* (Cambridge University Press). He has published more than 100 articles on infrastructure issues, joint venture activity and innovation. A recent publication is *Water Utility Benchmarking: Measurement, methodologies, and performance incentives* (International Water Association Publishing, 2010). His email address is sberg@ufl.edu.

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20. Water, women and marital violence in a Bangladesh village

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The global water crisis has affected women and men in different ways. There is evidence that millions of women as a result carry a double burden of disadvantage from the water crisis (Wallace and Porter 2010; United Nations Development Programme (UNDP) 2006). In many instances, water development projects and water privatisation restrict women's access to water, further increasing their burden (UNDP 2006; Brown 2010). In rural Bangladesh, women are primarily responsible for domestic water use and men are mainly engaged in irrigation (Jordans and Zwarteveen 1997). Technology-intensive water development initiatives have, however, largely emphasised irrigation, thus facilitating men's water needs at the expense of women's (Sadeque 2000; Chadwick and Datta 1999).

Gendered roles and marital violence in rural Bangladesh

Marital male violence against women is widespread in rural Bangladesh. A recent study showed that almost 62 per cent of married women were subject to either physical or sexual violence by their husbands (García-Moreno et al. 2005). Women are not, however, abused randomly. Researchers mention many cases of wife battery being used as a punishment for failing to fulfill gendered household obligations (Baden et al. 1994; Bhuiya et al. 2003). In a recent study we explored the implications of a groundwater development project on women's workload and their exposure to marital violence (Karim et al. 2012). Fieldwork was conducted in a northwest Bangladesh village between July 2004 and July 2005.

The water development project

Groundwater was the only reliable source of water in the vicinity of the study village. There were three means of lifting groundwater: deep tube-wells (DTWs), shallow tube-wells (STWs) and hand pumps. DTWs and STWs are operated by motorised pumps and are exclusively used for irrigation, whereas shallow hand pumps are used for domestic purposes. In the dry season, however, only a few hand pumps lift water because of a lowering of the groundwater table (Jordans and Zwarteveen 1997). The project facilitated DTW-based irrigation, which contributed to an increase in the area's agricultural productivity; however, many households faced a domestic water shortage in the dry season because the extra irrigation further lowered the groundwater table.

Gender roles, dry season water crisis and women's workload

Women's water needs were mostly related to their domestic obligations, whereas men's water needs were mostly related to irrigation. The study estimated that, on average, a woman spent seven hours and 25 minutes daily on domestic water-related work, but a man spent only 19.2 minutes. In the dry season, to fulfill their obligations, women had to walk to distant wells, which resulted in an increase of their domestic workload (see Table 1). A number of women (15.1 per cent) also faced severe difficulties in fulfilling their obligations because of the extra time spent collecting water (see Table 1). Therefore, the development project actually reduced the ability of women to fulfill their normative gender role.

Table 1: Survey of dry season water shortage, increased workload and women's difficulties

	N		Frequency		Percentage
Households with domestic water shortage	196		87		44.4
Women's water-collection time increased	185*		102		55.1
Women's water-related workload			**Mean (%)**		**Range**
Normal water collection time (minutes/trip)	185		14.35 (7.63)		02–35
Dry season water collection time (minutes/trip)	185		18.75 (10.4)		02–45
Extra water collection time in the dry season after project (minutes/day)	185		20.6 (22.57)		00–90
Extra water collection time following the water development project (minutes/day for affected women)	102		37.4 (17.14)		14–90
Women's difficulty in fulfilling obligations	**Extra time spent (mins/day)**				**N = 185 (%)**
	0	< 30	30–59	≥ 60	
No/little	77	26	8	0	111 (60.0%)
Moderate	6	10	30	0	46 (24.9%)
Severe	0	1	11	16	28 (15.1%)

Source: Authors' research; adapted from Karim et al. 2012. *11 households that did not have any female members who carried out water-related work were excluded.

Women's obligations, increased workload, and marital violence

Data indicated that women were obliged to unconditionally obey their husbands. A 36-year-old woman exemplified this obligation: 'but I made a mistake, as I argued with him … .' The interviews also indicated that women were expected to manage time. A woman who had experienced violence said that it occurred as a punishment for failing to fulfill her household duties. It also illustrates how the lack of water contributed to make the situation worse:

> I went to fetch water … It took a long time because there was a long line … but when I came back, I saw that the man was home. He asked me to serve lunch … . I replied that it took a long time to collect water (as our nearest three hand pumps had dried out). But he said that it was my problem if other women can cook on time for their husbands! So when I told him to go to see the deep (DTW) … he got angry and started beating me … I did not argue anymore; rather I went to cook …

The other informants supported a perception of marital violence being very common and justified, for a range of reasons such as burning the food while cooking, not having washed the husband's clothes, or not making palatable food. Because the water crisis meant that women had to walk to distant wells, sometimes several times in a day, it directly challenged the basic gendered norm system and increased the possibility of socially justified violence.

Conclusion

The water development project largely facilitated men's irrigation water needs by installing DTWs. Irrigation water became available all year, whereas the domestic water supply decreased. Many women thus walked to distant wells for domestic water collection, which increased their workload. This challenged their possibilities of fulfilling household obligations, thereby increasing the risk of normative marital male violence against women as a punishment for their failure.

In a patriarchal social context, a gender-blind water development project may have severe negative consequences on the lives of many women. We suggest that any water sector projects (e.g., irrigation, fisheries, or health and sanitation projects) should take women's contextual gendered roles and obligations and social aspects of marital violence into account. Before implementation, there is a need to explore how the development project may influence or be influenced by social norms that determine the relationship between men and women. At the same time, it is important for development interventions to challenge the existing gendered norm systems and to initiate a discussion within the community on gendered roles, rights and obligations.

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Part 5: Energy

21. Energy

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Energy and water resources are critical for human wellbeing, but measures to secure their supply are inextricably linked and often conflict (Pittock 2011). Common to these resources is the need to supply a growing and wealthier global population while sustaining environmental health and responding to climate change. The following chapters explore key links between sustainable management of water and energy supply.

Energy

Currently the world's energy is overwhelmingly sourced by combusting fossil fuels, a process that emits dangerous levels of greenhouse gases. Thermal electricity generators, including fossil fuel and nuclear power stations, require large volumes of water for steam generation to drive turbines, as discussed by Byers (Chapter 22) and Spang (Chapter 23). To mitigate climate change and increase energy self-sufficiency, there is great interest in low-carbon and renewable energy sources. Many renewable energy generators, however, also consume large volumes of water (Gerbens-Leenes et al. 2008). First-generation biofuels consume (transpire) an order of magnitude more water than other energy sources. Evaporation from reservoirs makes hydropower another thirsty energy source. Solar thermal power stations and geothermal generators may also require a lot of water, depending on the technologies used. While wind and solar photovoltaic technologies use little water directly, the deployment of these intermittent generators may require energy storage technologies or complementary sources that do consume significant volumes of water, such as hydropower.

Natural gas may be a 'transition fuel' that emits less carbon per unit of energy as our societies work out how to decarbonise our energy supplies. The combination of new technology and desire to source low-carbon energy domestically is driving the rapid expansion in exploitation of unconventional gas resources globally. This is exemplified by the debate over development of a shale gas industry in India, as outlined by Biswas and Kirchherr (Chapter 25). These resources include shale and coal seam (coal bed methane) deposits that are accessed by drilling, dewatering relevant geological structures and hydraulic fracturing (fracking). Water resources may be impacted by dewatering of aquifers and pollution from some types of fracking fluids, well blowouts and disposal of production water, as discussed by Hildebrand et al. (Chapter 24). This example highlights the risk that well-meaning policies in one or a few sectors, such as energy and climate change, may have perverse impacts on sectors like water if they are not managed well. Hence future energy policies will depend on adequate consideration of water management (Hussey and Pittock 2012).

Water

Water resources are unevenly distributed around the world. A growing portion of the world's people live in water-scarce areas that are naturally dry, or where increasing populations reduce the per capita share. Around a third of the world's people lack access to improved sanitation services and a sixth do not have adequate drinking water supplies. In most cases there are technological interventions that can supply water to people, and the global water community has concluded that lack of funding (economic water scarcity) and poor governance are the main barriers to more sustainable management (World Water Assessment Programme (WWAP) 2009). Water requires a lot of energy to move and can require a lot of power to purify. From a positive perspective, reducing water demand can also reduce energy consumption. However, as water becomes more scarce, or polluted and requiring of treatment, or where the sources of water supply are diversified as an adaptation to climate change, then the energy required to secure supplies increases. The high energy consumption of desalination plants exemplifies this trade-off (Pittock et al. 2013). Better practices may bring positive synergies, for example, use of wastewater treatment to generate energy (Byers, Chapter 22).

Further, as freshwater ecosystems are the most species-rich per unit area, one consequence of the growing exploitation of water resources is a loss of biodiversity. Ecosystems services (such as fisheries) that millions of people depend on for their livelihoods are also diminished, as they are usually externalities in water infrastructure development decisions (Millennium Ecosystem Assessment (MEA) 2005). Orr (Chapter 26) (Orr et al. 2012) outlines a particularly stark example of hydropower development on the Mekong River. The dam developments are driven in part by China's climate change mitigation policy and will seriously impact on freshwater biodiversity, and diminish the wild fish supply that is the main source of protein for the people of the lower Mekong. The research projects the significant land and water resources required to produce protein supplies to replace the fish lost to hydropower and highlights the risks of negative impacts from poorly considered sectoral policies.

The nexus approach

The four following chapters, as introduced above, are examples of the energy–water trade-off that, in recent years, has been dubbed a 'nexus' (Hoff 2011). Many other sectors are closely linked with energy and water and various international forums have been considering nexuses, including the links between climate, energy, health, food and water policies and practices. It is worth asking whether this nexus approach is just the latest piece of academic jargon, or whether it provides a useful, new way to better manage positive synergies and trade-offs across sectors?

Critics of the approach note that the various nexuses identified are subsets of and a possible distraction from the broader need to implement sustainable development. A further criticism is the anthropogenic focus of the current resources framing of these nexuses that largely excludes consideration of biodiversity and other aspects of environmental health. A contrary perspective of nexuses is that they enable focused debate between specific sectors that may otherwise be frustrated by the complexity of sustainable development writ large. This may enable identification of tractable solutions among a few sectors that have lessons for resolving other complex, multidisciplinary, multi-sectoral problems. The challenge for people applying the nexus approach is to move beyond naming problems by focusing on elucidating practical solutions. In one typology, the solutions that emerge from research on the energy–water nexus, and other nexuses, fall into four categories (Pittock et al. 2013): providing and drawing on information across sectors in decision-making; applying new technologies; using market-based mechanisms to reduce externalities; and, enhancing regulation and other forms of governance.

This contribution and the five following chapters highlight the trade-offs between energy supply and water consumption. Hopefully these writings will inspire readers to redouble efforts to identify positive synergies and find ways to minimise negative trade-offs between the energy and water sectors and, as a result, among a range of sectors that are vital for the wellbeing of people and the environment.

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22. Water security at the energy crossroads

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Water, sanitation, and energy are undoubtedly keystone components of civil infrastructure that enable cities to support populations; they are the foundations of civilisation. The growth of megacities is, however, rapidly depleting water resources and leading to declining levels of water security across the world. Failure of critical infrastructure services, such as water and energy, can cripple a city in a matter of hours and leave millions vulnerable.

Yet that which is most dear to us is now often subject to complex interactions before we are able to access it. Energy is used for pumping, transport and treatment of water and wastewater; water is used through most stages of energy production and generation. But most of the resources used are non-renewable, often involve pollution and bring us closer to the planetary boundaries defining the safe operating space of humanity (Rockström et al. 2009). Should we continue propagating the interdependencies between energy and water or should, in some cases at least, we be working to decouple these two crucial resources?

In the current system, increasing demands on one usually means increasing demands on the other. But there are alternatives and, hence, water security finds itself at the 'energy crossroads' through the multitude of options available for alleviating scarcity issues; options which may use disparate levels of energy. On the other hand, water security also meets energy at the crossroads in a future that is partly governed by the water-intensity of future energy systems.

Increasingly, the analysis of water supply options is conducted considering the energy intensity of exploiting that resource. A variety of capital-intensive options to meet marginal demands may be evaluated, including desalination, wastewater recycling, inter-basin transfers and increased storage capacity. The uncertainties in the performance and utility of each option may, however, be large. These variabilities are driven by the energy sector and stem from variation in demand growth, energy price fluctuation and dependency on climate-vulnerable water resources. These uncertainties, amongst others, present a challenge in predicting future operational expenditure, the majority of which is usually energy costs. In the United Kingdom, higher water-quality standards have resulted in a doubling of energy use since the 1990s, and this is set to rise (Council for Science and Technology (CST) 2009); lower river flows during the more frequent droughts projected under climate change will require more stringent wastewater treatment as receiving bodies will have less capacity to dilute effluent (Hall et al. 2012).

Supply	Energy intensity kWh/Ml	Source and notes
Conventional	500-900	Water UK 2010; Perrone et al. 2011. Variable on plant size.
Water recycling	2,500-6,500	Water UK 2010; Perrone et al. 2011. Depends on level of treatment, Primary, Secondary, Advanced.
Desalination • **Brackish** • **Sea water**	 9,500-22,000 34,000100,000	Perrone et al. 2011; WRA (2011) Variable on water salinity and technology, and some of the energy demand can be met through waste heat or solar PV.
Imported water	0.04	Derived from Sampson et al. 2007, into kWh/Ml/km distance/ ΣΔm positive elevation from source to treatment.

Figure 1: Ranges of energy intensity for different water supply options can vary by orders of magnitude. With depleted resources, however, energy intensive supply is increasingly competitive

Source: See table.

There is, however, great benefit in decoupling this nexus of water and energy use. One irony is that wastewater has a chemical energy content higher than the energy required to treat it, the former just needs to be harnessed (Heidrich et al. 2011). Increasingly, anaerobic digestion (AD) is being deployed around the world in both high-tech and low-tech configurations. AD is the breakdown of biodegradeable matter in the absence of oxygen and can be used to treat both solid and liquid waste. Biogas is one of the main byproducts and consists mostly of methane, which can be burnt for electricity generation, heating or cooking. AD applications in developed countries will play a small part towards energy security and low carbon energy supply, whilst flipping the energy balance of wastewater treatment. In less developed countries, AD can provide a meaningful step towards proper sanitation and associated health benefits, whilst free biogas used for cooking drastically reduces indoor air pollution, a killer of 1.5 million women and children each year (World Health Organization (WHO) 2006). Conversely, seawater desalination and long-distance transport and pumping, such as the California State Water Project and the Central Arizona Project, result in roughly ten times the energy intensity of conventional treatment facilities (Water Reuse Association (WRA) 2011) due to the long distances, evaporation losses and changes in elevation.

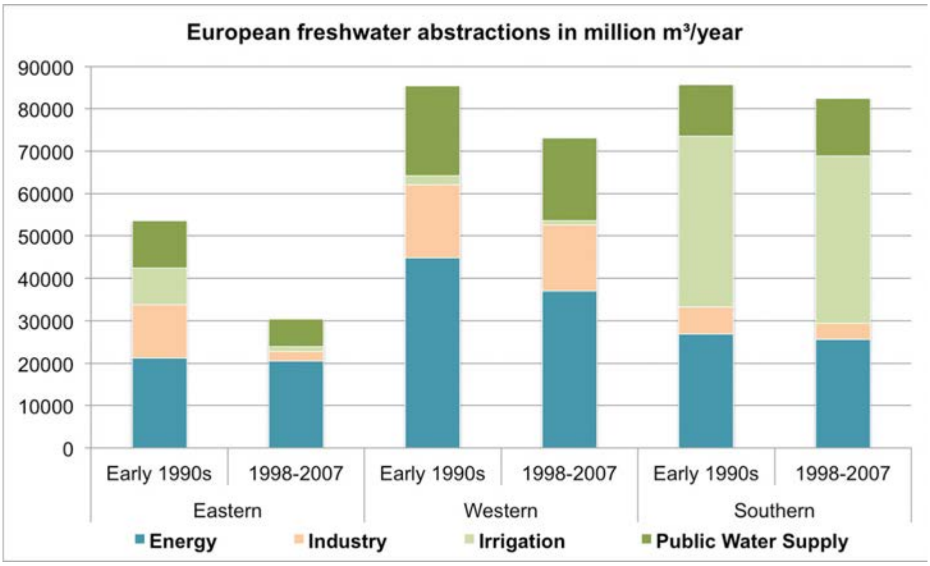

Figure 2: Freshwater abstractions by the energy sector are decreasing, yet the proportions remain substantial

Source: EEA 2010.

In many countries, energy is produced by thermoelectric power stations on surface waters abstracting proportions of cooling water far exceeding those taken for public water supply and often matching agriculture (United Kingdom: 56 per cent, United States: 41 per cent, Europe: 45 per cent; see Figure 2 for further details on Europe). Most is returned, but evaporative losses from cooling towers can reduce this amount by 75 per cent. Energy demands are growing, thermal efficiencies are not improving rapidly enough, and power plants with carbon capture and storage (CCS) increase water consumption in the order of 80 per cent (National Energy Technology Laboratory (NETL) 2009). The strong prospects for shale gas and coal with CCS look set to lock electricity supply into another half-century of water-thirsty power plants. Even the fuels used require water for extraction and processing, leading to contamination. In recent years, thermoelectric nuclear and fossil fuel plants in the United States, Europe and China have faced output reduction and even shutdown due to low river flows and high water temperatures (Averyt et al. 2012; Pan et al. 2012 *Economist* 2013), a problem that is expected to worsen with climate change (van Vilet et al. 2012). Alternatives to water-intensive energy supply do exist, mostly in the form of some renewables and more strategic siting of power stations and grid balancing. But in order to play the crucial role of increasing both energy and water security, the benefits of the options need to be recognised in planning processes, alongside caveats that may include lower efficiencies and higher costs.

Capital investment projects in both sectors lock in decisions for decades that span considerable uncertainty. Short-term demand reductions and market mechanisms can ameliorate cross-sector risks, but the resource interdependencies will remain. Thus long-term planning that reduces critical resource interdependencies and improves performance under wide ranges of uncertainty, such as climatic changes or geo-political risks, is needed.

In its current state, the energy sector poses unacceptable risks to the public water supply and agriculture sectors that must be addressed with robust decisions encompassing sustainability, security of supply and affordability. Whilst the challenges facing each sector of the water–energy–food nexus are great in themselves, decision-makers must recognise the win-win-win opportunities that are presented by tackling them together, which are elegantly summed up by Wangari Maathai (2012), 'Our planet is finite, our fates are intertwined, our choice is clear — stand together or fall divided.'

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23. A thirst for power: A global analysis of water consumption for energy production

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Water and energy resource systems are fundamentally interrelated. Secure and reliable access to both resources is critical to basic survival, as well as ongoing economic development at all scales and in every region of the world. At the most basic level, water is required in the production of energy, and energy is required in the treatment and transport of water — a linked relationship known as the water–energy nexus. While both sides of the water–energy nexus merit attention for improving resource use, this research effort focuses on the water requirements of energy systems and the associated implications for national water security.

As competition for finite freshwater resources intensifies around the world, it is increasingly important to balance the demand for water across multiple sectors while also protecting ecosystems (Palaniappan et al. 2008). Understanding the water demand of energy systems is fundamental to overall national water security, since the production of energy requires significant quantities of freshwater. While agricultural demand dominates overall demand for water in many regions of the world (United Nations Educational, Scientific and Cultural Organisation (UNESCO) 2003), the demand for water from the energy sector can be a major competitor. In the United States it is a relatively even split between water withdrawals for irrigating crops (40 per cent of total) and for cooling thermoelectric power plants (39 per cent) (Department of Energy (DOE) 2006). Further, the division between agricultural and energy-based demand for water is no longer straightforward as irrigated crops are increasingly being converted to biofuels in many regions (Gerbens-Leenes et al. 2009).

The quantity of water consumed by the energy sector varies substantially by the technology deployed for fuel extraction and processing (fossil fuels, nuclear fuels and biofuels) as well as electricity production (thermoelectric and renewable technologies). As a regional portfolio of energy production technologies changes or expands, there is an associated fluctuation in the burden on local water resources. Figure 1 represents a consolidation from the literature of water consumption estimates for a variety of energy technologies (note that the estimates are provided in log scale to show variability within and across technology categories).

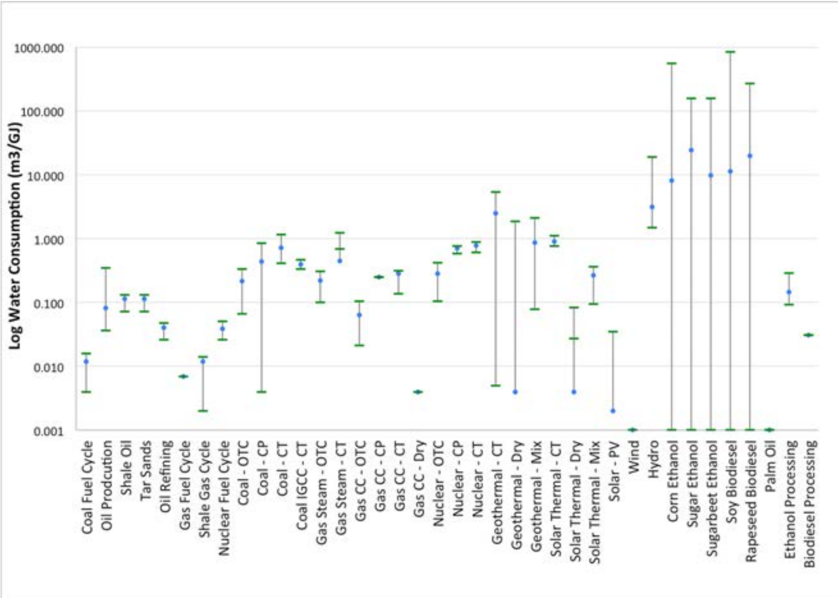

Figure 1: Water consumption coefficients for energy technologies (log scale)

Source: Gleick 1994; Fthenakis and Kim 2010; Mekonnen and Hoekstra 2010; Mielke et al. 2010; Macknick et al. 2011; Wu et al. 2009; National Renewable Energy Laboratory (NREL) 2010; Mittal 2010.

Given the potential impacts of energy policy decisions on regional water security, the application of metrics to assess the water burden of national energy portfolios is underdeveloped. Most of the literature has focused on estimating: the water consumption of specific energy technologies (see sources listed for Figure 1); country-level or regional analyses of water consumption across a complete energy portfolio (DOE 2006; Elcock 2010); or, a global analysis of water consumption by a single energy type (Vassolo and Döll 2010). A clear estimation of water consumption for complete national energy portfolios at the global scale does not, however, currently exist.

This research addresses this knowledge gap by synthesising and expanding previous work to develop a global distribution of water consumption by national-level energy portfolios. The water consumption for energy production (WCEP) indicator was defined and calculated to quantify the relative water use of 158 national energy systems. WCEP is an estimation of freshwater consumption across all energy categories, including fossil fuels, nuclear fuels, biofuels and electricity production. Hydroelectricity is not included in the analysis because its associated water consumption (often defined as the estimated evaporation from the reservoir) is only partially linked to energy consumption. The majority of dams serve multiple purposes, including the essential water security services of flood control and water storage (Briscoe 2009). An overview of the global results of the WCEP assessment is provided in map form in Figure 2.

Research results estimate global WCEP at approximately 45 billion cubic metres of water per year. Of course, there is high variability in the WCEP across the 158 countries that were assessed (ranging from nearly zero to 12.6 billion cubic meters). As expected, larger countries with greater economic activity had the highest WCEP values. In terms of the per capita estimates for WCEP, the countries that were heavy producers of fossil fuel or biofuels demonstrated greater intensity of energy-based water consumption (see Figure 3). These results suggest that the economic imperative to develop fossil fuels drives higher WCEP, even in countries that lack sufficient water supplies. Meanwhile, biofuels require so much water that any national commitment to their production has significant water consumption implications.

While these results are based on a comprehensive review of currently available data, future research in this area could be significantly enhanced through better data and widespread adoption of consistent reporting mechanisms. Additional opportunities to expand the field include increasing the resolution of the study regions, characterising WCEP trends over time, and exploring innovative policy approaches to managing national WCEP effectively.

This research contributes an improved set of metrics to characterise the baseline conditions of integrated water–energy systems. By benchmarking water consumption for energy to standard measures, policy-makers can better understand and track the status of this coupled system. They are then able to set targets to minimise water consumption, or at least understand some of the water implications of particular energy policy initiatives. Given the critical role that the monitoring of greenhouse gas emissions has played in shaping energy portfolios, it is time to similarly incorporate water consumption implications into energy portfolio planning.

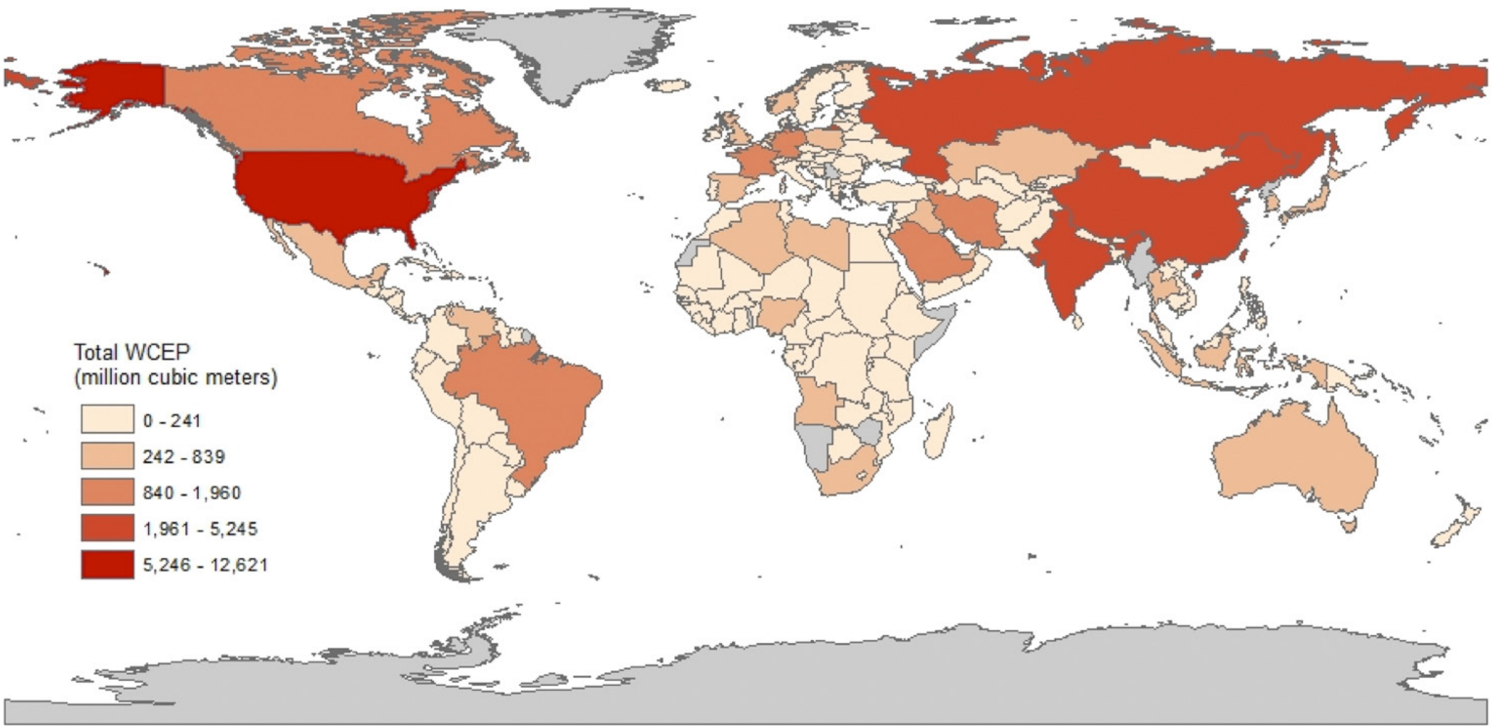

Figure 2: International results map for WCEP calculations

Source: Author's research.

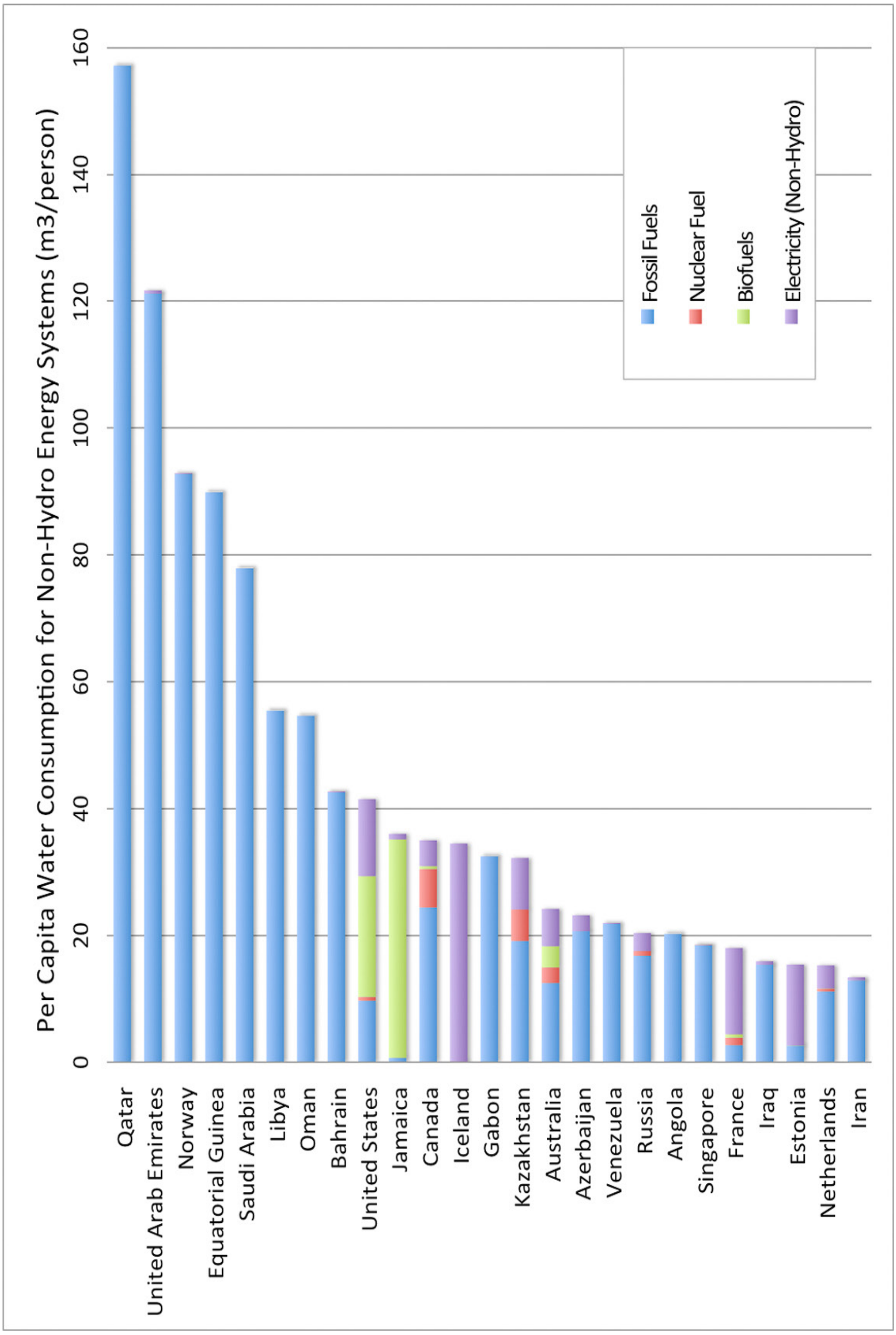

Figure 3: Per capita water consumption for non-hydropower energy systems

Source: Author' research.

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24. New perspectives on the effects of natural gas extraction on groundwater quality

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Over the past decade natural gas has emerged as a versatile source of energy and has been described as a transition fuel. It has facilitated the shift from coal to renewable energy resources while helping reduce CO_2 emissions and curtail the power sector's production of industrial chemicals (Vidic et al. 2013). Advancements in unconventional drilling techniques, such as hydraulic fracturing and shale acidisation, have made the extraction of natural gas from previously inaccessible deep shale formations both practical and profitable.

Hydraulic fracturing involves a pressurised injection of water, proppants and chemical additives to expand fissures or fractures in shale formation to release trapped gases. Acidisation uses large quantities of hydrochloric acid under low pressure to dissolve sediments and solids, which serves to increase the permeability of the shale formation.

Despite the effectiveness of these technologies in liberating sequestered natural gas, they are not without environmental risk and are a cause for concern in today's society. Anxieties over environmental stewardship, in conjunction with the prospect of using natural gas as a catalyst in achieving energy independence, have provided the impetus for a number of investigations designed to characterise the relationship between unconventional gas extraction and groundwater quality.

At the forefront of the unconventional natural gas extraction discussion are concerns over the potential migration of methane gas, the leaching of harmful chemical compounds and the mishandling of produced waste. Each of these can have potentially negative effects on the surrounding groundwater. In areas where deep shale formations co-exist with shallow aquifers, methane — the main component of natural gas — can leach into private water wells from both natural and anthropogenic processes (Vidic et al. 2013).

Methane occurs naturally in two forms, biogenic methane and thermogenic methane. Biogenic methane is produced at shallow depths as a byproduct of bacterial metabolism. Thermogenic methane, the primary target of unconventional natural gas extraction, is formed by geological processes at depths exceeding 1000 metres as a function of high temperature and pressure transforming decomposing organic material into methane gas.

Isotopic (Osborn et al. 2011) and hydrocarbon ratio (Jackson, R.B. et al. 2013) analyses have been used to determine the source of methane found in private water wells in the Marcellus shale of Pennsylvania. The majority of methane detected was characteristic of deep, thermogenic methane that could only have been liberated through unconventional drilling activities. Methane was detected in approximately 80 per cent of the collected samples (Osborn et al. 2011) with concentrations reaching their highest levels in close proximity to natural gas wells. The root cause of methane contamination events could be attributed to the opening of fractures by unconventional drilling activities that allowed thermogenic methane to migrate into water wells from abandoned historical gas wells (Jackson, R.E. et al. 2013).

In the case of Pennsylvania, approximately 350,000 legacy oil and gas wells have been drilled and the exact locations of ~100,000 of these are unknown (Pennsylvania Department of Environmental Protection). Additionally, instances of methane and chemical contamination can result from gas-well casing failures, a phenomenon that occurs in approximately three per cent of new gas well operations (Vidic et al. 2013). Changes induced by hydraulic fracturing can also facilitate advective transport of fracturing fluid and flowback into groundwater aquifers depending on the hydraulic conductivity and the presence of water-filled voids in the geological formation (Saiers and Barth 2012).

In addition to the aforementioned pathways where groundwater can be directly affected by unconventional drilling activity, our research team at The University of Texas at Arlington has examined the effects of unconventional natural gas extraction on groundwater quality and found evidence for indirect mechanisms that could potentially lead to groundwater contamination (Fontenot et al. 2013).

In a recent peer-reviewed study published in *Environmental Science and Technology*, our team sampled 100 private water wells to assess the potential effects of natural gas extraction on water quality in the Barnett Shale formation of north Texas (see Figure 1). Our analyses revealed levels of heavy metals above the US Environmental Protection Agency's Maximum Contaminant Limit (MCL) for drinking water in private water well samples collected near natural gas extraction sites. Most notably, 29 of the 91 samples collected within five kilometres of an active natural gas extraction site had arsenic concentrations above the MCL of ten parts per billion (ppb), with a maximum concentration of 161 ppb.

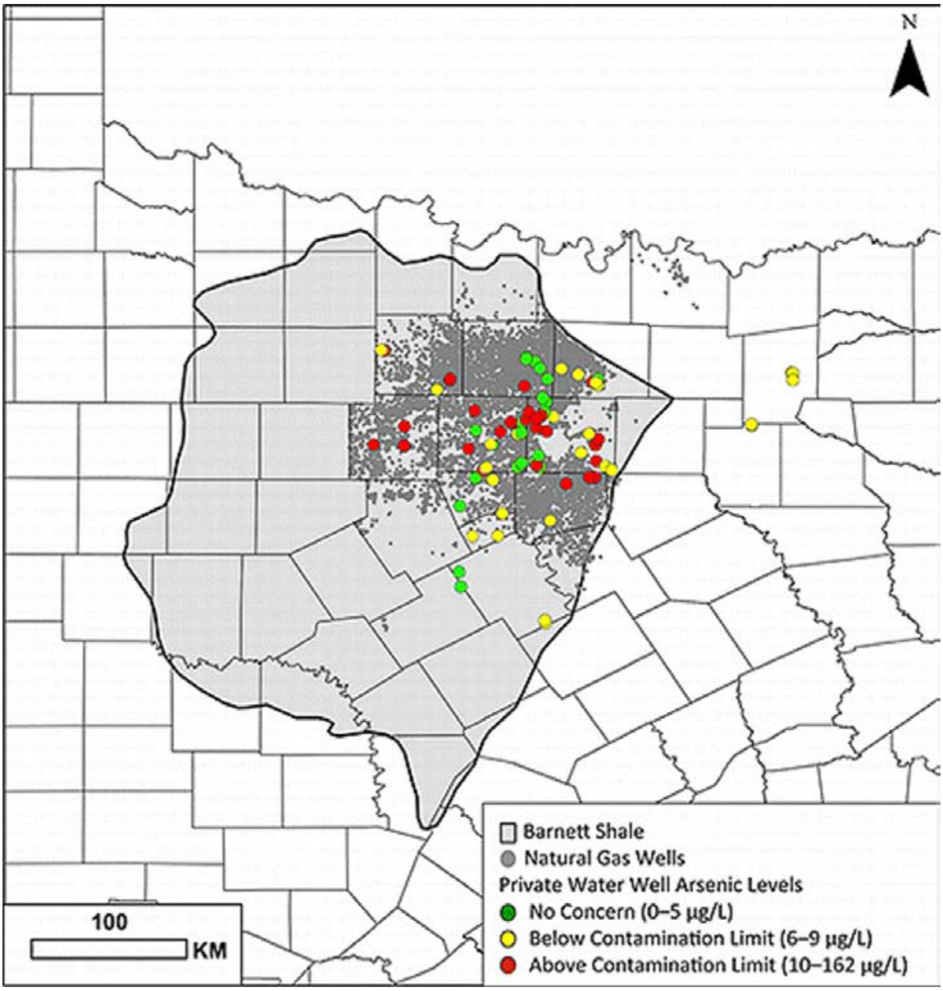

Figure 1: Map of the Barnett Shale aquifer and the study area

Source: Reprinted with permission from Fontenot et al. 2013. Copyright 2013 (American Chemical Society).

The maximum concentration discovered in one well was nearly 18 times greater than both the maximum concentration sampled from private water well samples located more than 14 kilometres from any active gas wells and the maximum concentration sampled from historical data collected in the Barnett Shale prior to the expansion of unconventional extraction activities (http://www.twdb.state.tx.us/groundwater/data/). We also found selenium and strontium at elevated concentrations, with selenium detected exclusively within two kilometres of natural gas wells.

One plausible explanation for the observed results involves large withdrawals of groundwater used in hydraulic fracturing operations that could cause localised declines in the water table. Such decreases can be associated with higher arsenic content in waters drawn from shallow water wells (Reedy et al. 2007). Another scenario to explain elevated heavy metals could be the mechanical vibrations produced from unconventional drilling activity. In this scenario, vibrations from nearby intense drilling activity could mechanically disturb a poorly maintained private water well that has accumulated rust, sulfate and/or carbonate scale. Once the rust and scale in the water well are disturbed, arsenic, selenium and strontium that were previously bound in oxide complexes could be mechanically liberated and released into the well water (Fontenot et al. 2013).

Our understanding of the relationship between groundwater quality and unconventional natural gas extraction is evolving. Future studies should focus not only on direct mechanisms of contamination from unconventional drilling activities such as fluid and methane leaks, but also on indirect mechanisms that could potentially lead to groundwater contamination. Additionally, a greater emphasis needs to be placed on the collection of baseline measurements prior to unconventional drilling activities.

In highly productive regions like the Bakken shale formation of North Dakota, or the Barnett, Eagle Ford and Wolfcamp shales of Texas, drilling operators are not required to perform baseline testing, making the characterisation of potential industrial contamination events extremely difficult. California is one of several states that have proposed legislation where groundwater monitoring efforts would be required before and after any well stimulation, as well as proposals for procedures to safely recycle or dispose of produced and flowback wastewaters. Whether these proposed laws are established and become more widely accepted remains to be determined. Regardless, the collection of baseline measurements prior to any natural gas extraction is the most direct way to quantify the environmental effects of unconventional drilling activity, and will greatly enhance our understanding of the relationship between shale gas extraction and groundwater quality.

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25. Shale gas for energy security in India: Perspectives and constraints

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India lacks energy. In 2011, almost 300 million people — 25 per cent of the country's population — had no access to electricity. Even 65 years after independence, only nine states — Andhra Pradesh, Gujarat, Karnataka, Goa, Delhi, Haryana, Kerala, Punjab, and Tamil Nadu — out of a total of 28 have been officially declared as electrified (British Broadcasting Corporation (BBC) 2012). But even in these so-called electrified states, power shortages and power cuts are often common. In July 2012, the worst energy blackout in a decade left more than 620 million Indians without electricity, and total energy demand currently outstrips supply by as much as 15 per cent.

Chronic energy shortages and unreliable supplies threaten India's economic growth. For investors, continuous and reliable supplies of energy are essential requirements for any ventures. According to estimates by HDFC Bank, the country's chronic energy shortages have already slowed down GDP growth from 8 per cent to 6.5 per cent (*Economic Times* 2012). With accelerating energy demand, poor management, political and institutional inertia and bureaucratic constraints, India's energy gap is likely to remain for at least the next two decades. Policy-makers are urgently seeking solutions to ensure that the economy is not starved of energy.

Shale gas in India

Shale gas is a possible solution and the Indian Government plans to exploit the country's shale gas resources to address the country's energy problems. In September 2013 a shale gas exploration policy was released allowing two state-run institutions, Oil and Natural Gas Corporation and Oil India Limited, to explore shale gas that was previously allotted to them on a nomination basis. During the next phase, the government may offer shale oil and gas blocks to other companies.

It has been estimated that India may have recoverable shale gas reserves of as much as 96 trillion cubic feet; the exact amount is still unknown (livemint 2012). Large reserves have been confirmed in Khambhat, Assam-Arakan, Gondawana, and Cauvery. Currently, gas accounts for approximately 11 per cent of the country's energy mix, nearly half of energy consumed is generated from coal, followed by hydropower at 25 per cent.

Shale gas now receives attention in many countries of the world. The International Energy Agency (IEA) has even announced that the world could enter a 'golden age of gas' (2011). Indeed, shale gas has turned the US energy market on its head and the country is about to switch from being a gas importer to a major exporter.[1] China, which is estimated to hold the world's largest shale gas resources, aims to replicate this American success story, with plans to produce as much as 3500 billion cubic feet of shale gas annually by 2020.

Technological and hydrological constraints on shale gas development

While the excitement in India over shale gas is understandable, it may be premature for two reasons.

First, India lacks the technological capabilities necessary to access its reserves. Hydraulic fracturing, commonly known as fracking, is the sophisticated and complex technique by which shale gas is exploited. Currently, only North America — with its favourable geology — has been able to exploit shale gas commercially on a large scale. India would have to enter countless strategic and long-term partnerships with foreign governments and private sector companies to acquire these technologies and skills and adapt them to its specific geology. This will take time and is unlikely to be as straight-forward as its proponents suggest.

Second, extensive exploitation of shale gas in India is likely to devastate the country's water resources, offsetting any social benefit from increased energy production by worsening India's water crisis. The main constraint in this regard is likely to be India's failure to treat wastewater. Exploiting shale gas requires massive amounts of water which becomes heavily contaminated during the exploitation process (Cooley and Donnelly 2012). There is now considerable uncertainty over whether it is possible to cost-effectively recycle shale gas wastewater (Ferrar et al. 2013). Because the growth of the American industry has outpaced regulatory guidelines, it is not yet possible to test systematically

1 The US shale gas industry grew by 45 per cent per year between 2005 and 2010 (*Economist* 2012a), reducing the American gas price from US$30.00 to as little as US$03.00 per million British thermal units (mBtu) (*Economist* 2012b).

and objectively if the treatment has been sufficient or appropriate. It is known, however, that the exploitation of shale gas can lead to the migration of toxic injection fluids into water sources, which may later be used for drinking, and contamination of groundwater by released methane gas also entails a range of health risks.[2]

India is, sadly, a world leader in water pollution: the Holy Ganges contains more than 60,000 faecal coliform bacteria per 100 millilitres in many parts, which is 120 times more than what is considered safe for bathing (*Economist* 2008). In most parts of the country, including the capital region Delhi, sewage is disposed of to nearby rivers without any treatment. This is because India lacks sufficient treatment capacity and, even where such treatment plants exist, their proper operation and maintenance practices have been often poor.

In a country with such a record of wastewater treatment, it may be unrealistic to expect that wastewater from shale gas exploitation would be adequately treated. Indeed, even in the United States, with its record of wastewater treatment, there have been many reports of improperly disposed toxic wastewater from the fracking process. If India acquired the necessary technology and expertise to exploit shale gas, it may still fail to treat the resulting wastewater. Such a failure may offset any energy gain. For India's poor, clean water often may be more important than access to energy.

For fracking to be practiced widely in India, the country will also have to allocate significant new sources of water. At present, because of poor management of water, the country is facing serious scarcity of water in most regions (Biswas 2011). The interstate disputes on water are already fierce and the water available in the country is already over-allocated. The groundwater levels in provinces like Punjab, Haryana, Rajasthan, Gujarat and Maharashtra are declining precipitously. There is not a single important city which can provide 24-hour water supply to its citizens. Since water is free or heavily subsidised, and there is significant political opposition to water pricing, widespread water conservation is an unrealistic proposition for the foreseeable future. Under these conditions, it is unlikely that India will be able to divert water to a new, intensive use like fracking.

Outlook

The global perception of shale gas and its potential is still evolving. Hence, India may take the wrong path if it attempts to exploit its shale gas resources without considering the serious and unintended consequences.

2 See Hildenbrand et al. (2014) in this volume for further discussion of fracking impacts on groundwater quality.

India must first carefully reassess the size and value of its recoverable shale gas reserves and weigh the potential benefits against the risks, particularly those related to water. Only if sufficient reserves are available and more pressing policy challenges are faced, should India then continue to build up its technological shale gas capabilities.

Notably, India has already started to emphasise addressing some of the relevant policy challenges, particularly improving energy use and water efficiency. Faced with looming water and energy scarcities, many major industrial concerns are changing their industrial processes and practices.[3]

Despite such positive trends, India's energy and water problems will most certainly continue to increase if the aspirations and expectations of its people are to be met. For example, India is now already the fourth largest energy consuming country of the world, yet its per capita energy consumption is low and it will continue to increase for decades, irrespective of all conservation measures. The country has to focus on the difficult task of concurrently expanding its energy sources *and* increasing energy conservation. Proponents will likely continue to propose shale gas as an option to address the first of these challenges.

On the other hand, water has become an increasingly critical resource in the country, primarily because of poor management. During the campaign for the 2014 general election, for the first time water has become a part of the electoral strategy of all the major parties. Thus, there is no question that current and future water scarcities mean widespread fracking, even if it was possible at present, is not a viable option. Furthermore, legal and administrative arrangements for the land acquisition required for fracking are more complicated in India compared to the United States, and there are also the aforementioned technological barriers.

In some ways, these constraints may prove to be a blessing in disguise for the country. The delay in solving the institutional, legal, land and water-related problems will take at least a decade to overcome. One hopes that during this period the country can assess carefully and objectively the economic benefits and social and environmental costs of fracking so that the right decision can be made for the future.

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3 For example, between 1997–2012, Nestlé India reduced its water requirements to produce a tonne of product by 74.3 per cent, and energy needs by 65 per cent (Authors' research).

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26. Dams on the Mekong

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Recent research carried out by World Wide Fund for Nature (WWF) and The Australian National University (ANU) reveals the indirect impacts of 11 dams that are proposed to be built on the mainstream of the lower Mekong River (Orr et al. 2012). The study evaluates the volume of additional water (i.e., the water footprint) and area of land (i.e., the land footprint) that would be required for the four Lower Mekong Basin (LMB) nations to replace calorie and protein loss from changes in fish catches following dam construction.

The water footprint and agricultural land analyses presented in this study are based on the available data. While limitations on this data mean that the specific results may be contested, the research highlights the need for a more detailed understanding of the indirect consequences of the proposed dams in order to better inform decision-making.

Background

A recent strategic environmental assessment (SEA) of hydropower on the Mekong mainstream concluded that such projects would have significant negative impacts on both the fishery and agricultural sectors (International Center for Environmental Management (ICEM) 2010a, 2010b). The losses in fisheries due to the mainstream dams were estimated to be US$476 million per year, excluding effects on the coastal and delta fisheries. In addition, the assessment found that 54 per cent of all riverbank gardens along the Mekong would be inundated, which, combined with losses in agricultural land for reservoirs and transmission lines, was estimated to cost US$25.1 million per year.

Estimates of the freshwater fisheries catch in the LMB vary and, as such, WWF has relied on the most recent Mekong River Commission (MRC) assessments for the purposes of this research (Baran and Myschowoda 2009). On the basis of this data, the annual yield is estimated to be around 2.6 million tonnes, or two per cent of global marine and freshwater fisheries landings. The per capita freshwater fish consumption in the region is 33.7 kilograms per year, or around 80 grams per person per day for each of the 60 million people in the basin. The economic value of the LMB wild migratory fishery is US$2.5 billion.

Research

The research undertaken by WWF and the ANU estimated the land and water requirements for alternative livestock protein sources, assuming that the 11 proposed mainstream dams lead to a reduction in fish production of 60–70 per cent, which is a major source of dietary protein for the people of the lower Mekong basin.

It is important to note that people might adopt any number of dietary habits to substitute the loss of calories and protein from fish. The dynamics of consumer behaviour are complex and this study was limited to the most plausible scenario: that the share of meat proteins consumed in the LMB nations would increase in response to a fall in fish production. While vegetable protein intake could also increase and would come with its own costs, such scenarios have not been considered in this research and should be explored in further research.

By assuming an increase in the demand for meat protein to replace lost fish catches, our calculations suggest that water consumption for livestock protein production — the water footprint — will increase from six per cent to 17 per cent and will be considerably higher in Cambodia and Laos. Southeast Asia as a whole is not water scarce; however, such a major increase in consumption is likely to have significant opportunity costs. Substantial volumes of water in the natural environment are needed to sustain important ecosystem services in the basin, such as capture fisheries, low-input flood recession agriculture and maintenance of the delta. The proposed hydropower reservoirs would have a land footprint of at least 14,865 square kilometres (km^2)—including 1350 km^2 of land proposed to be inundated for the dams—and this area of land includes some of the most productive riverside farmland in the LMB.

In addition, the area of pasture land required to replace fish protein with domestic livestock was estimated to range from 7080 to 24,188 km^2 (13 per cent to 63 per cent). This will not be easy given that high quality agricultural land in the region is already occupied and agricultural rates of conversion are stagnant.

Consequently, the change in protein away from local river fisheries will have substantial social, economic and environmental implications, including greater water consumption, land use conversion and greater reliance on imports. Increased food prices associated with higher costs of livestock production could impact the poor and exacerbate poverty.

The supporting institutional and investment infrastructure required to accommodate these changes is substantial, yet the issues of ensuring that dam construction does not impact the food sources of vulnerable populations have been overlooked. All stakeholders should be entitled to know what alternatives and strategies are in place for any situation where basic food supplies are at such a high risk of disruption.

Conclusion

Hydropower development is often justified by the projections of social and economic advantages, using assessment processes that are narrowly focused on the environmental and social impacts of the areas directly impacted by dam construction and inundation (World Commission on Dams (WCD) 2000). Indeed, the current assessment processes underway for the proposed dams on the main stem of the LMB appear to mirror this approach.

The data used in our assessment is the best available and these findings are first approximations of land and water requirements resulting from the proposed dams. The methods adopted here to estimate the impact on protein supplies due to dam construction are conservative in the use of SEA assessments of the loss in fish production and scaling up supply of other proteins in proportion to their existing consumption.

Further, the data used here does not yet account for future population increases and resulting demand for protein. Similarly, other possible protein scenarios could be modelled and would add considerably to a wider understanding of the impacts and options available. Comprehensive estimations are required to establish detailed accounting of food costs, land and water use and access, livelihoods, equity and poverty. Studies for individual nations would determine a wider range of impacts and should be used to explore the institutional challenges that lay ahead. In this manner, the benefits of dams can be better compared to the negative trade-offs involved.

Regulatory authorities for these dam projects have an obligation to draw on the best available data to ensure their decisions optimise the benefits for their citizens and the environment.

Stuart Orr has been with WWF since 2006 and works with the private sector on a range of water-related issues. Orr has published mainly on water risk and water stewardship and has recently co-drafted guidelines for the United Nations compact on corporate engagement in water policy. He has an academic and research background in agricultural systems and water resource management and has worked for many years in the private sector in Asia and the United States.

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Part 6: Water concepts

27. Water concepts

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While Integrated Water Resources Management (IWRM) remains the dominant concept informing water policy and management, the sector is now replete with others that are used by scholars and practitioners alike. For example, 'water security', 'hydropolitics', 'virtual water', water as a critical component of the 'energy-water-food nexus', 'water-sensitive-urban-design' and the typology of green, blue and grey water are all relatively new concepts with a degree of currency in the water sector. The emergence of broader concepts, such as 'ecosystem services' and 'resilience', are also influential in discourses on water resources. In addition, the last 20 years has spawned new tools for managing water resources, many of which are infused with the key tenets of neoclassical economics, and terms like 'water trading', 'water harvesting', 'water footprinting' and 'water pricing' are now part of the sector's vernacular.

Of course, the emergence of so many concepts, indicators and tools reflects our increasing understanding of the challenges that humanity faces in managing water resources. We have moved beyond a blunt appreciation of 'droughts' and 'floods' to a nuanced appreciation of the degrees of impact afflicting different jurisdictions and the underlying causes of those impacts; hence the formulation of concepts such as 'water stress', 'water deficit' and 'water scarcity'. Similarly, where once we might simply have referred to floods in relation to water-related natural disasters, significant breakthroughs in climate science have afforded considerable understanding about the reasons for, consequences of, and connections between, sea-level rise, flash floods, and storm surges. The consequence of this knowledge and the conceptual thinking it has spawned is that a jurisdiction's ability to undertake detailed and rigorous water profiling is significantly enhanced, but it also makes any subsequent debates about appropriate policy interventions more complex.

It is, as they say, a crowded space.

But what should we make of this plethora of concepts informing water policy and management? How can so many concepts and indicators be understood and reconciled? Do they 'speak' to different audiences? Are they sufficiently different as to be individually useful and collectively complementary? Is there evidence that each successive, new concept is building on, and adding value to, the concepts that came before it? The authors in this section make excellent contributions to our understanding of the key concepts and indicators at play in the water sector and in 'unpacking' these questions. All the chapters identify differences in the way key concepts are defined, measured, and applied in policy and investment decisions; and many question the benefits to be gained from so many 'new' concepts.

In his critique of 'water scarcity', White (Chapter 28) grapples with the inherent tension that exists between the ease of using straight-forward indicators based on easily accessible data, with the contextual nuances and detail that is inevitably lost when more complicated indices are used. The existence of several definitions of water scarcity (he explores four), and indeed the different measures to capture aspects of it, can result in varied, sometimes contradictory, findings in relation to a region's water stress. It is, therefore, important to understand which definition is 'fit for purpose', and to avoid relying on any single measure. A region's capacity to employ multiple indices in decision-making will, however, necessarily be constrained by the skills, knowledge, and data available to it, suggesting that even if definitional clarity is achieved, the value of using such concepts remains a direct function of the institutional capacity in that region.

One of the most interesting developments in recent years has been the emergence of *non-traditional* security threats, and in particular the concept of 'environmental security' (Dalby 2002). The appeal of 'securitisation' as a conceptual frame lies in its realist roots: it is a familiar concept and draws considerable favour with the powers-that-be, not least because security issues are almost always in the purview of national governments. As a consequence, debates about environmental issues are afforded considerably more attention than might otherwise be the case — or so the argument goes. Interestingly, environmental security was very quickly disaggregated into 'climate security', 'energy security', and 'water security', and it is the meaning and practical utility of the latter concept to which Lautze and Manthrithilake (Chapter 29) turn their attention. Specifically, their article is a plea for the concept of 'water security' to be defined in such a way as to be practically applied, and their suggestion is to develop some quantifiable criteria against which to evaluate a region's water security — even though they are openly sceptical about the value of promoting yet another concept in this crowded space.

Wichelns (Chapter 30) is similarly cautious in his chapter on the use of the 'water footprint' as a tool to inform policy. Of all the concepts and terms to emerge recently, surely it is water footprinting that has captured the imaginations of the public and politicians most completely. Certainly, there is something very appealing about distilling what is a very complex problem into a single, simple unit of measurement, but as Wichelns most ably demonstrates, the use of such an overly simplistic tool in isolation from other indicators could do more harm than good. And yet it persists and its use proliferates.

The wariness of new concepts continues in the next chapter, in which Iyer (Chapter 31) provides both an amusing and forensic analysis of the current misunderstandings of virtual water. Correctly, Iyer points to the misuse of 'virtual water' in debates about the import and export of different products and the desire by many to use the term to inform the validity or otherwise of countries producing and exporting certain commodities. In this regard, Iyer points to the penchant for neo-liberal economic philosophy as a contributing factor, but whatever the cause, his projections of where the concept of virtual water might inadvertently take us is almost Kafkaesque, and delightfully so.

Reimer (Chapter 32) responds to Iyer and argues that, instead of dismissing the concept, 'virtual water' should be redefined in line with existing practice in international trade theory. In essence, Reimer calls for a clarification of virtual trade in water to give prominence to the *services* provided by that trade, and he further highlights the potential the concept offers in enabling countries to use 'at the border' policies to encourage more sustainable practices in the exporting country. The merits of such an approach ought to be debated vigorously — not least because of the implications it poses for the principle of free trade — but it does at least offer a tangible use for an otherwise confused concept.

The last chapter in this section tackles a particularly nebulous concept: 'resilience'. As Smith (Chapter 33) laments, it is 'intuitively appealing yet stubbornly intangible', and while there are a number of ways in which the concept of resilience can be operationalised, there is as yet no consensus on the feasibility of those options writ-large and over time.

In many ways, the proliferation of new conceptual frameworks for understanding what are, essentially, ancient problems brings to mind the children's fable 'The Emperor's New Clothes'. In contrast to the role played by the stubbornly silent advisors in the original story, however, the authors in this section do a creditable job of critiquing the *value* of many of the concepts currently influencing regional, national and international water policy. Overall, their assessments are both enlightening and sobering.

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28. Understanding water scarcity: Definitions and measurements

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Water scarcity, which can broadly be understood as the lack of access to adequate quantities of water for human and environmental uses, is increasingly being recognised in many countries as a serious and growing concern. As a result, the term 'water scarcity' is regularly used by the media, government reports, nongovernmental organisations (NGOs), international organisations such as the United Nations (UN) and Organisation for Economic Co-operation and Development (OECD), as well as in the academic literature, to highlight areas where water resources are under pressure.

Despite its frequent use, however, there is no consensus on how water scarcity should be defined or how it should be measured. Thus, a reference to water scarcity in one report may measure something different to other reports that use the same term. This can create confusion as to what water scarcity means and lead to different answers to the question of which regions are under the most water stress.

In order to reduce this confusion, this chapter looks at some of the most commonly used methods of defining and measuring water scarcity, so that readers can understand what is meant in each case.

One of the most commonly used measures of water scarcity is the 'Falkenmark indicator' or 'water stress index'. This method defines water scarcity in terms of the total water resources that are available to the population of a region; measuring scarcity as the amount of renewable freshwater that is available for each person each year. If the amount of renewable water in a country is below 1700 cubic metres (m^3) per person per year, that country is said to be experiencing water stress; below 1000 m^3 it is said to be experiencing water scarcity; and below 500 m^3, absolute water scarcity (Falkenmark et al. 1989).

The water stress index method is commonly used because it is straightforward, easy to use, and the data needed is readily available. Such a simplistic approach does, however, have limitations:

1. It ignores important regional differences in water availability, only measuring water scarcity at a country level.

2. It fails to account for whether or not those water resources are accessible, for example, some of the freshwater resources of a country may be stored deep underground or may be heavily polluted.
3. It does not include man-made sources of freshwater, such as desalination plants, which increase water availability beyond what is naturally available.
4. It does not account for the fact that different countries, and regions within countries, use different amounts of water. In Australia for example, most of the demand for water is focused around the major urban and agricultural centres such as in the Murray-Darling Basin, with much less used in the sparsely populated centre (Rijsberman 2006).

An alternative way of defining and measuring water scarcity is to use a criticality ratio. This approach relaxes the assumption that all countries use the same amount of water, instead defining water scarcity in terms of each country's water demand compared to the amount of water available; measuring scarcity as the proportion of total annual water withdrawals relative to total available water resources (Raskin et al. 1997). Using this approach, a country is said to be water scarce if annual withdrawals are between 20–40 per cent of annual supply, and severely water scarce if they exceed 40 per cent.

While this approach avoids the simplistic assumption that all countries have the same demand for water, it also has its limitations:

1. It does not consider man-made increases in water supply (such as desalination).
2. It ignores water withdrawals that are recycled and reused.
3. It doesn't consider the capacity of countries to adapt to lower water availability through changing behaviour or new technology (Rijsberman 2006).

A third measure of water scarcity was developed by the International Water Management Institute (IWMI). This approach attempts to solve the problems listed above by including: water infrastructure, such as water in desalination plants, into the measure of water availability; recycled water, by limiting measurements of water demand to consumptive use rather than total withdrawals; and, the adaptive capacity of a country by assessing its potential for infrastructure development and efficiency improvements (Seckler et al. 1998).

Using this approach, the IWMI classifies countries that are predicted to be unable to meet their future water demand, without investment in water infrastructure and efficiency, as economically water scarce; and countries predicted to be unable to meet their future demand, even with such investment, as physically water scarce (Molden et al. 2007).

While the IWMI measure of water scarcity is more sophisticated, its complexity means that it requires significant amounts of time and resources to estimate. This approach also fails to consider the ability of people within countries to adapt to reduced water availability by importing food grown in other countries, or by using water saving devices. The ability to adapt also depends on the economic resources available in countries as a whole, as well as to individuals within a country. For instance, wealthy residents in rich countries are more likely to be able to adapt to reduced water availability than poor people in developing countries.

A fourth approach to measuring water scarcity is the 'water poverty index'. This approach attempts to take into account the role of income and wealth in determining water scarcity by measuring: (1) the level of access to water; (2) water quantity, quality, and variability; (3) water used for domestic, food and productive purposes; (4) capacity for water management; and, (5) environmental aspects (Sullivan et al. 2003). The complexity of this approach, however, means that it is more suited for analysis at a local scale, where data is more readily available, than on a national level.

There is, therefore, no single definition of water scarcity; different measurements capture different aspects of the pressures on water resources, and there isn't one measure that captures them all. This point is illustrated in Figure 1, which shows two different measures of water scarcity for Africa and Western Europe; one which accounts for the impact that access to water technology can have on water scarcity, and one which does not.

First, by using a criticality ratio, the authors estimate the level of water scarcity based on a number of stressors (labelled in Figure 1 as Incident HWS threat). Since this measure does not include the impact that investment in technological development can have on improving water security, they then estimate an 'investment benefits factor', which measures the investment capabilities of each country. This includes the investment benefits factor with the measure of water scarcity to estimate an adjusted measure of water scarcity when technological capacity is taken into account (labelled as Adjusted HWS threat) (Vorosmarty et al 2010).

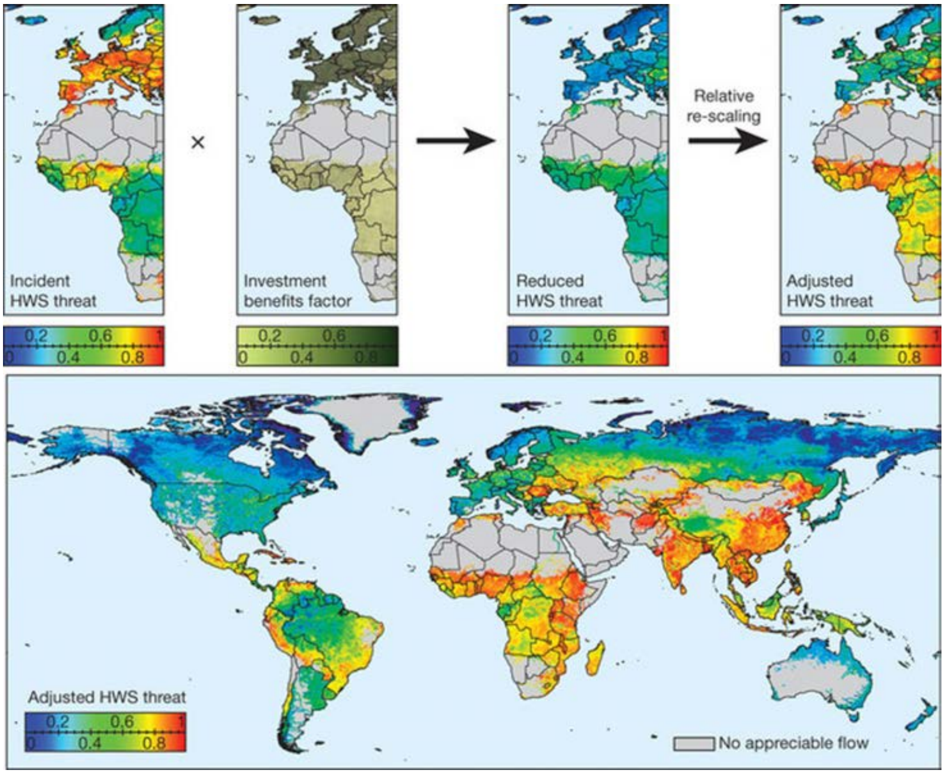

Figure 1: Different measures of water scarcity can produce different answers to the question of which regions are under the most water stress

Source: Vorosmarty et al. 2010.

As Figure 1 shows, the way in which water scarcity is defined and measured has direct, and sometimes contradictory, implications on how serious the issue is perceived to be in different regions. As a result, relying on a single indicator may give a misleading impression about water scarcity issues. It is therefore important when discussing 'water scarcity', to be clear how the term is defined and which aspects of water scarcity it measures and to recognise that one measure by itself is not enough to give the whole picture.

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29. Water security: Converging toward common understanding through quantification

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Water security has come to assume an increasingly prominent position in the international water and development community in recent years. Staff at the World Bank have explained that water security is critical for growth and development (Grey and Sadoff 2007). The importance of water security for the sustainable development of countries like China has been recognised nationally (Liu et al. 2007). Water security has been at the heart of high-profile negotiations on, for example, a Cooperative Framework Agreement in the Nile Basin (WaterLink 2010). Finally, academia and other development actors have also emphasised the concept (Briscoe 2009).

What is missing?

Despite the elevated status that the term has increasingly acquired in policy documents and development discourse, the concept of water security remains largely unquantified. There are several benefits to translating water security into numerical terms. First, it can encourage clarity and common understanding of a concept around which there currently exists substantial ambiguity. Second, it can help to foster discussion and debate on scales and thresholds for evaluating the presence, absence or degree of water security. Third, it can help to assess the extent to which the concept is really being achieved on the ground in different locations. In a recent paper we devised an index that quantifies water security at a country level in order to encourage a more concrete understanding of the term (Lautze and Manthrithilake 2012).

Table 1: Water security indicator framework

Overall Water Security = A + B + C + D + E			
Component	Definition	Scoring System	Source
A = Basic Household Needs	Percentage of Population with Sustainable Access to an Improved Water Source	High percentage of population with access to improved water source = 5 to low percentage of population with access to improved water source = 1	WHO (2009)
B = Food Production	The extent to which water is available and harnessed for agricultural production	Water security for agricultural production = (a + b)/2 a. Water availability (RWR/population): From low availability = 1 to high availability = 5 b. Water use (Withdrawal/population): From low withdrawal = 1 to high withdrawal = 5	FAO AQUASTAT (2007)
C = Environmental Flows	Percentage of Renewable Water Resources (RWR) available in excess of environmental water requirement (EWR). That is, [RWR – (environmental water requirement + withdrawn water)]/RWR.	High percentage above EWR = 5 to low percentage above EWR = 1	converted from Smakhtin *et al.* (2004)
D = Risk Management	Risk Management measures the extent to which countries are buffered from the effects of rainfall variability through large dam storage	Risk Management = (a + b)/2 a. Inter-annual CV: From low CV = 5 to high CV=1 b. Storage: From high storage = 5 to low storage = 1	Mitchell *et al.* (2002); ICOLD (2003); FAO AQUASTAT (2007)
E = Independence	Independence measures the extent to which countries water and food supplies are safe and secure from external changes or shocks	From low dependence on external waters = 5 to high dependence = 1	WRI (2009)

Source: Lautze and Manthrithilake 2012.

Quantifying water security

The paper identified five key components of water security and translated them into numerical indicators that were applied across the countries of the Asia-Pacific. Based on several definitions of the concept, a conceptual framework was developed that contains the following components: basic needs, agricultural production, the environment, risk management and independence (Table 1). Using publicly accessible data, country scores in each component were developed and placed on a five-point scale. To generate a score for overall water security, results for each of the five components were summed, producing a 25-point scale. Just as five-point scales indicate the degree of water security achieved in individual components, the broader score on a 25-point scale indicates the degree of overall water security in a particular country.

Results

Comparing the strength of overall water security scores across countries reveals substantial dispersion (Figure 1), with scores ranging from very poor (less than ten) to very good (greater than 20). Noticeably, even in those countries that appear water secure, there still exist weak spots (Figure 2). For example, despite Australia's overall high level of water security, the specific component of risk management appears only mediocre, and Japan appears limited by its poor score in water security for the environment. While the results hold few surprises, if presented in countries where local knowledge may already exist on water sector strengths and weaknesses, a primary benefit of applying a water security framework such as this is to understand how water secure countries are in relation to one another. A secondary benefit, if the framework is reapplied in the future, is monitoring the rate and direction of change in water security to enable comparison over time.

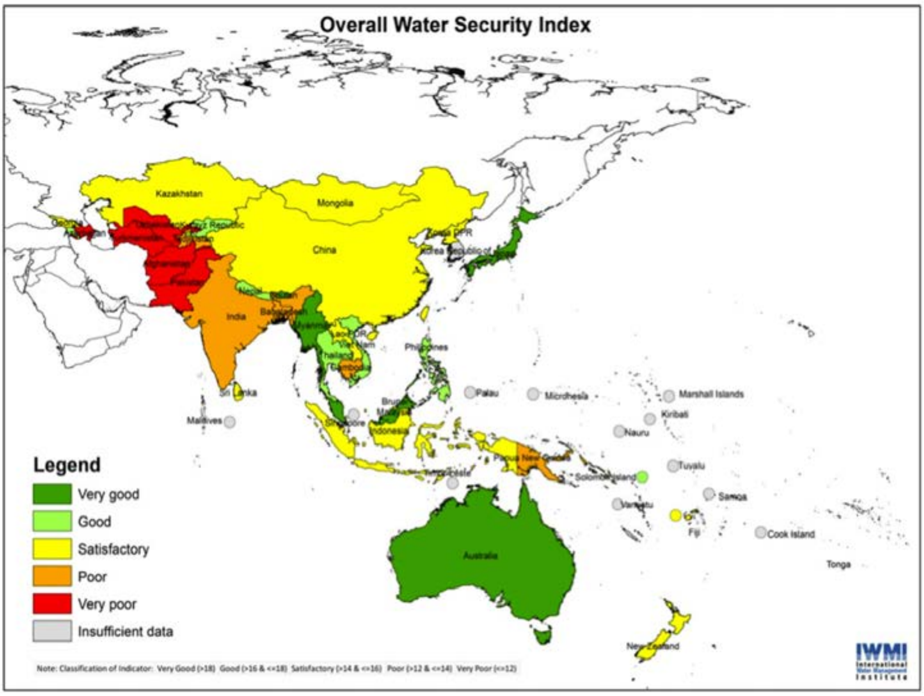

Figure 1: Overall water security index

Source: Lautze and Manthrithilake 2012.

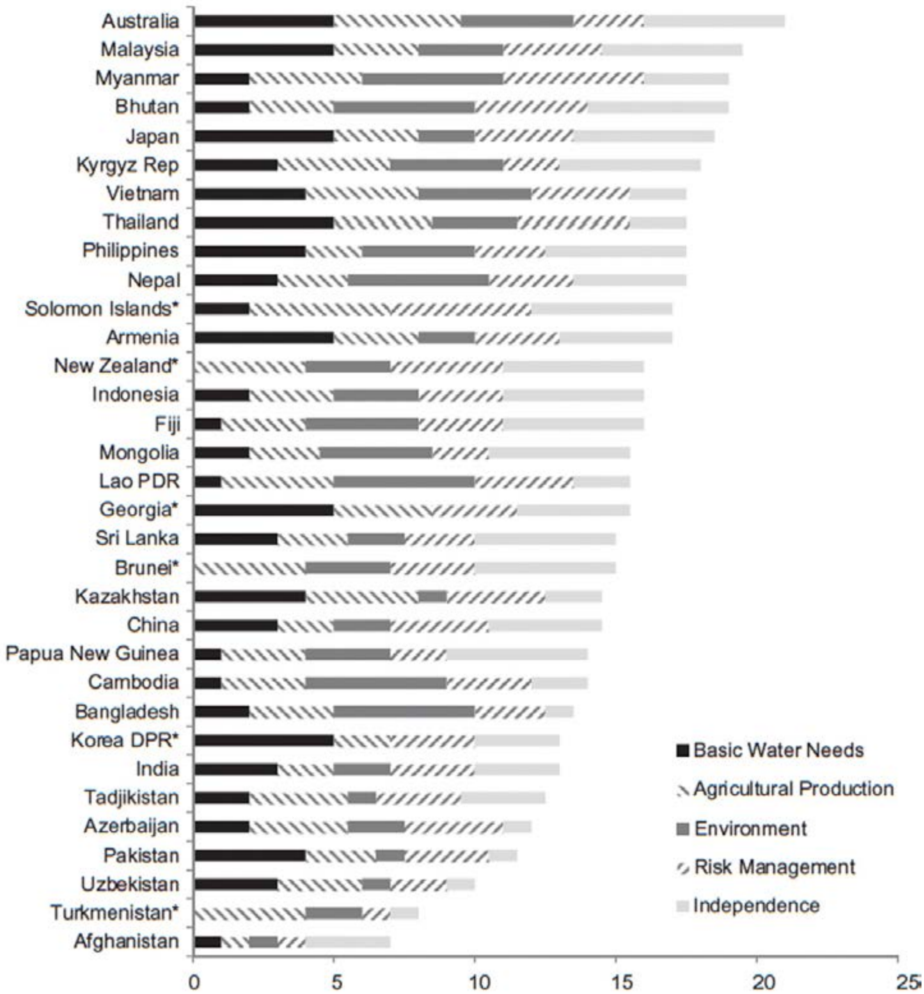

Figure 2: Water security in the Asia-Pacific, ordered from greatest to least water secure. *Indicates that data are available for only four of the five components. Countries with data for less than four components are not displayed

Source: Lautze and Manthrithilake 2012.

So what?

An important goal of this paper was identifying some of the key issues inherent in assessing water security in order to spur more concrete discussion on what the concept truly means. One fundamental issue raised by the methods employed relates to assessment of relative versus absolute water security. More broadly, the development and application of the approach utilised in this paper has helped clarify the notion of water security, and prompts at least two overarching suggestions for understanding the meaning and practical utility of the concept.

A first suggestion for reaching a more common understanding of the concept is to move beyond qualitative definitions to make a list, or finite set of criteria, on which water security is determined and evaluated, as proposed in this paper. While the criteria utilised in this paper may not be perfect, it is believed they mark a valuable step toward arriving at a clear meaning of the concept.

A second suggestion is to clearly focus on the *ends* of water security — not the *means* to water security, and not the *ends beyond* water security. For example, conventional indicators in agricultural water management — such as water productivity and related sub-indicators of efficiency or yield per unit of evapotranspiration — could be proposed to measure water security. While improving water productivity is clearly a way to increase agricultural production and water security, it is simply one *means* and may not be essential. In areas of low water storage, for example, water storage augmentations may be far more important than productivity increases.

Related to *ends beyond* water security, water security can be considered essential to enabling a range of development outcomes, such as adequate food consumption, health status, economic opportunities, and environmental conservation. Achieving water security, however, is a necessary but insufficient condition for achieving security in these other areas: water security can imply that economies are insulated from droughts and floods, but it does insulate them from external shocks, such as global financial crises. Similarly, while water security could imply sufficient agricultural production to feed a community or country, it is not associated with the many other aspects of food security, such as timely crop selection, distribution and provision. As such, water security is but one contributor to the security of other areas, such as food and the environment, because their ultimate security relies on factors over and above those specific to water.

Final thoughts

The approach utilised in this paper constitutes an initial effort to assess the central components of water security and identify some of the major issues in undertaking such an exercise. In terms of the issue posed at the outset about the added value of introducing the concept of water security, the results are mixed. While focusing on five priority issues related to water management is important, the benefits of bundling these five issues under the umbrella of a new paradigm are not immediately apparent. On the contrary, with so many other new concepts related to water permeating discourse (e.g., IWRM, water governance, hydropolitics), there may be confusion, scepticism, and even fatigue associated with introduction of another new term that is not concretely defined, yet which is supposed to comprise a panacea for water managers.

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30. Water footprints: Policy relevant or one-dimensional indicators?

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Water footprints are gaining traction in policy circles in several countries. In Spain, the Ministry of the Environment requires the discussion of water footprints in river basin plans that are prepared in compliance with the European Union Water Framework Directive (Aldaya et al. 2010). In the Netherlands, the Dutch House of Representatives has produced a motion requesting

> that the government, in its economic policy, aim for Dutch companies to present their water footprint and to reduce this footprint in those areas that are affected by water scarcity, for example, by actively addressing companies that receive support through export guarantees or innovation subsidies to reduce their water footprints, and to request that these companies calculate their water footprints and include this information in their sustainability reports. (Witmer & Cleij 2012)

In India, the Ministry of Water Resources convened a seminar on water footprints in New Delhi as part of India Water Week 2013. Several statements regarding water footprints appear in India's new National Water Policy (Government of India 2012). The statements, which appear in the section pertaining to demand management and water use efficiency, are as follows:

> i. A system to evolve benchmarks for water uses for different purposes; i.e., water footprints and water auditing should be developed to promote and incentivise efficient use of water; and
>
> ii. The project appraisal and environment impact assessment for water uses, particularly for industrial projects, should, *inter-alia*, include the analysis of water footprints.

Promoted originally as attractive indicators of the amount of water required to produce a good or service, it appears water footprints are now being considered and adopted as policy tools in national legislation. These examples from India, Spain and the Netherlands might be the first of many cases in which governments consider requiring firms to measure and reduce their water footprints.

Thus, it seems prudent to ask if water footprints are indeed policy relevant. Do water footprints provide the information and insight required to determine and design smart policy measures? Or might a focus on water footprints distract public officials from considering the broader set of inputs and impacts that require their attention when evaluating policy options? Might a focus on water footprints reduce net social benefits by motivating changes in water use that are not socially optimal?

It is likely that water footprints have succeeded in promoting greater awareness of the role of water in the production of many goods and services. In water-scarce areas, such an outcome is certainly desirable. Yet, even in water-scarce areas, water is just one of many inputs. In many settings, producers, consumers and public officials must consider issues that extend beyond water when crafting public policies, or when determining optimal production and consumption strategies. Information is needed regarding the opportunity costs of water in each setting and use. Insight is required also regarding the potential impacts of changes in water use on the livelihoods of individuals engaged in household or productive activities that require water as an input. The remainder of this chapter explores these issues in more detail.

Information is not adequate

Water footprints consider only the volume of water used in production, without considering other inputs or opportunity costs. Water volumes, alone, are not sufficient indicators of the benefits or costs of water use in any setting. The benefits and costs are functions of complex interactions involving physical, economic and social dimensions that are not contained or reflected in estimates of water footprints.

Comparing two water footprints across activities, locations, or time is not a helpful exercise if one does not have information regarding water scarcity conditions, the opportunity costs of water and water's role in supporting livelihoods in each setting. The water footprint of coffee might be 140 millilitres per cup, but that estimate provides no insight regarding the opportunity cost of water in the region where the coffee is produced, or the livelihoods earned by persons engaged in coffee production. Coffee produced in a country with abundant water might place no pressure on water supplies. Yet the activity might provide livelihoods to many residents who have few alternative sources of employment. Such aspects of water allocation decisions are not reflected in estimates of water footprints.

It is critical to consider both the opportunity cost of water (its scarcity value) and the opportunity cost of labor (alternative employment options) when evaluating policies that impact the allocation and use of water and other productive inputs. The water footprint of a coconut might be 2500 litres per kilogram, but most coconuts are produced in humid regions with abundant water supplies. In such settings, the opportunity cost of much of the water used in coconut production is not substantial, and local residents might have few alternatives to earning their livelihoods in the production and processing of coconuts.

Inadequate consideration of costs and benefits

Reducing water footprints is not always a desirable objective. Water footprints consider only water volumes, which are not sufficient indicators of the benefits or costs of water use in any setting. The benefits and costs are functions of complex interactions involving physical, economic and social dimensions that are not reflected in estimates of water footprints. For example, in many humid areas, the costs of reducing water deliveries to agriculture might exceed the benefits. The expenditures on labour, energy and equipment required to improve irrigation management might exceed the incremental value of reducing irrigation diversions, particularly in regions where surface runoff and deep percolation are useful resources.

Public officials must consider an array of questions pertaining to incremental benefits and costs, before reaching decisions regarding water-resource allocation and use. For example, they must consider the scarcity costs and environmental implications of non-water inputs in the production of goods and services. Examples include land, labour, energy, fertiliser, pesticides and machinery. Farm-level decisions regarding water use can also influence the amounts of these other inputs that are used. Efforts to reduce water footprints can result in greater use of electricity or farm machinery, thus increasing any off-farm impacts associated with those inputs.

One must also carefully consider inherent water scarcity conditions. It might be unwise to reduce water footprints in areas where water is not scarce, particularly if there are notable direct or indirect costs involved in such efforts. Water and other natural resources are critical inputs in household production functions for much of humanity. Efforts to reduce water footprints regionally or as part of a national strategy, can have severe implications on employment opportunities in agriculture and on household-level access to water resources. Public officials must consider the potential impacts of initiatives regarding water resources on food security and livelihoods, rather than simply attempting to reduce a volumetric measure of water use.

In addition to its role as a critical input in crop production, water is required for many activities at the household level (Smits et al. 2010; van Coppen and Smits 2010). In many areas of developing countries, individual and household water footprints are too small, rather than too large. Yet the manner in which water footprints generally are presented in the literature suggests that smaller is better, and that consumers and producers everywhere should endeavour to reduce their water footprints. A broader view that embraces the many benefits of water use would be more appropriate, particularly when discussing public policies.

Summing up

Water footprints do not provide the information or insight required to serve as a policy-relevant analytical construct. Analysts considering only water footprints cannot determine optimal policy measures or interventions. Water footprints do not describe the opportunity costs or the incremental benefits of water use in any setting, and they do not describe potential implications for livelihoods. Thus, policies designed on the basis of estimated water footprints might have the effect of moving society further away from desirable outcomes.

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31. Virtual water: Some reservations

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J.A. (Tony) Allan's concept of virtual water, now two decades old (see Allan 2003), is widely regarded as a major contribution to the discourse on water, and it received the accolade of the Stockholm Water Prize in 2008. The concept has been theoretically challenged (Merrett 2003; Iyer 2008). Allan's statement that the concept is a descendant of the Ricardian theory of 'comparative advantage' (Allan 2003) has been questioned, and it has been argued that the two concepts might lead to different practical results in a given situation, that the concept can be misleading as a policy prescription, and that production and trade decisions by countries are based on many other considerations (Wichelns 2010). The concept has, however, gained common currency, along with its offshoot 'virtual water trade', and scholarly literature on the subject is growing (see Yang et al. 2006; Hoekstra 2003; Zimmer and Renault 2003; Siebert and Doll 2010; Dalin et al. 2012).

Merrett (2003) puts forward two criticisms of the concept. His first point is that what goes into the production of rice or wheat is real water and not virtual water. That is true enough, perhaps even obvious. At the production stage, the water is indeed real. It is when the rice or wheat is traded that the concept of virtual water comes into play: we can then say that when a country exports rice or wheat it is 'virtually' exporting the water that had gone into its production.

Merrett's second point is that the terms 'virtual water' and 'import of virtual water' are unnecessary. He refers to this as a case of the application of Occam's razor; that is, in the context of agriculture,'virtual water' can be replaced by 'the crop water requirements of food exports' and 'the import of virtual water' can be replaced by 'the import of food'.

Let me now state my critique of the concept, which is on somewhat different lines. I agree with the proposition that the concept of virtual water is useful as a warning signal to countries (or areas within a country) to be aware of the quantity of water that goes into what they produce and consume or export. Here I differ from Merrett. I do, however, have to qualify my acceptance of the concept with two reservations.

First, in the context of the general dominance today of a certain economic philosophy, there is a tendency to misuse the ideas of 'virtual water' and 'virtual water trade' in international forums as instruments for the doctrinaire advocacy of neo-liberal economic prescriptions. What I am referring to is the strong advocacy of the opening up of the markets of developing coutries to imports from developed coutries. In that pressure the concept of virtual water tends to become one more argument against domestic production. We need to be wary of that tendency, though of course Allan cannot be held responsible for it.

Secondly, while it is in order to say that large quantities of water are used in the production of certain agricultural commodities or industrial products, and that the export of those commodities or products is therefore virtually like exporting water, it does not follow that water is being in reality exported. The term 'virtual export of water' has become 'export of virtual water', and this leads on to the further term 'virtual water trade'. 'Virtual water' tends to be regarded as a real commodity in which trade is taking place, and this in turn leads to the compilation of statistics of that unreal trade. This is an instance of what Wittgenstein might have called the bewitchment of the intelligence by language.

At the risk of stating the obvious, it needs to be said that when a country exports or imports sugar or rice or cotton, it is exporting or importing sugar or rice or cotton, and not water. (Merrett (2003) makes this point, but in a different way.) It is misleading to talk about 'virtual water trade' in this context. The only trade in water is where (real) water itself is traded in bottled form or in the form of soft drinks, or in exceptional cases of exports or imports of water in bulk.

Further, the water needed to produce a product is not the same thing as the water content of that product. This is another reason why the concept of 'virtual water trade' is misleading. (Allan had initially used the term 'embedded water', which he rightly corrected later to 'virtual water', but a bit of that original error seems to be surviving in the new term.)

A water-rich country may import a product instead of producing it domestically for various reasons, which have nothing to do with water. A water-short country may import a commodity or product because it does not have enough water to produce it, or for various other reasons, but it may not think of the import of that commodity or product as an import of water. The statement that a country that is not well endowed with natural resources may have to depend on imports is a statement of the obvious; there is no need for a concept of 'virtual water trade' to explain this. To regard such imports/exports of commodities or products as 'water trade' seems a seriously misleading proposition.

I am not arguing against the concept of 'virtual water' as a means of promoting an awareness of the water implications of the production or export of certain commodities or products. It is indeed useful for that purpose. The concept is also a useful adjunct to that of 'water footprint'. 'Virtual water', however, is a metaphor, and we must not push that metaphor too far and muddle ourselves into thinking that there is a real commodity called ‘virtual water’ and that there is a large international trade in it.

Incidentally, every export can be re-described with reference to what has gone into the production. If exports of rice and wheat can be treated as exports of water, they can also be treated as exports of fertilisers and pesticides; exports of iron ore, and of iron and steel produced from iron ore, can be regarded as exports of the soil of the country because the ore is part of that soil (or of coal because coal is used in the conventional blast furnace); exports of aluminium products can be described as exports of electricity because aluminium is produced in electric smelters; and so on. Should we then create concepts of ‘virtual fertilisers/pesticides’, ‘virtual soil’, ‘virtual coal’, ‘virtual electricity’, and so on, and compile statistics of those virtual trades? Water is of course a special case because of its importance in our lives and its scarcity. The point that I am making here is that the concept of ‘virtual x’, whether it is water or coal or electricity or whatever, has essentially the cautionary purpose of drawing attention to what goes into the production of a certain crop or commodity, so that a producer/exporter can make an informed decision as to the production of that crop or commodity for domestic sale or export. It is fallacious to stretch that purpose and treat these as cases of virtual trade in x.

Besides, the theorists of virtual water trade fail to note an asymmetry between exporting and importing countries.

Trade implies two parties — a seller and a buyer. Even if we grant that the country selling rice needs to be aware that it is indirectly selling water, it does not follow that the country buying rice from abroad needs to be (or is in fact) aware that it is indirectly buying water. As already mentioned, it may have decided to import rice for various reasons unconnected with water, and may not be interested in or conscious of the water that has gone into the production process. If so, how can we talk about ‘trade’ in virtual water?

Reimer proposes the terminology of ‘trade in water services’ (Reimer 2012). It may be an improvement on ‘trade in virtual water’, but it is difficult to see how it is an answer to the questions raised by me. Is the importing country aware of or even interested in the fact that ‘water services’ have gone into the production of the commodity or product that it is importing? If not, how can we talk about trade in water services?

It will be seen that while Merrett (2003) says that (at the production stage) real water is mistakenly described as virtual water, I point out that in the context of trade, ‘virtual’ water is mistakenly treated as real water. Both are valid and necessary criticisms.

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32. Virtual water trade means ‘trade in water services’

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Disenchantment with the virtual water concept (Allan 1998) is summarised in Merrett (2003) and Iyer (2014). One concern is with the characterisation of virtual water, with Merrett (2003) noting that the ‘forging’ of appropriate terminology is ongoing and that, at this stage, the appropriate language is ‘still in the furnace’. Beyond the issue of terminology, these authors argue against the idea that virtual water can somehow be viewed as being traded.

Disenchantment also arises when virtual water is promoted as a framework for making water-allocation decisions. Critics point out that virtual water measures cannot serve as an indicator of environmental harm, or quantify the marginal value of water across time or space — at least without a good deal of additional information. A third general reason for disenchantment is that empirical studies show that relative water endowments, by country, are poor predictors of trade in water intensive goods (Reimer 2012).

In this paper I will address these concerns from the perspective of an international trade economist. With Merrett’s observation that the language is still in the furnace, I argue that what is needed is a new name: ‘trade in water services’. Why such a change? The phrase ‘virtual water’ has led to confusion. For example, Allan (2003) states that it is ‘confusing to suggest that water was being traded in the process of moving water intensive commodities, such as grain, from one place to another’. Building on this point, Merrett (2003) calls for an end to the term virtual water, suggesting that the phrase ‘import of virtual water’ be replaced by ‘the import of food’.

This latter approach has important limitations. First, it eliminates any reference to water. Second, there are many products, other than food, that are traded and which place a heavy burden on water supplies. Third, this phrase does not acknowledge that virtual water is a new twist on an old idea, as I explain below. For these and other reasons I propose the name ‘trade in water services’.

To understand my reasoning, it’s important to emphasise that there are two legitimate ways to view trade between regions (Davis and Weinstein 2003). The first is as the overt exchange of a product, such as wheat. The second way is as the international exchange of the ‘factor services’ that were used to produce the wheat, with 'factors' referring to natural and other resources such as water, labour, land and capital used to produce wheat or its intermediate inputs. A major point of this paper is that virtual water is this latter approach of viewing trade between regions.

The associated theory, trade in factor services, is a long-standing way of viewing trade between regions, with contributions dating back to economists Heckscher (1919), Ohlin (1933), Samuelson (1949), Leontief (1953) and Vanek (1968). The idea is that when factors of production are immobile across regions, trade in products allows regions to consume more of something than they otherwise would. Regions specialise in the activity for which they have comparative advantage, according to relative factor abundance, and import products for which they are at comparative disadvantage. The associated theorem is called the Heckscher–Ohlin–Vanek theorem. A lengthy subsequent literature shows that many new insights are available when one works in terms of factor services.

In this framework, when we focus on labour as a factor of production, we use the term 'labour services'. When we focus on land as a factor of production, we use the term 'land services'. It follows that there is also something called 'water services', and that this includes all the water that was necessary for production and distribution of a product.

Let us turn now to Iyer's (2013) statement that '"Virtual water" tends to be regarded as a real commodity in which trade is taking place, and this in turn leads to the compilation of statistics of that unreal trade.' Far from characterising it as unreal trade, economists routinely calculate the exchange of factor services (Reimer 2006, 2011; Reimer and Hertel 2010). Calculations of this sort date back at least to the time of Leontief, who won the Nobel Prize in economic science in part for his use of input-output analysis to examine trade flows in labour services and capital services (Leontief 1953).

Many interesting findings come out of such calculations. For example, when a US citizen buys a garment manufactured in Bangladesh, he is importing not only the services of Bangladeshi water, labour and capital, but also — if the shirt was made of US-grown cotton — some services of US water, labour and capital.

In this light, Iyer's (2013) concerns about theoretical challenges are undue. Instead of saying 'import of food' (suggested by Merrett), which eliminates any reference to water, I believe we should refer to 'trade in water services', and acknowledge that this is but a particular application of a long-established theorem.

We should not expect relative water endowments, by country or time, to be a strong predictor of trade in water intensive goods, when we are looking at a broad sample of goods and countries. This point is emphasised by Iyer (2013) and especially Wichelns (2004), who suggests that international technology differences are significant in agriculture, for example, and may be a source of comparative advantage alongside relative abundance of water. Policy-related trade barriers, such as tariffs, can also be high in water-intensive sectors, such as agriculture, and therefore obscure the role of water (Reimer and Li 2010). This does not nullify trade in water services as a framework for analysis of water in the international economy. It simply means that additional information is needed if one is to fully account for observed patterns of trade. This is routinely done in the literature (Reimer 2006, 2011; Reimer and Hertel 2010).

The concept of trade in water services is linked to the literature of trade policy and its insights into how international border policies (subsidies, tariffs, quotas) influence water use in ways that are otherwise hard to discern. For example, suppose that export of agricultural products is associated with the depletion of an aquifer. It may not be politically feasible to intervene directly at the level of production, due to producer resistance. A more politically attractive approach might be to discreetly inhibit water use — say by export restriction. Yet any kind of policy undertaken at a national border often has hard-to-anticipate consequences on consumption and production in multiple regions. The international economics literature contains analysis of many such examples, and a means for comparing alternative policy choices.

Concluding thoughts

I have attempted to demonstrate that the virtual water concept is but a special case of a general theory in international economics, a venerable theory taught to virtually every undergraduate student who takes a course on international trade. I argue that the name we should use is trade in water services. This name emphasises that it is the services of water (as embodied in a product) that get traded, not the water itself. This is a wholly legitimate way to view trade, and such calculations are routinely made for land, labour and capital. I believe it is fine to do this for water as well, and that many insights can be gained in the process.

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33. Understanding resilience: Implications for the water sector

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Policy rhetoric around water resources and infrastructure increasingly emphasises the need to promote 'resilience' within water and wastewater systems. This trend is particularly evident in countries like the United Kingdom — take, for instance, the Water Services Regulation Authority's (Ofwat) recent report on the need for 'Resilient [water] supplies' (Ofwat 2010). The UK Government also recently published the *Water for Life* White Paper (Department for Environment, Food and Rural Affairs (DEFRA) 2011), which outlines its strategy for reforming the water sector and stresses the need to develop 'secure, sustainable and resilient water resources'.

It is worth questioning, however, whether 'resilience' has simply joined a long list of intuitively appealing yet stubbornly intangible concepts (e.g., 'sustainability'). It's certainly no easy matter to define resilience, or specify what a resilient system might look like.

Some are certainly trying to pin the concept down more firmly — for instance the European Union (EU)-funded Transitions to the Urban Water Services of Tomorrow (TRUST) project is aiming, in part, to understand and promote resilience within urban water cycle systems. The work builds on previous efforts to define the idea, such as the US National Infrastructure Advisory Council's report on *Critical Infrastructure Resilience* (NIAC 2009), which states:

> Infrastructure resilience is the ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event.

In light of this definition, infrastructure resilience is about delivering services, regardless of disruptive events that may occur — the ability to 'take a licking and keep on ticking' (to quote the old Timex slogan). This understanding of resilience seems to be a relatively common one in the water sector, and reports from the United Kingdom echo it.

Water and wastewater systems, however, are more than the sum of their engineered parts. They can be described as socio-technical or socio-ecological systems, as they involve complex interactions between human, technological and environmental components. And, among researchers who study the behaviour of such big systems, the idea of resilience has broad implications. Its origins are often traced to early developments in the field of ecology.

In the 1970s, ecological theory was dominated by the idea that ecosystems have a single, relatively fixed point of equilibrium — one ‘steady state’. Resilience was, therefore, seen as an ecosystem’s ability to recover from disturbance and return to equilibrium. A common analogy is a rubber band — a resilient system could be subjected to stress and strain, but ultimately had the ability to return to its original state. The shorter the ‘return time’, the more resilient the system. This was referred to as ‘engineering resilience’ (Folke et al. 2010).

There were, however, those who challenged the idea that ecosystems have one single steady state. Holling (1973) proposed instead that ecosystems have multiple ‘domains of stability’, and that they could (and did) shift between these alternate steady states. Holling therefore viewed ecosystems as fundamentally dynamic — ‘disturbance’ is the rule rather than the exception and, in response to disturbance, systems are continually changing and developing, not just returning to the same point of equilibrium.

This also creates an alternative view of resilience, which can be seen as a system’s ability to absorb disturbances and reorganise itself into a better configuration, while still retaining its fundamental characteristics (Walker et al. 2004). In this view, resilient systems are less like rubber bands and more like plasticine — when subjected to stress they can adopt and retain a suitable new shape, rather than return to their original state.

It’s no wonder, then, that the concept of resilience has, for some, become nearly synonymous with ideas of adaptability and adaptive management — ensuring that systems have the ability to adjust in order to suit changing circumstances. These ideas are increasingly applied to social systems, particularly those focused on environmental/resource management. They are also becoming more powerful in light of climate change, as we increasingly have to ask ourselves how to manage for the unexpected.

For the water sector, these ideas imply moving beyond ‘engineering resilience’, and the traditional ‘predict and withstand’ approach for extreme conditions, towards a more dynamic and flexible system. There is, however, inevitable tension here — namely, can these ideas fit within a system that relies heavily on inflexible assets like pipes and treatment plants?

There are ways of making the built infrastructure more flexible and adaptable. On the water-supply side, for instance, two strategies are often suggested — diversification and connectivity. Diversification implies incorporating a broad range of source options within a water system, so that if one source is disrupted, others can help to compensate (Staub and Moreau-Le-Golvan 2011). Similarly, the United Kingdom's recent water white paper argues that improving connectivity between water supplies in different parts of the country (e.g., by encouraging water companies to share/trade water) will lead to a similar result (DEFRA 2011).

There are also ways of introducing flexibility within patterns of water demand. For instance, the scheme devised for the California San Francisco Bay/San Joaquin Delta water management program (CALFED) allowed different groups of users to 'trade' water allocations, so that patterns of use could be swiftly adjusted as water availability changed. This helped to overcome the frequent conflicts and stalemates that arose over allocations, and helped ensure that water was used where it was needed most (Booher and Innes 2010).

There is, however, significant uncertainty around such approaches. For instance, how much flexibility is needed or appropriate? Additionally, some argue that fostering resilience means supporting innovation and experimentation — in other words, allowing room for developing and trialling new technologies and new management approaches, learning from the outcomes and, perhaps most importantly, acting on those lessons learned (Olsson and Galaz 2009). Similarly, some argue that it means favouring reversible decisions over irreversible ones (Staub and Moreau-Le-Golvan 2011). But when it comes to planning future water infrastructure, especially large-scale assets, such ideas can be something of a luxury.

Planning processes may favour options with known benefits and consequences, particularly when spending must be justified to consumers and/or public bodies. For something as fundamental as water, it can be difficult to foster an appetite for creativity and experimentation. Furthermore, given the lengthy timeframes over which large-scale projects are decided and implemented, and the level of investment required, it is hardly feasible to ensure that all such decisions are reversible.

These challenges are certainly not unique to the water sector, and there are no easy answers for them. It is nonetheless important that they are considered and debated if resilience is to become a true operational concept, and not simply an intuitively appealing buzzword.

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Part 7: UNESCO Water Chairs and Centres

34. UNESCO Water Chairs and Centres

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The United Nations Educational, Scientific and Cultural Organisation's (UNESCO) engagement in the water sector is built on three tracks: (1) supporting scientific research that informs water-management policy, (2) facilitating education and capacity-building in the hydrological sciences, and (3) water resources assessment and management to achieve environmental sustainability (UNESCO 2014). An important way in which these objectives are achieved is through the establishment and ongoing support of UNESCO Water Chairs at higher education institutions and UNESCO Water Centres throughout the world. These research centres focus on specific subject and geographic priorities in areas of water science and policy.

The approximately 50 Water Chairs and Centres share knowledge and expertise through the International Hydrological Programme (IHP) network hosted by UNESCO. The IHP is the only intergovernmental program of the UN system that is devoted to water research, water-resources management, education and capacity-building. Other facets of the UNESCO freshwater program include: co-ordinating the publication of the annual World Water Development Report into the state of the world's freshwater resources, and support for UNESCO-IHE, the world's largest international graduate water education facility, which is based in Delft, the Netherlands.

The following section presents the research and activities of five UNESCO Water Chairs and Centres. The wide range of activities in different disciplines and locations highlights the important policy-focused research that UNESCO is supporting globally. Ganoulis, Quartano, and Skoulikaris (Chapter 35) provide an overview of the work of the UNESCO Chair on Sustainable Management of Transboundary Waters and Conflict Resolution at Aristotle University of Thessaloniki, Greece. Established in 2003, this Chair conducts innovative research and education programs in the Balkans region of Europe. Working in a region affected by conflict in recent decades, this UNESCO Water Chair has supported transnational cooperation through: (1) the development of collaborative monitoring and data-sharing programs for transboundary waters, including the region's over-exploited, yet previously under-researched, groundwater aquifers; (2) the implementation of models for collaborative management of transboundary waters between water authorities in different countries; and, (3) the establishment of networks through which scientists from different countries collaborate on shared projects despite ongoing social and political problems, thereby acting as indirect links between their respective national institutions on transboundary water management.

Transboundary water management is also a major focus of the Centre for Water Law, Policy and Science that operates at the University of Dundee under the auspices of UNESCO. Litke and Rieu-Clarke (Chapter 36) provide an overview of the most authoritative instrument of international water law developed to date: the UN Watercourses Convention (UNWC). Adopted by the UN General Assembly in 1997, the Convention is the only global treaty on shared freshwater resources. It is principle-driven and provides a framework for rules that can be tailored to the circumstances of each international watercourse. Despite the pivotal role played by the UNWC in the development of international water law and its influence in many river basins of the world, the treaty itself is not yet in force; 31 states have ratified the treaty, four short of the required 35. As part of an international awareness campaign to secure the ratification of additional parties, the Centre for Water Law, Policy and Science developed the *UNWC User's Guide*. This document provides an accessible, non-technical summary of the UNWC's individual provisions and demonstrates the benefits of ratification. In addition, an online user's guide has been developed that is being updated on an ongoing basis with case studies and additional educational materials.

Addressing existing problems of scarcity in the face of burgeoning urban water demand is arguably one of the greatest challenges facing water governance. Tajrishy, Abdolghafoorian, and Abrishamchi (Chapter 37) from the UNESCO Chair in Water and Environment Management for Sustainable Cities at Sharif University of Technology consider Tehran's growing water crisis. Population growth and rising incomes are fuelling greater water consumption that is becoming increasingly unsustainable as ground and surface water resources decline. Fortunately, there are substantial unexploited opportunities to increase the efficiency of water use within the city. To illustrate possible ways forward the authors construct a detailed model of Tehran's water and wastewater system, including major sources, treatment facilities and users. They demonstrate the substantial economic gains from supplying additional recycled wastewater and treated runoff to users that do not require high-quality water, such as parks, industrial plants and construction projects. Rather than being an intractable problem, they show that Tehran's water crisis can be mitigated by appropriate investments in an integrated approach towards water and wastewater use.

The UNESCO Chair in Sustainable Water Services at Tampere University of Technology focuses on the governance and policy issues associated with water services, particularly urban and rural water supply and wastewater services (Chapter 38). In partnership with the Polytechnic of Namibia, the University of Nairobi and another eight institutions in industrialised and developing countries, this Chair promotes education and research on sustainable water governance and the needs of local communities. Key aspects of this research agenda include: reform processes; whether water access should be considered an economic good or a human right; good governance; the importance of history in water-sector reform; and, the commonalities across research agendas of industrialised and developing countries, such as ageing water infrastructure.

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35. Promoting cooperation for transboundary water security: The experience of the UNESCO Chair/INWEB

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The UNESCO Chair/INWEB (International Network of Water/Environment Centres for the Balkans) at the Aristotle University of Thessaloniki (AUTh), Greece, was established in 2003 as part of the UNITWIN/UNESCO Chairs program. It links INWEB, a water resources management network of academic and non-academic groups in south eastern Europe (SEE, or the Balkans) that has been active since 1999, with the UNESCO Chair on sustainable management of transboundary waters and conflict resolution.

The UNESCO Chair/INWEB focuses on two main activities:

- promoting and carrying out innovative research and educational programmes, and
- contributing to bridging the gap between academic research and practical implementation of new knowledge in the field.

Being part of the extended UNESCO organisation means that INWEB seeks to promote cooperation, capacity-building and access to new knowledge in the Balkan countries and developing regions outside Europe.

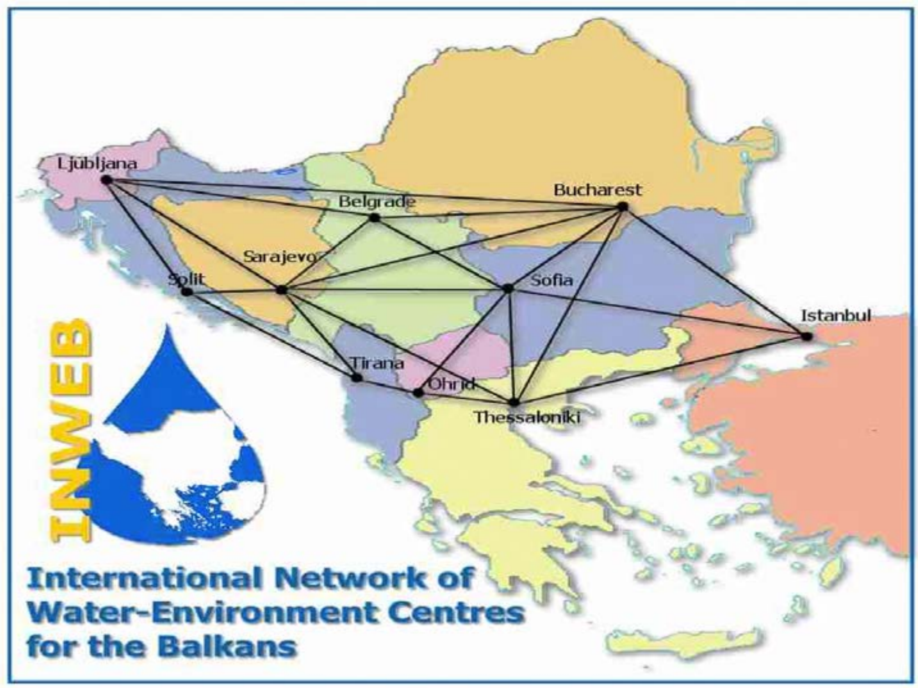

Figure 1: The UNESCO Chair/INWEB in SEE — the Balkans

Source: Authors' research.

In this region of Europe, water cooperation among countries is vital because many surface and groundwater resources are shared by two or more countries. Taking both the Sub-Danubian transboundary river and lake basins and the internationally shared aquifers into account, more than 80 per cent of the water resources in this region are transboundary (INWEB 2008).

In the interests of mutually beneficial development it is necessary to develop shared plans for the protection and management of transboundary water resources to safeguard them against pollution and floods, and also to jointly plan the construction of major infrastructure.

International cooperation at the basin level in the Balkans continues to be fragile. The problems of minority groups, perceptions of injustice and nationalistic tendencies continue to pose a threat to the stability and social and economic development of the region. INWEB provides a framework within which relationships between scientists from all ten Balkan countries can be developed and reinforced in a spirit of rebuilding scientific cooperation across SEE. With this in mind, INWEB promotes cooperation by using water as a tool for peace. Our belief is that regional concerns over water issues can unite rather than divide, and that countries can work together to improve water quality and ensure long-term water security. It is clear that successful regional cooperation begins with all participants understanding the importance of sharing information and knowledge at the appropriate time.

INWEB's regional inventories of transboundary waters

Monitoring programs in the Balkans were in many cases disrupted, or even abandoned, during regional conflicts. Data is therefore difficult to obtain and may be incomplete. The new institutional structures within the multitude of small international river basins created by the collapse of the former Yugoslavia cannot in many cases provide consistent and complete historical information. There is an urgent need for improved development and sharing of both water quantity and quality data in transboundary river basins throughout the area. INWEB is working to address this need, as can be seen from the identification in 2008 of 17 Sub-Danubian transboundary river and lake basins in the SEE (Figure 2).

Groundwater exploitation in SEE has increased dramatically during recent decades. Over-exploited aquifers are consequently a major concern in most countries. Many groundwater resources are at risk of being exhausted to meet the rising demands of irrigated agriculture, tourism and industry. The pressures on groundwater resources are highest in the summer period, when natural supply is minimal and water demand is at a maximum for irrigation and tourism. Groundwater scarcity is often accompanied by poor water quality, particularly in coastal aquifers where water is often highly saline and unusable. In addition to a general trend towards over-extraction, contamination in recharge areas and mismanagement of irrigation practices has led to a general deterioration in groundwater quality in many parts of the Mediterranean region.

Transboundary aquifer systems are important sources of fresh water in many regions of the world, particularly under the arid- and semi-arid climatic conditions which prevail in the Mediterranean region. With growing groundwater scarcity and quality deterioration, the demands on these shared aquifers to meet growing regional water demand are only likely to increase. In this situation, a fundamental task for joint management is the production and sharing of reliable scientific knowledge and information to mitigate potential conflicts between neighbouring countries. Furthermore, cooperative arrangements to jointly develop, manage and protect shared aquifers will become a necessity, not only to avoid conflict, but also to optimise utilisation and to achieve water security.

Figure 2: Sub-Danubian transboundary river and lake basins in SEE

Source: INWEB 2008.

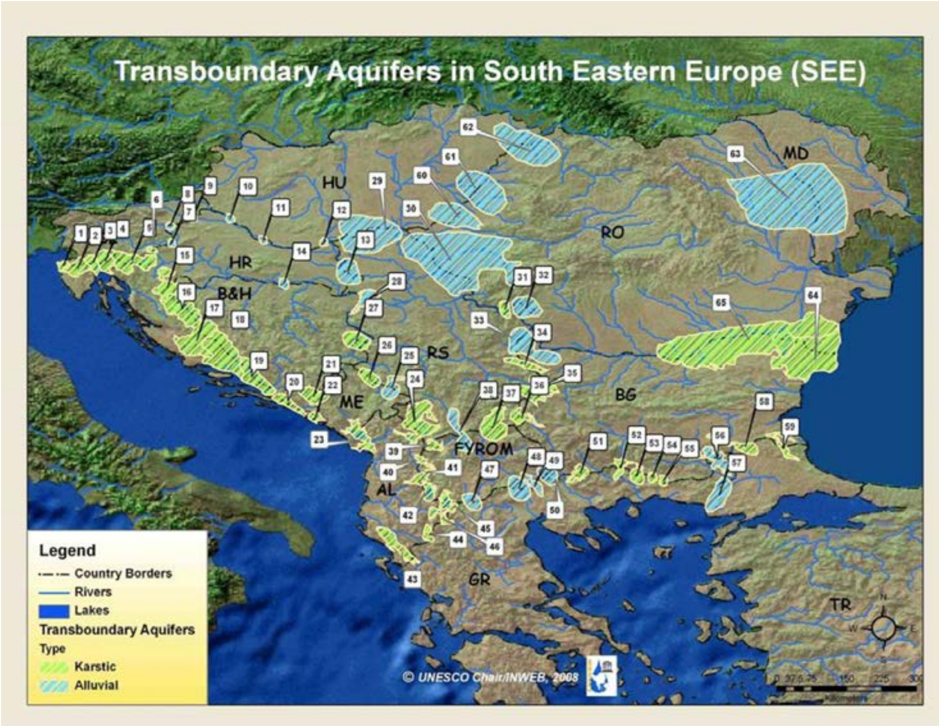

Figure 3: Overview map of transboundary aquifers in the SEE region

Source: Authors' research.

In order to facilitate an integrated approach to transboundary groundwater-resources management in the Balkans, INWEB adopted the UNESCO/ISARM (International Shared Aquifer Resources Management) initiative. This was launched in June 2000 at the 14th Session of the Intergovernmental Council of UNESCO-IHP (International Hydrological Programme) and is an intergovernmental project involving all national IHP Committees.

A number of UNESCO-ISARM activities have taken place in the Mediterranean region, particularly in SEE. In this region the UNESCO Chair/INWEB has worked with UNESCO/IHP, the Economic Commission for Europe (ECE), the Economic and Social Commission of Western Asia (ESCWA), and the Economic Commission of Africa (ECA) to investigate shared aquifer resources using a two-step methodological approach: (1) collate available data from a wide range of sources and develop an inventory of the transboundary aquifers across the entire region, and (2) make an interactive online meta-database available to all stakeholders using Google Earth technology.

Some transboundary aquifers in the region had previously been identified and noted in earlier UNECE and INWEB inventories. The region has, however, seen major political change in the last two decades and many aquifers that were located within a single country are now shared between new countries. For example, while the previous UNECE inventory recorded 23 regional transboundary aquifers and the draft INWEB reported 47, this latest assessment identified 65. The locations of these aquifers are shown in Figure 3.

The database of transboundary aquifer resources in SEE is available on INWEB's web platform (http://www.inweb.gr). Two main types of aquifers are distinguished:

1. Sedimentary basins with shallow unconfined aquifers and deep confined layered aquifers, namely alluvial aquifers. Unconfined aquifers are found in river channels or in floodplains and are usually recharged by direct infiltration of rainfall or streamflow; nevertheless due to their shallow nature, they are subjected to contamination and pollution risks. On the other hand, the water volume stocked in confined aquifers is under pressure, since an overlaying impermeable layer deteriorates the quality of water seeping into or out of the aquifer. The replenishment of these aquifers occurs only in areas where the porosity of the confining layer allows water infiltration, usually at some considerable distance away from the aquifer. The recharge procedure is a long-term process and groundwater in these aquifers dates back centuries.
2. Karstic carbonate aquifers. This type of aquifer is found in areas where chemically soluble rock, such as limestone or dolomite, is dominant. This is due to the fact that flowing water containing carbon dioxide dissolves these rocks. For the countries along the Adriatic coast, the karstic aquifer complex known as the Dinaric karst (estimated at 110,500 square kilometres (km^2)), is the main source of water supply. More than 73 per cent of the national territories of Croatia, Bosnia and Herzegovina, Montenegro and Albania lie over this significant aquifer complex. These aquifers are vulnerable to contamination since rock porosity, together with swallow holes, facilitate the diffuse or point infiltration of contaminants of pollutants.

Integrated management of transboundary waters

Different models for collaborative activities related to transboundary water resources management (TWRM) have been proposed globally (UN World Water Development Report (WWDR) 2006, 2009), and for the SEE region in particular

(Ganoulis et al. 1996, 2000, 2006, 2011). The approaches of such models differ according to the particular associated scientific discipline or professional community.

On the one hand, engineers, hydrologists, hydrogeologists and environmental professionals, emphasise the physical and ecological assessment and modelling of transboundary hydro-systems in terms of:

- delineating their natural borders; i.e., hydrologic basins for transboundary rivers and lakes, and hydrogeological boundaries for groundwater aquifers
- analysing relationships between physical and ecological variables, such as precipitation, groundwater recharge, river flow, pollutant inputs, lake water quality, and ecological biodiversity, and
- suggesting constructional projects, such as dams, diversion channels and irrigation networks, or non-structural measures, such as demand management, ratification of EU legislation, developing agreements and implementing guidelines.

On the other hand, lawyers and social scientists (i.e., geographers, economists and sociologists) emphasise human factors that can be complex and difficult to analyse and predict, such as institutional cooperation, stakeholder participation and negotiation strategies. The main challenge here is whether different national administrations will implement international rules at the domestic level and, at the same time, coordinate their activities with their neighbours through bilateral or regional cooperation agreements. One way to address this challenge is to raise public and stakeholder awareness of and engagement with participatory processes involving national institutions, academic partners and international organisations.

In reality, all the above issues and approaches coexist and are inter-related. In order to achieve effective TWRM these models, whether descriptive or prescriptive, need to merge. Ganoulis et al. (2011) present two main strategies for achieving such integration: (a) through effective capacity building and training in TWRM, and (b) by producing and analysing a general framework of conflict resolution based on how riparian countries may share benefits and risks.

The UNESCO Chair/INWEB has chosen the Mesta/Nestos Basin as a case study of integrated TWRM in SEE. The river rises in the Rila and Pirin mountains in southern Bulgaria and flows some 230 km through Bulgarian and Greek territory before emptying into the North Aegean Sea (Fig. 4). About 126 km of the river flows through Bulgaria and about 130 km through Greece, with a total catchment area of 5613 km^2 (2770 km^2 in Bulgaria and 2843 km^2 in Greece). The Mesta/ Nestos River is the most important water resource in the region and has been the subject of bilateral negotiations for many years. For both countries it provides municipal water supply, irrigation and hydroelectric power production.

Figure 4: Location of the Mesta-/Nestos transboundary river basin

Source: Authors' research.

A conceptual model for TWRM in the Mesta/Nestos Basin is illustrated in Figure 5. This model employs the following seven steps and may be adapted to any case study of transboundary waters.

1. stakeholder consultation and collaboration, social issues, legal and institutional agreements: this step should interact with each following step
2. problem definition: transboundary diagnostic analysis (TDA)
3. agree on data collection, common monitoring and data sharing
4. develop a common vision and common strategic action plan (CSAP)
5. physical and environmental assessment and modelling
6. scenario analysis and decision support systems (DSS) and
7. transfer of models and DSS to stakeholders, applications.

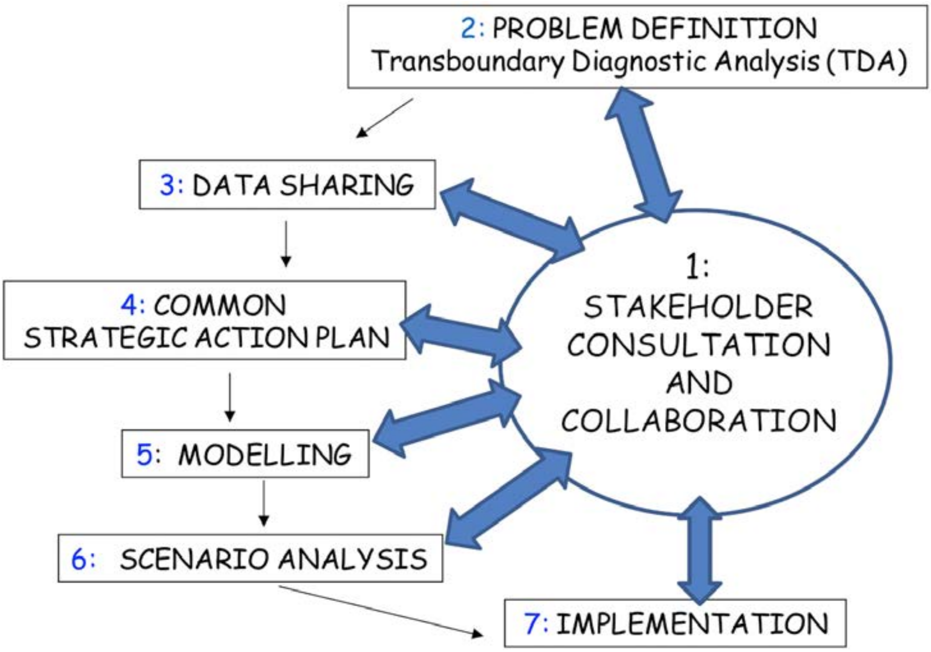

Figure 5: A conceptual model for effective management of transboundary water resources

Source: Authors' research.

In the Mesta/Nestos Basin, step 1 of the proposed model aiming to address the lack of communication between scientists, experts, water managers and public stakeholders was achieved with the organisation of a series of workshops and roundtables. TDA analysis (step 2) focused on improving the understanding of water resources in the project region and their environmental status, in order to identify issues of transboundary concern and their causes. The prepared TDA was the baseline for the interventions and priority actions that were specified in the CSAP. Step 3 targeted the development of common protocols on data collection, installation of monitoring sensors, in situ measurements in both countries and, last but not least, sharing of the available information between the two countries. CSAP prioritised water management issues and computer based models (step 5) were used for investigating the importance and impacts of these issues. The models coupled hydrological modelling, hydropower production tools, economic tools, and agricultural models with climate change scenarios (Skoulikaris et al. 2011). The simulation results set the base for the scenario analysis and the development of DSS with the use of multi-criteria decision analysis methods (step 6, see Ganoulis et al 2008). The final outputs (step 7) were communicated to water management authorities.

Conclusions

Ongoing social and political problems continue to pose a threat to stability in the Balkans. This atmosphere, in some cases, has hindered INWEB's ability to develop transparency and sharing, and it has sometimes been difficult to achieve full cooperation between stakeholders. There is no precedent for data sharing on an international basis in the Balkans, and hesitancy may be encountered when cooperation is proposed.

One of INWEB's greatest achievements, however, has been to establish the framework under which scientists can cooperate and work together on various joint projects. The fact that INWEB has facilitated the forging of personal links and trust is reflected in how individual scientists present cooperative projects to their respective national institutions. This result cannot be quantified, but it clearly cannot be disregarded. Overall, the work of the UNESCO Chair/INWEB at the Aristotle University of Thessaloniki demonstrates that effective networking and information sharing are strategic instruments to promote peace and stability through transboundary water resources management.

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36. The UN Watercourses Convention and its complementary User's Guide: Indispensable ingredients for global water cooperation

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International water law (IWL) has developed mainly over the second half of the twentieth century, and has enjoyed increasing legitimacy in recent times (McCaffrey 2013). A range of legal instruments have progressively strengthened key principles of international water law and defined the rights and duties of states with respect to their uses of shared watercourses,[1] such as: the International Law Association's 1966 Helsinki Rules (ILA 1967), the United Nations Economic Commission for Europe 1992 Helsinki Convention (UNECE 1992), the International Law Commission's 2008 Draft Articles on Transboundary Aquifers (ILC 2008), numerous regional and basin-specific agreements (Wolf 2002) and decisions by international courts.

Within the context of this development of IWL, the UN Watercourses Convention (UNWC) holds an important position. The Convention was negotiated on the basis of Draft Articles developed by the ILC and its final text, adopted at the UN General Assembly in 1997, is the result of ardent discussions between states and the recommendations of no less than five special rapporteurs.[2] The UNWC was proposed as a response to the acknowledgment that a global legal instrument was needed to bolster cooperation between states over their shared water resources and mitigate the potential for conflict. It is also important to note that the UNWC was meant as a global treaty whose role was to *support* other watercourse treaties by acting as a template and filling the gaps where coverage was lacking (McCaffrey 1998).

Along with the UNECE Helsinki Convention (which will soon be open to accession by non-UNECE members (UNECE 2013)), the 1997 UNWC is the

1 See Wolf (2002) for a list of transboundary water-related agreements.
2 For details of the negotiation and adoption process see Salman (2007).

only global treaty governing transboundary watercourses (McCaffrey 2008). As a framework convention, it is principle-driven rather than result-driven; it provides rules that can be tailored to the distinct circumstances of each international watercourse and gives liberty to watercourse states to take the actions that suit their needs and interests as required by the singularity of the situation (McCaffrey 2008). Both the Southern African Development Community (SADC) 2000 Revised Protocol on Shared Watercourses, and the 2009 Agreement on the Nile River Basin Cooperative Framework provide examples of instruments that have tailored the provisions of the 1997 UNWC to a regional and basin-specific context.

The UNWC, which is now widely recognised as the most authoritative source of international water law, is a pivotal document of IWL in a number of ways: it creates a strong framework for water governance arrangements (Rieu-Clarke and Hayward 2007) and a basic common ground that enhances predictability and encourages reciprocity (Rieu-Clarke and Lopez 2013); it codifies and clarifies existing norms and develops emerging principles of customary IWL; it constitutes a model that can guide the interpretation of other treaties and the negotiation and drafting of future ones (Rocha Loures et al. 2013); and, it has informed the judgments of international and regional courts (McCaffrey 2008).

The key aim of the Convention is to 'ensure the utilisation, development, conservation, management and protection of international watercourses and the promotion of the optimal and sustainable utilisation thereof' (UNWC 1997). The provisions of the Convention develop and consolidate fundamental principles of IWL:

1. Equitable and reasonable use and participation, stipulates that states reconcile any competing claims to an international watercouse on the basis of equity whilst protecting the sustainability of the system. Pursuant to the 1997 UNWC such claims should be reconciled based on all relevant factors and circumstances, and no use enjoys inherent priority (articles 5 and 6).
2. Obligation not to cause significant harm, which places states under a due diligence obligation to take all appropriate measures not to prevent signifcant harm to other watercourse states, unless it can be ascertained that such harm is both equitable and reasonable (Article 7).
3. Protection of ecosystem, whereby states are under an obligation, either individually or where appropriate jointly, to protect and preserve the ecosystems of an international watercourse (Article 20).
4. General obligation to cooperate, which requires that states cooperate on the basis of sovereignty, equality, territorial integrity, mutual benefit and good faith (Article 8). Such cooperation may lead to the adoption of watercourse agreements and joint institutions.

5. Notificiation and consultation, whereby states must notify, exchange information and, if necessary, consult and negotiate with other watercourse states, on the possible effects of planned measures that may have a significant adverse effect upon other watercourse states (Part III).
6. Regular exchange of data and information, which obliges states to exchange data and information on the condition of the watercourse (Article 9).
7. Peaceful settlement of disputes, which requires states to settle their disputes in a peaceful manner via a range of mechanisms including negotiation, mediation, conciliation, third-party fact-finding, arbitration and adjudication (Article 33).

Despite the discernable role played by the UNWC in the development of IWL and its influence in many river basins of the world, the treaty itself is not yet officially in force. Fifteen years after an overwhelming majority of states voted in favour of the adoption of the Convention, it has received 31 instruments of ratification, four short of the 35 needed for its entry into force. A range of reasons have been suggested as to why the convention has been slow to enter into force. These include treaty congestion at the time of its adoption, lack of awareness relative to the content of the UNWC and low levels of understanding about its relevance, an absence of leadership in promoting ratification, and a number of highly vocal — but not necessarily widely representative — opponents who claim that there is no need for a global legal instrument (Rieu-Clarke and Hayward 2007; Dellapenna et al. 2013).

This situation has led a number of actors across the globe to campaign for the ratification of the Convention by raising awareness and understanding of the Convention's text and organising events to publicise the benefits that the UNWC'S entry into force would bring to water governance. These awareness-raising efforts have been assisted by 2013 being declared 'International Year of Water Cooperation' by the UN General Assembly. A series of events, programs, projects and activities were organised throughout the year to promote water cooperation, several of which addressed the role and relevance of the UNWC (Rieu-Clarke 2013).

The UNWC Global Initiative, launched in 2006 by the World Wildlife Fund for Nature (WWF), is one of the high-profile campaigns surrounding the UNWC.[3] The Global Initiative has mobilised a range of actors including governments, international organisations and academics in an effort to raise awareness, build capacity, and support countries interested in ratifying the Convention. In order to deepen knowledge and understanding of the relevance of the Convention, the initiative has supported research related to the Convention in various regions, basins and countries, with a view to securing additional state ratifications and the instrument's eventual entry into force.

3 Learn more about the Global Initiative at WWF 'UN Watercourses Convention'.

A key output of the UNWC Global Initiative was the *UNWC User's Guide* (Rieu-Clarke et al. 2012) developed by the Centre for Water, Law, Policy and Science under the auspices of UNESCO at the University of Dundee. This Guide is one of the major tools supporting the efforts towards the Convention's entry into force. It was conceived out of the recognition that increased awareness and enhanced accessibility are the key to the effective adoption and implementation of the UNWC. Indeed, the guide is intended to foster knowledge of the Convention among all relevant stakeholders, including policymakers, bodies responsible for transboundary water issues, and anyone wishing to gain insight into the Convention. It was designed to disseminate information about the UNWC and enhance understanding of the text and relevance of the Convention.

In addition to an overview of the legal architecture surrounding transboundary watercourses, recounting the history of the adoption process of the Convention and listing the opportunities and challenges of the UNWC's entry into effect, the guide offers a precise and thorough analysis of each of the Convention's provisions. It also provides examples of the benefits of the UNWC by demonstrating how it might be applied within a range of settings and scenarios, such as when determining whether a certain activity complies with the principle of equitable and reasonable utilisation, or in deciding whether or not a state should notify other states of a planned measure.

An Online User's Guide has been developed (Rieu-Clarke et al. 2013b) to complement the material provided by the user's guide. In addition to the Convention's text and the analysis provided by the user's guide, the website includes: exclusive media content, fact sheets and resources which feed into to the analysis of the role and relevance of the UNWC; case studies analysing the role and relevance of the UNWC in regions around the globe; and quizzes to test knowledge and understanding of the Convention.

The purpose of the online user's guide is to create a forum where documents can be freely accessed and the tools and analysis necessary to enhance knowledge and understanding of the UNWC are provided. The website also regularly posts news stories to allow readers to keep tabs on the latest developments in the world of international water law. One day, it is hoped that the title of one of those news stories will be: 'UNWC enters into force'.

The UNWC Online User's Guide can be accessed at: http://www.unwatercoursesconvention.com. You can also follow UNWC-related activities via twitter: @unwconline. The PDF version of the user's guide can be found at: http://dl.dropboxusercontent.com/u/391260/UN%20Watercourses%20Convention%20-%20User%27s%20Guide.pdf.

The Centre for Water Law, Policy and Science under the auspices of UNESCO at University of Dundee was created in 2006. It is a world leader in its field and works to find new ways of effectively integrating law, policy and science to address water challenges of the twenty-first century. The centre undertakes a wide breadth of research and consultancy, recognising that if water law is to effectively implement integrated water-resource management and help the international community reach international development targets, it is essential to have legal frameworks to manage water rights and water quality and establish institutional mechanisms.

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37. Water reuse and wastewater recycling: Solutions to Tehran's growing water crisis

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Introduction

Over the last century, global and rapid urbanisation and population growth have produced serious water shortages and water pollution in urban areas. Consequently, interest in wastewater reuse has grown over the past decade, particularly in arid regions, as a technology that can promote sustainable, efficient, and appropriate water use (Maksimovic and Tejada-Guibert 2001).

Tehran's water resource problems

Tehran, the capital of Iran, has a population of over 7.5 million. Population growth will place immense demands on the city's water resources within the next decade. The mean annual precipitation is only 250 millimetres, most of which falls during winter and spring. The most important freshwater resources in Tehran are the Karaj, Lar, Latian, Mamloo and Taleghan reservoirs. Water from these dams is transferred to four water treatment plants (WTP). Tehran supplements surface water with groundwater to mitigate the water shortage, and at least 250 million cubic metres (MCM) of water is discharged from wells annually in Tehran (Tajrishy and Abrishamchi 2005). Table 1 shows the maximum water capacity of each of Tehran's water resources.

Table 1: Maximum water capacity of Tehran's water resources

Water resource	Aqueduct	Well	Karaj Dam	Mamloo Dam	Latian Dam	Lar Dam	Taleghan Dam
MCM/year	96	595	330	90	180	150	150

Sources: Ministry of Energy (MoE) 2009.

Table 2 lists Tehran's population and annual water consumption from 1966 to 2006 and demonstrates that water consumption has increased more than an order of magnitude over these years.

Table 2: Population and water consumption in Tehran

Year	Water consumption (MCM/year)	Population (thousands)	Per capita water consumption (lit/day.capita)
1966	98	2720	99
1976	346	4530	209
1980	443	5454	223
1986	542	6042	246
1991	681	6475	288
1996	780	6759	316
2006	1100	7798	386

Sources: MoE 2009.

Iran's water and sewage utility (ABFA company), states that per capita water production in Tehran is currently about 378 litres per day. If water consumption continues to follow current trends, water consumption will be 1290 MCM/year in 2026 (MoE 2009). In this situation, even if all water resources were utilised to their fullest capacities, the city would still be faced with a water shortage of more than 100 MCM/year in drought years.

Water resource managers in Tehran are faced with increased water demand and waste production due to population growth and socioeconomic development, decreased availability of water per capita, large losses of urban water, and local depletion and pollution of surface and groundwater. In countries facing similar freshwater crises, such as Australia, Japan, France and Germany, water reuse and wastewater recycling are already being deployed (Chu and Chen 2004). The time has come for these options to be considered in Tehran.

Wastewater reuse potential

In semi-arid cities like Tehran, water for irrigating natural vegetation, landscaping and park areas is in short supply. Tehran has more than 7000 hectares of parks that require more than 130 MCM of water per year, and most of them use groundwater for their irrigation. Many of these parks are located close to wastewater treatment plants (WWTP), but the discharge of outflow from these plants into seepage pits and surface storm water channels wastes a potentially valuable resource. Moreover, wastewater from treatment plant effluent could also be used for groundwater recharge in the eastern part of the city, which is under development and is faced with a falling groundwater level.

Water efficiency is very low in the industrial sector of Iran, and water recycling and reuse are not sufficiently emphasised. After treatment, municipal wastewater can be reused for cooling and processing water in industry, as has become an established practice in many countries. The greatest potential for industrial water reuse in Tehran lies in supplementing or replacing the potable water demand of the Ray Petrochemical Complex with treated municipal wastewater effluent (MoE 2009). Other industries in the western part of the city (Karaj Industrial Park) could use reclaimed wastewater for landscape irrigation, direct evaporative cooling, indirect refrigeration (food processing), or for in-plant transport and washing.

There are nine public and 18 private WWTP in Tehran that can treat more than 100 MCM of wastewater per year. This capacity will increase to 250 MCM per year after the Tehran Wastewater Project is completed. There are many small canals that join the two main canals (Kan and Darband), and these small canals transfer more than 400 MCM per year; but the water quality in these canals is not suitable for many reasons, including discharge of wastewater from surrounding houses and industrial centres. The water quality can thus be improved at little cost by controlling discharge or treating runoff, and this water could then be used as another new resource that has not yet been utilised in Tehran.

Methodology

In recent research, we categorised the city's primary water users (users that consume more than 300,000 cubic metres of water per year and can use reclaimed wastewater and runoff, such as parks and industries) and evaluated the quality and quantity of water they required. Then, we analysed different water resources, including WWTP effluent, groundwater (wells), runoff in canals and transferred water from dams (Karaj, Lar, Mamloo, Taleghan and Latian). After determining the possible water transfer pathways (according to the water quality that users require and the water quality of each water resource), a linear programming optimisation model, with the object of cost minimisation for the water provision and sewage management utility (ABFA Company), was used to allocate the water among users and resources. This research builds upon existing literature in water reuse planning and management modeling (Chu and Chen 2004; Ganoulis and Papalopoulou 1996; Oron 1996; Keckler 1997; Zhao and Chen 2008; Mohammadnejad and Tajrishy 1998) to model a user-supplier water resources network for the first time in a city of Iran.

In our model, urban water is used for three primary purposes: domestic uses, industrial processes and the irrigation of parks and landscapes. Domestic users require high-quality water. Because of the lack of modern treatment technology in Tehran's WWTP, the water network includes industries and parks as normal users, even though these users do not require high-quality water. The superstructure of the model is shown in Figure 1. Only the users that require more than 300,000 cubic metres per year are considered network elements in our model.

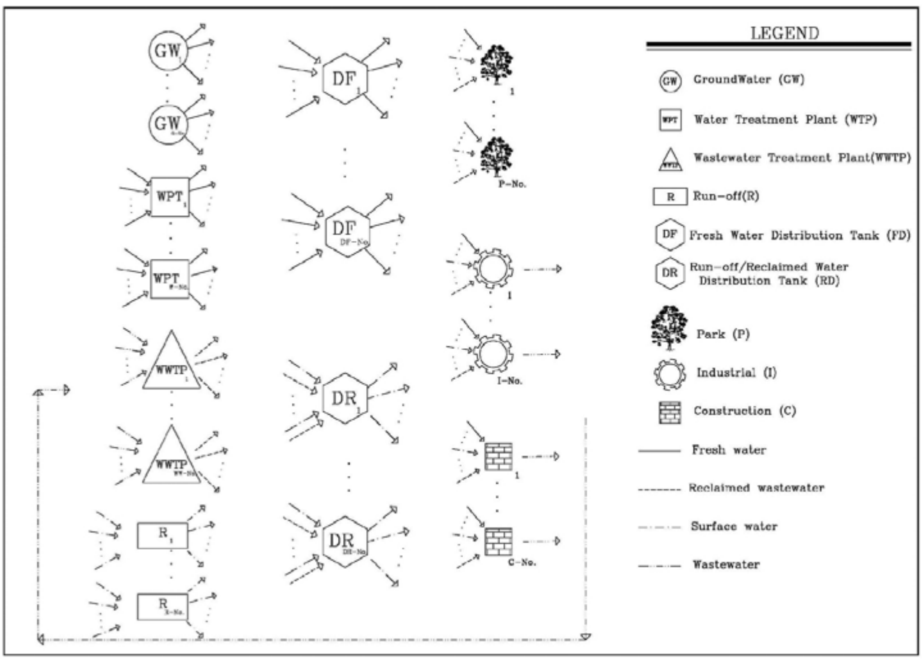

Figure 1: Superstructure of the model

Sources: Authors' research.

Water suppliers in Tehran are divided into four groups:

1. WTP effluent: There are four WTP in Tehran, which receive water from five reservoirs near the city.

2. Well (groundwater): There are 260 wells located throughout the city. In the model, these wells are divided into 20 groups according to location, and 20 virtual wells are defined as 20 supplier elements to represent each group of wells in the model (with the capacity of each virtual well being equal to the sum of the capacities of the wells in the corresponding group).
3. WWTP effluent: There are 14 large WWTP in Tehran with capacities ranging from 770 to 18300 cubic metres/day.
4. Water in canals: Two main canals crossing the city from north to south have been confined and canalised by concrete and stone. Local WWTP effluent and storm water are discharged to these canals.

Results and discussion

Currently, the two main canals and the effluent of wastewater treatment plants in Tehran are not of suitable quality for irrigation and industrial processes, so the model is run under three different sets of conditions:

1. Present Condition: In this case, the water quality of all suppliers in the model is the same as current data reported from laboratory tests. Only WTPs and wells can supply any users' water demands. The WWTPs do not treat their effluent streams to sufficiently high quality for user's purposes, and the quality of the water in the canals is not sufficient for reuse because local WWTPs and factories discharge their effluents directly to the canals.
2. Improved System: In this case, it is assumed that simple actions, such as reduction of WWTP loads, disinfection, filtration and protecting the canals against pollution have been taken and that the water quality of canals and WWTP effluent has sufficiently improved for use in irrigating parks with restricted access and in some industrial processes. Under these conditions, WTPs and wells can supply the water demand of any user, while WWTPs and canals can supply the water demands of users with limited access.
3. Ideal System: This case incorporates technical improvements to WWTPs such as adequate filtration and using ozone or ultraviolet (UV) light for disinfection. Water quality in the canals is also improved, and WWTPs and industries are forbidden to discharge effluent to the canals. In this case, all suppliers provide water of sufficient quality to supply the water demands of all users in the network.

Table 3 shows an economic and environmental comparison of the three cases. The major finding is that developing WWTPs, improving the quality of WWTP effluent, and controlling the runoff into canals would result in reduced freshwater and groundwater usage. Increasing the use of WWTP effluent will reduce soil and groundwater pollution in the south of the city because the transfer of sewage is prevented. As fresh water and groundwater usage decreases, the growing requirements for sanitary water will be met through other means, and the falling groundwater level will stabilise. Clearly, Tehran could compensate for water shortages in drought years whilst preserving its aquifers.

Naturally, the total cost of water transmission and distribution in the Ideal System is greater than in the Improved System because treating wastewater to a high-quality level costs more than treating it to moderate quality. The total cost of water transmission and distribution in the Present Condition is, however, higher than in either of the other two cases because of the high energy costs associated with pumping water from wells and transferring water from dams. The cost savings that would result should encourage the authorities to improve WWTP technology and control runoff quality.

Table 3: Comparison between Present System and two new systems

	Present Condition	Improved System	Ideal System
Freshwater usage (MCM/year)	51.7	7.7	0
Groundwater usage (MCM/year)	115.8	23.4	0
WWTPs effluent usage (MCM/year)	0	21.5	37.8
Channel usage (MCM/year)	0	115	129.7
Transportation cost (10^6 $/year)	1.4	1.3	1.5
Purchase cost (10^6 $/year)	1.3	0.2	0
Operation cost (10^6 $/year)	41.8	28.3	33.5
Benefit (10^6 $/year)	13.9	10.8	11.1
Total cost (10^6 $/year)	30.6	19.0	23.9

Sources: Authors' research.

In order to test the conclusions, we also conducted a sensitivity analysis of model parameters. A number of observations emerge:

- If the costs of wastewater and runoff treatment increase, the resulting water allocation in the network changes. Until the cost of wastewater treatment is higher than that of runoff treatment, runoff usage is preferred to use of WWTP effluent (because the other costs of these two resources are nearly identical) and the latter is therefore the best solution as far as reducing total cost and adjusting usage of water resources.

- Reducing the income from selling WWTP effluent and runoff produce a reduction in the overall benefit to ABFA and, as a result, it becomes economical for ABFA to distribute fresh water and groundwater instead of WWTP effluent and runoff.
- If the price ABFA must pay to the MoE to buy water from dams and wells increases (e.g., due to new policies that reduce subsidies), then supplying water from WWTP effluent and runoff becomes more economical than using fresh water and groundwater.

Conclusions

Like many megacities in the world, Tehran is faced with increasing freshwater demand and limited water resources because of rapid population growth. Our model's results demonstrate that positive economic impacts result when users that do not require high-quality water, such as parks, industrial plants and construction projects, utilise WWTP effluent and treated runoff rather than fresh water and groundwater.

Although improving WWTPs and controlling runoff quality require large initial investments, over time, they are likely become more economical than the present system. This result is dependent, however, on the cost of treating wastewater and runoff and the purchase cost of fresh water and groundwater, with the latter result being a direct function of policy settings.

Tehran may have a pressing need for solutions to its water crisis, but there are solutions available. Our research demonstrates that water reuse and wastewater recycling are not only physically feasible but also economically attractive options. In future the complexity of urban water issues will increase, continuing to push the traditional boundaries of water and sewage management into the areas of integrated solutions within the water sector. The most plausible option is to integrate water supply, wastewater and stormwater to satisfy outdoor water use demands of sprawling megacities in the developing world.

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38. Water services and cooperation

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Background and objectives of the UNESCO Chair in Sustainable Water Services

The biggest global challenges of mankind are all, in one way or another, related to water — its availability, occurrence and quality. In terms of water uses, community water supply is generally set as the highest priority for policymakers (Katko and Rajala 2005), yet water quality, water pollution control and water-use conflicts are also a huge concern in many areas.

Currently some 0.8 billion people lack access to improved sources of drinking water, and as many as 2.5 billion cannot access basic sanitation (United Nations Children's Fund (UNICEF)/World Health Organization (WHO)2012). Looking beyond the Millennium Development Goals, water was identified as one of the seven Critical Issues at the UN Conference on Sustainable Development (Rio+20 Summit) in 2012. At Rio+20, UN-Water emphasised that the success of the broader green economy depends on sustainable, integrated and resource-efficient management of water resources, and on safe and sustainable provision of water supply and adequate sanitation services (UN-Water 2012).

The UNESCO Water Chair No. 27 in Sustainable Water Services (UNECWAS) was established at Tampere University of Technology (TUT), Finland, in 2012, and is linked to the Capacity Development in Water and Environmental Services (CADWES) research team based at TUT. The foci of the Chair are management, development, governance, policy and institutional issues associated with water services, particularly urban and rural water supply and wastewater services.

The overall development objective of the Chair is to promote education and research on sustainable water governance, especially services, based on co-creation principles (see Frontier Strategy 2009) and the needs of local communities. A major objective is also to strengthen knowledge creation and sharing and enhance the capacity of partners through North–South–South collaboration between six universities in the South, two UNESCO centres in the North, and three other European partners.

Research agenda

Reform processes

The two biggest challenges confronting the water supply and sanitation sector in both industrialised and developing countries are increasing coverage and infrastructure maintenance (Prasad 2007). Many developing countries are presently undergoing or planning substantial policy and institutional reforms of their water sector to overcome these challenges. Typically, these processes entail reform of both policy and the legal and administrative water rights framework (Aagaard and Ravnborg 2006). These reform processes are often driven by foreign experts and donors. International water policies and strategies have in the past, however, concentrated on a few fashionable and, based on research, questionable aspects — like privatisation of urban water delivery — instead of being holistic and comprehensive (Seppälä 2004). Although the reforms have been on the agenda for several years in the south, little research has been carried out on how reforms are implemented and the process occurs.

Water access as an economic good or a human right?

In 1992 a high-level meeting of water experts released the Dublin Statement on Water and Sustainable Development (ICWE 1992), also known as the Dublin Principles, that would provide the foundation for Integrated Water Management and subsequent thinking on water. Dublin principle no. 4 recognised that water has an economic value in all its competing uses and it should be treated as an economic good: 'managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources' (Global Water Partnership (GWP) no date). The same principle also pointed out, however, the vital importance of recognising the fundamental right of all human beings to have access to clean water and sanitation at an affordable price.

Shortly after the Dublin Principles were developed — with the economic good aspect being the main emphasis of subsequent interpretations — privatisation of water supply in developing countries emerged, largely at the prompting of international financial bodies. As Franceys (2008) mentions, this 'privatisation decade' lasted roughly from 1995–2003. The belief behind it was that private investments could be attracted through the involvement of multinational companies. For many reasons this has not been the case, and it seems that multinational companies are, rather, withdrawing from water services operations in developing economies (Annez 2006; Hukka and Katko 2003; Bakker 2010; Castro 2008). One of the main pitfalls was the question of regulation and the fact that private operations require a strong public sector and regulation capacity. In several cases, in Latin America and even in Paris and Berlin, municipalities have assumed responsibility after the concession or operational contract expired. Consequently, some 90 per cent of the world's water utilities are currently publicly owned and managed; in sewage the share is about 95 per cent (Hall et al. 2011).

After gaining independence in the 1960s and 1970s, many Sub-Saharan countries introduced a free water policy. It was considered justified in the prevailing political climate, but soon proved unrealistic (Mashauri and Katko 1993). The mainland of Tanzania, for example, abandoned its free water policy at the national level in the 1990s, while Zanzibar, the other part of the United Republic, held out until 2006. Yet, water as a basic human right was promoted by the United Nations Committee on Economic, Social and Cultural Rights, November 2002, which reminded that access to water as a human right — a social and cultural good, not merely an economic commodity — defines the public nature of water as 'a limited natural resource and a public commodity fundamental to life and health'. This process continued and culminated in the historic United Nations (2010) resolution 'Right to water and sanitation' in July 2010.

Governance and stakeholders

It is clear from the above discussion that water services governance has multiple objectives and criteria to incorporate. Beyond the economic good/human right distinction, these also include: balancing the water requirements of households, food production, energy production and the environment. Besides, water also has various dimensions as a cultural good, common pool resource, natural resource, public good and social good.

The numerous examples of different water requirements and dimensions stated above show how strong external pressures can be applied to water services. Indeed, the operational environment of water services is complex with a number of stakeholders whose preferences and priorities can create conflicts (see Figure 1). Whatever the priorities, it is obvious that mechanisms are required to co-ordinate and balance various interests and, particularly, to keep in mind the fundamental purpose of water services: to serve citizens and the society at large.

As pointed out by United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) (2003), addressing inefficiencies and shortcomings of water and sanitation service production are essentially a governance problem in many countries. Failure to observe good governance principles is considered to be one of the root causes of all major problems associated with public and private sector administration. In the case of water, for example, the 2nd World Water Development Report (WWDR2) (UN-Water 2006) noted the linkages between 'water and poverty', water and governance' and 'water and environment', and emphasised that 'the water crisis is essentially a crisis of governance'.

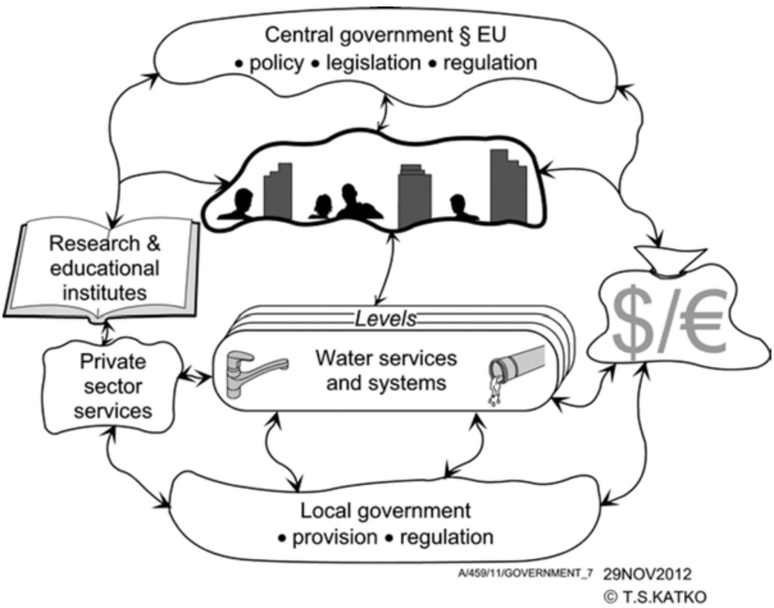

Figure 1: Internal domain framework: major stakeholders of water services

Source: Authors' research.

Good governance is participatory, consensus-oriented, accountable, transparent, responsive, effective and efficient, equitable and inclusive and follows the rule of law (UNESCAP no date). It also ensures that corruption is minimised, the views of minorities are taken into account, and that the most vulnerable members of society are considered in decision-making. It is also responsive to the future needs of society. One positive example of movement towards these standards in recent times are the national transparency activities now common in developing nations, such as Kenya (Transparency International Kenya (TIK) 2014) and Uganda (Transparency International Uganda (TIU) 2014). It should be noted, however, that whatever the water governance systems and frameworks present in any country, the likelihood of achieving better and more sustainable development is low without educated experts.

The importance of history

The current challenges of water-sector reform show how history and past policies and decisions impact our futures. The concept of path-dependence, which originated in economics, has recently been applied to the history of technology (Melosi 2000). The premise is that major decisions may have postponed the introduction of certain systems, decisions may have been made that limit options, or decisions may have been made that severely restrict available options (Figure 2). The importance of these factors are evidenced in historical research of water-sector reforms in Kenya (Nyangeri 2011).

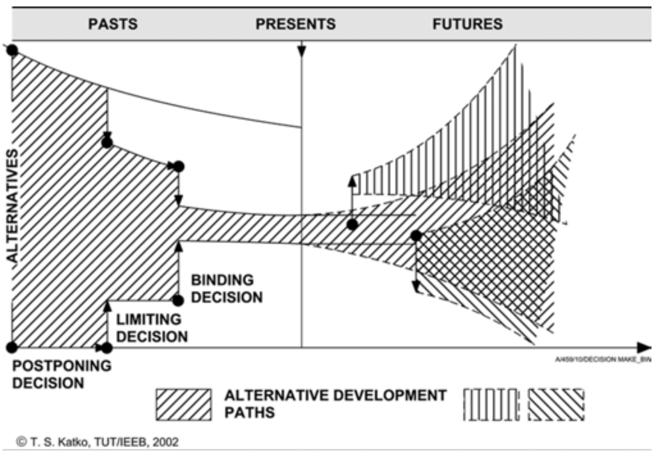

Figure 2: Path dependence: postponing, limiting and binding decisions and their impacts on future options

Source: Kaivo-oja et al. 2004.

Presents (or potential present states) are bound by laws and regulations, compliance with them and their enforcement, and political objectives and decisions that are inevitably related to alternative futures. Futures (or potential future states) can be classified as possible, credible and preferable. Analogies and path dependencies link pasts (or alternative past states), presents and futures to each other (Juuti and Katko 2005). The plural form is used deliberately to point out that several interpretations of each time dimension exist. Note that an understanding of water-sector reforms requires a lengthy period to analyse the driving forces across time, and the implications of changes and strategic decisions need to be considered for each period.

Futures researchers emphasise the evolutionary nature of development. Accordingly, development and technology are not deterministic and bifurcations (or turning points) are bound to occur, as shown in Figure 3. Sometimes revolving paths are encounterd, such as in the selection of urban raw-water sources in Finland. In the late 1800s groundwater was favoured by cities, this declined in the 1920s, began again in the 1960s, and has now been contested in the early twenty-first century (Katko et al. 2006).

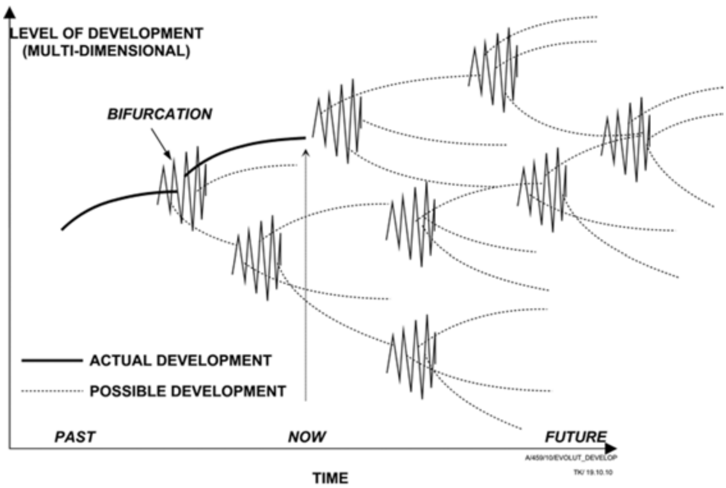

Figure 3: Bifurcate nature of technological development

Source: Adapted from Mannermaa 1991.

Common research agendas in both North and South

The current research themes of the partners of the UNESCO Chair show that social needs in the water services sectors of the South and the North are remarkably similar: regionalisation, operational improvements, pricing, asset management, rehabilitation, ageing infrastructure, ageing workforce and tacit knowledge management, small systems management, public-private collaboration, leadership and stewardship, more transparent decision-making, and significance of water.

An example of common research agendas is the broad issue of ageing water infrastructure, though the physical manifestation of the issues may vary greatly by location. A recent study in Finland (Heino et al. 2011) based on the views of 48 sector experts showed this to be the most severe challenge to water services. Similar findings have been made in other industrialised countries, such as

Sweden, Norway and the United States. Moreover, ageing infrastructure is also one of the biggest challenges in the Sub-Saharan region, in addition to related specific issues such as delivery challenges in peri-urban and unplanned areas.

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