ROUTLEDGE SPECIAL ISSUES ON WATER POLICY AND GOVERNANCE

Water Management and Climate Change

Dealing with Uncertainties

Edited by
Cecilia Tortajada, Asit K. Biswas
and Avinash Tyagi

THIRD WORLD CENTRE FOR WATER MANAGEMENT

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Water Management and Climate Change

To plan successfully and manage the increased uncertainties posed by likely future climate change, knowledge needs to advance much more for the water profession beyond what is now available. Meeting these challenges does not depend exclusively on advances in climatological-hydrologic models. Policies for adaptation and strategies for mitigation measures have to be formulated on the basis of what are likely to be the potential impacts. These will have to be regularly fine-tuned and implemented according to changing needs as more reliable knowledge and data become available. Even more challenging will be the politics of policy making and implementation, which will require a quantum leap from current policy-making and implementation processes. One can even say that, in addition to the development of more reliable models, the politics of climate change and water management remains one of the greatest uncertainties for the water profession.

This book addresses water management practices and how these should and could be modified to cope with climatic and other related uncertainties over the next two to three decades; the types of strategies and good practices that may be available or have to be developed to cope with the current and expected uncertainties in relation to climate change; and the types of knowledge, information and technological developments needed to incorporate possible future climate change impacts within the framework of water resources management. Decision making in the water sector under changing climate and related uncertainties, and societal water security under altering and fluctuating climate are also discussed. Several case studies are included from several basins, cities, regions and countries in both developed and non-developing countries.

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Routledge Special Issues on Water Policy and Governance

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Most of the world's water problems, and their solutions, are directly related to policies and governance, both specific to water and in general. Two of the world's leading journals in this area, the *International Journal of Water Resources Development* and *Water International* (the official journal of the International Water Resources Association), contribute to this special issues series, aimed at disseminating new knowledge on the policy and governance of water resources to a very broad and diverse readership all over the world. The series should be of direct interest to all policy makers, professionals and lay readers concerned with obtaining the latest perspectives on addressing the world's many water issues.

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INTRODUCTION

Water management and climate change, their numerous interlinkages and the extent of their hydrologic, economic, social and environmental impacts over time and space are complex issues that can be predicted at our present state of knowledge only with a great deal of uncertainty. Lack of scientific understanding of the complex and interacting interrelationships and absence of reliable data are only two of the factors which prevent our forecasting likely future multidimensional and multisectoral impacts with any degree of accuracy. This, in turn, makes proper planning and investment decisions in a cost-effective and timely manner a most challenging task, even under the best of circumstances.

It is widely recognized that at the present state of knowledge, there are a number of important uncertainties in predicting the impacts of climate change in the water sector. These include but are not necessarily limited to: estimating future emission scenarios; analyzing them for greenhouse gas concentrations; predicting how these are likely to affect future global, regional and local rainfall patterns; interpreting their overall impacts on the hydrologic cycle at different scales; and assessing their impacts.

At present, it is still not possible to predict even how the annual average temperature in various regions of the world may change, let alone the rainfall pattern. Additionally, the latest generation of models to forecast average rainfall at the river basin and sub-basin levels have to be considerably improved before they can be used for water resources planning and management purposes. For water management, the problem becomes far more complex, because it must deal not only with the average changes in annual rainfall on the basin or sub-basin scale but also, and more importantly, with extreme rainfall events like serious floods and extended drought. The magnitude of the uncertainties increases several-fold when attempts are made to forecast extreme rainfall events based on increases in annual average temperatures, and even more when rainfalls have to be translated into river flows. In spite of these uncertainties, however, the overall perception is that climate change is responsible for nearly every serious flood or drought the regions and countries have witnessed in recent years.

In the final analysis, efficient water management over the long term requires reliable data and information, as well as understanding – both of the present and of expected events in the future. Historically, water infrastructure has been designed, and will continue to be designed (at least for the next several decades), on the basis of forecasts of future extreme rainfall and river-flow events that will continue to require past data and historical information. In the absence of better and more reliable estimates of expected future extreme rainfall events than the ones now available, the objective may have to be to continue constructing all types of new water infrastructure with the best knowledge available, and maintain and operate existing structures more efficiently in the event of prolonged droughts or serious floods.

To plan successfully and manage the increased uncertainties posed by likely future climate change, knowledge needs to advance much more for the water profession beyond what it is now available. Meeting these challenges does not depend exclusively on advances in climatological-hydrologic models. Policies for adaptation and strategies for mitigation measures have to be formulated on the basis of what are likely to be the potential impacts. These will have to be regularly fine-tuned and implemented according to changing needs and as more reliable knowledge and data become available. Even more challenging will be the politics of policy making and implementation, which will require a quantum leap from current policy-making and implementation processes. One can even say that, in addition to the development of more reliable models, the politics of climate change and water management remains one of the greatest uncertainties for the water profession.

To address the challenges and uncertainties related to water management and climate change, the Aragon Water Institute and the International Centre for Water and Environment of the then Ministry of Environment of Aragon, the Third World Centre for Water Management in Mexico and the International Water Resources Association jointly organized a meeting on "Water Management and Climate Change: Dealing with Uncertainties", held in Zaragoza, Spain, from 28 February to 2 March 2011.

Well-known international experts in the field of water management and climate change were specially invited to discuss future-oriented issues such as: water management practices and how these should and could be modified to cope with climatic and other related uncertainties over the next two to three decades; the types of strategies and good practices that may be available or have to be developed to cope with the current and expected uncertainties in relation to climate change; and the types of knowledge, information and technological developments needed to incorporate possible future climate change impacts within the framework of water resources management. Decision making in the water sector under changing climate and related uncertainties, and societal water security under altering and fluctuating climate, were two matters that were also discussed in depth. Several case studies were presented from basins, cities, regions and countries, such as the Ebro Basin and the Himalayas; the Aragon and Catalonia regions in Spain and the state of Gujarat in India; the city of Zaragoza; and countries such as Australia, Greece, Mexico, Singapore, Spain and the Netherlands. The session also addressed the implications climate change may have for agriculture in India and in OECD countries.

The papers were extensively reviewed by the authors and are now included in this thematic issue. Nevertheless, with the objective to give them further dissemination, these papers have been available on-line for several months on the journal's website: http://www.tandfonline.com/toc/cijw20/current. To further contribute to global discussions on climate-related topics, this thematic issue also includes two state-of-the-art reviews. One of them addresses water and disasters and provides an in-depth review and analysis of the policy aspects; the second focuses on management of drought risks in European water-supply systems.

Finally, we would like to once again invite the academic, research, policy and water and development communities to further question, debate and challenge prevailing wisdom; we believe this is the only way to promote the advancement of knowledge.

Cecilia Tortajada and Asit K. Biswas
Editors-in-chief

Adapting to climate change: towards societal water security in dry-climate countries

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Water security needs priority in adaptation to global change. Most vulnerable will be the semi-arid tropics and subtropics, home of the majority of poor and undernourished populations. Policies have to distinguish between dry spells, interannual droughts and long-term climate aridification. Four contrasting situations are distinguished with different water-scarcity dilemmas to cope with. Some countries, where the climate is getting drier, will have to adapt their water policy to sharpening water shortage. In many developing countries it will be wise to go for win-win approaches by picking the low-hanging fruit, i.e. taking measures needed in any case. A fundamental component of adaptive management will be social learning to help people recognize their interdependence and differences. Rethinking will be needed regarding how we manage water for agricultural production, integrating solutions with domestic, industrial and environmental uses. Adaptation to global change will benefit from basin management plans, defining medium- and long-term objectives. Conceptual clarity will be increasingly essential. Water – so vital in the life support system – needs to be entered into climate change convention activities.

> Political stability, economic equity and social solidarity are very closely related to water, its management and governance. Hence the future should be viewed through a "water" lens.
>
> Global Water System Project (GWSP, 2011, p. 6)

Introduction

At the Second World Water Forum, in The Hague in 2000, the Ministerial Declaration declared a goal of providing water security in the twenty-first century, in the sense of "ensuring that freshwater, coastal and related ecosystems are protected and improved; that sustainable development and political stability are promoted, that every person has access to enough safe water at an affordable cost to lead a healthy and productive life, and that the vulnerable are protected from the risks of water-related hazards" (quoted in GWSP, 2011, p. 3). Safeguarding societal water security has two basic dimensions: on the one hand to meet water needs in their relation to socio-economic production; and on the other to limit water-related risk, primarily in situations of flood and drought, to an acceptable level.

Large-scale emission of greenhouse gases has been warming the atmosphere, increasing sea evaporation and thereby exacerbating the warming through the additional greenhouse effect from increased atmospheric water vapour (GWSP, 2011). This has lead to changes in precipitation patterns, increasing their intensity and variability. Global warming is in other words speeding up the hydrological cycle, while land use changes alter the rainwater partitioning at the land surface between the blue and green branches, i.e. what goes to rivers and groundwater as opposed to what goes to the vegetation. The outcome is alteration of all the different hydrological elements: precipitation, evaporation, river flow, lake levels and groundwater recharge.

However, the real challenge is not the proceeding climate change alone but coping with global change after also incorporating other fundamental driving forces: the ongoing population growth that adds some 80 million people every year to the world population; the effects of socio-economic development and the increasing water expectations that it involves. In terms of its implications for water requirements and pressure on the available water, Vörösmarty, Green, Salisbury, and Lammers (2000) have shown that population growth dominates greatly over climate change as a driving force towards water scarcity. One should also remember that most of the population added will in fact be living in urban areas, as a consequence not only of population growth as such but of rural push and urban migration of poor rural inhabitants, leading to greater demands on water services, changing diets, etc. All these changes are in reality moving targets and interlinked in a nexus of ongoing change that policy makers have to navigate.

Achieving water security involves the twin goals of reducing the destructive potential of water and increasing its productive potential (Gray & Sadoff, 2007). How will global change influence the water management situations in different parts of the world? What main differences are there in vulnerability predicaments? And what steps are there to take for a country in adapting to the ongoing climate change and safeguarding their particular water security?

This paper will have its focus on climate change implications as regards the role of water deficiency for water security, and how to cope with them. Special care will be taken in terms of the distinction between water scarcity and drought, in line with the recent Dakar recommendation (INBO, 2011).

Critical vulnerability differences

Fundamental differences in exposure

Hydroclimate exposure differences

Most critical in terms of life support conditions, besides temperature, is the relation between precipitation and atmospheric uptake capacity (potential evapotranspiration). Figure 1 illustrates core differences in water balance between three main climatic zones: the temperate zone, where most of the advanced industrial economies have developed; the semi-arid zone, where the majority of poor and undernourished live (approximately one billion, of which around 450 million depend on rainfed agriculture); and the humid tropics, which host a series of emerging economies. All the zones are exposed to increased rainfall variability. Most exposed to water deficiencies, however, will be the semi-arid tropical zone, in view of the large water requirements for food production.

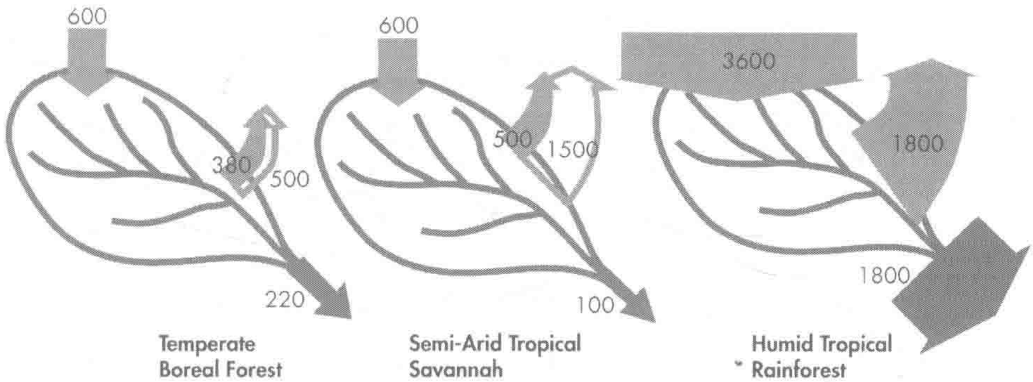

Figure 1. Fundamental water balance contrasts between three different hydroclimatic zones (units are mm/yr).

The Ministerial Declaration at The Hague referred to earlier reflects the insight that basic water security is vital for a country to be able to enter the path towards socio-economic development. Already at early development stages, countries strive for water storages to compensate for their sensitivity to drought. Gray and Sadoff (2007) have observed vital differences between those that have *harnessed* their hydrology by water storages etc. (see Figure 7, described later), i.e. mainly industrial countries; those that are *hampered* by their hydrology (Lundqvist, 2010), partly by flood events, droughts and water pollution, i.e. mainly emerging economies; and those that remain *hostages* of their hydrology, mainly poor developing economies with particularly challenging climatic conditions and low ability to improve their water security through water resources management.

Water security calls for the ability to meet water dependence through adequate water management efforts. Differences in ability have in fact coloured the global situation considerably, as pointed out by Vörösmarty et al. (2010) in their demonstration of contrasts between basic human security and achieved water security. They indicated that rich countries have been able to lower their exposure to what they refer to as incidental threats to human security through technological and management investments for an overall population of 850 million, while minimal investments in developing countries have left 3400 million with high vulnerability. Currently, about one-third of humanity is estimated to remain excluded from what we call progress (GWSP, 2011). These different observations in terms of fundamental differences in both exposure and ability to secure adequate water security suggest that the third group – those hampered by difficult hydrological phenomena – is especially important to analyze and discuss from a climate change perspective.

Agricultural exposure to climate variability

Agricultural exposure to climate variability is particularly large in regions where the effects of rainfall fluctuations can seriously impact political stability, i.e. countries in the semi-arid tropical region, where agriculture dominates the national income. CGIAR's recent comparative research of a number of catchments in different developing situations demonstrated a strong correlation between the dominance of agriculture and early stages of the development trajectory (Kemp-Benedict et al., 2011; see Figure 2). It is therefore fair to assume that in such countries rural small-scale farmers are particularly exposed to the increasing rainfall variability, and the implications of continuing population growth are most pronounced.

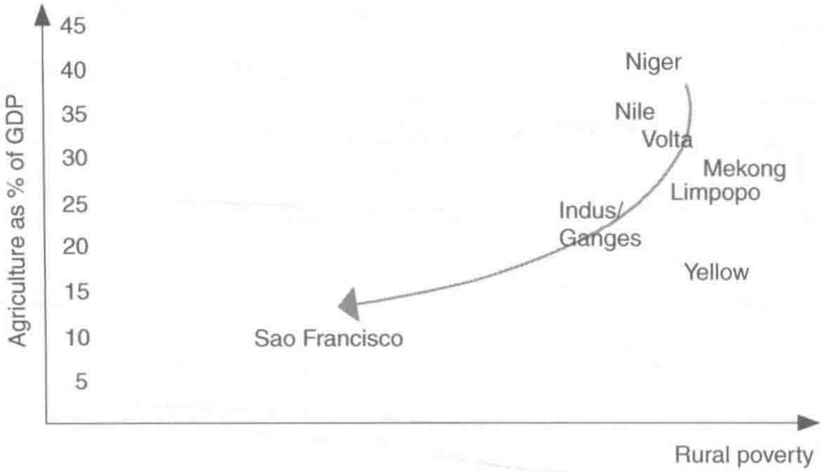

Figure 2. Dominance of agriculture in early stages of the development trajectory. (Redrawn with kind permission from Kemp-Benedict et al., 2011).

Blue-water competition and closeness to limits

But some dry-climate countries like Australia have been able to make their way to higher positions on the development trajectory. There, water scarcity shows up as high levels of demand-driven water stress (Figure 3). In so doing, such countries have reached a level of development complexity that makes them particularly vulnerable to disturbances related to increased unpredictability and variability in blue-water availability (mainly river flow).

Figure 3 further clarifies different types of water scarcity predicament in terms of different modes of blue-water scarcity: demand-driven water scarcity along the vertical axis and population-driven scarcity along the horizontal axis. Two limits are of particular interest here: the *environmental flow reserve* in view of the need to leave some 30% of the

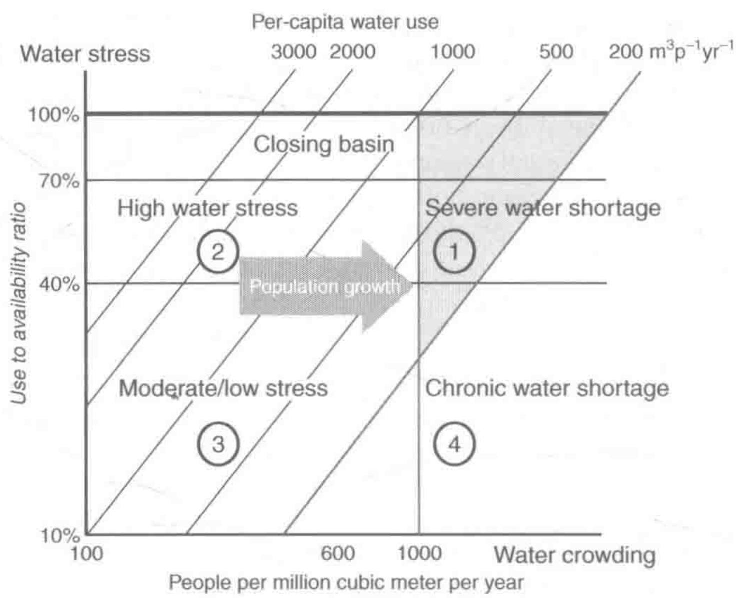

Figure 3. Blue water competition and limits. Two dimensions of blue water scarcity. Horizontal axis shows population-related shortage (water crowding), vertical axis demand-related shortage (water stress). Diagonal lines show per capita water use.

available flow for aquatic ecosystem health; and *societal water supply requirements* for municipal and industrial needs – some 200 m^3 per person per year (Falkenmark & Lundqvist, 1997). This means that particularly vulnerable are basins close to (a) the 70% horizontal level, and (b) the 200 m^3 per person per year diagonal line. Most critical from a water shortage perspective are basins in the severe-water-shortage triangle.

Four different vulnerability situations

It is clarifying to compare four contrasting situations with rather different water scarcity dilemmas (see Figure 3).

Region 1 refers to the vulnerable triangle beyond the water crowding level of 1000 people per 10^6 m^3 per year (chronic water shortage) and above the diagonal line for water use of 200 m^3 per person per year, which is often referred to as what is needed for urban and industrial water supply (Falkenmark & Lundqvist, 1997). This is a region sensitive to both climate aridification and droughts, where competing water demands will be particularly challenging.

Region 2 refers to the upper left-hand corner of the graph, where many well-developed countries with high levels of water use, primarily irrigated agriculture, lie. For them, the dominating challenge is long periods of drought years when irrigation water needs cannot be met and policy makers start preparing for reduced allocations but social acceptance is hard to secure.

Region 3 refers to the area low or moderate in both directions, i.e. in the lower left-hand part of the diagram, where many of the poor developing countries still remain highly sensitive to rainfall variability and green-water problems.

Region 4 refers to the lower right-hand area, where some poor and highly crowded countries may be found with very low water security.

For our further analysis we can seek illustrations of basins in these different predicament categories based on official data from various sources for precipitation, evaporation and water use for domestic and industrial water supply and irrigation. In Category 1 we find large irrigated river basins in North China and India with severe water shortages and very low per capita water availability even compared to modest water demands (500–700 m^3 per person per year). Population growth will push these basins closer to the diagonal line for 200 m^3 per person per year, where most water is needed for municipal and industrial use. Category 3 represents the predicament of many poor and semi-arid countries dependent on dry-land agriculture. By their lack of financial resources, many such countries have not been able to develop their rivers to provide agricultural water security through irrigation – this is called 'economic water scarcity' by the IWMI (Molden et al., 2007) (see also Figure 7, described later). This is the predicament typical for many African countries.

In Category 2 we find rich countries with advanced, irrigation-dependent economies with high water demand (more than 2000–3000 m^3 per person per year) and large-scale export of agricultural products playing a core role in the national economy, like Australia or California. Since per capita water use is quite high, water demand management stands out as an essential policy mode. In Category 4, finally, we find exceptionally water-short and overpopulated basins, one example being the transnational Limpopo Basin in Southern Africa.

From the perspective of climate change vulnerability, we may conclude that it will be necessary for countries to be better prepared for exacerbated hydrological complications but that, depending on the type of water-scarcity predicament, climate change adaptation

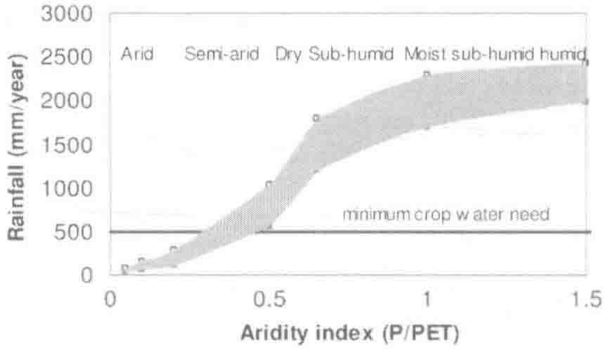

Figure 4. Rainfall variability as a function of aridity index. Horizontal line shows crop water need. From Molden et al. (2007), IWMI.

will take rather different forms. In Categories 1 and 2, vulnerability is related to blue-water problems in terms of aridification (see also Figure 4, described later), depleted blue-water sources (Falkenmark & Molden, 2008), and difficulty in meeting water demands from municipalities, industry and irrigation projects. In Category 3, climate change problems will involve mainly green-water problems, hitting rainfed agriculture on millions of small-holder farms and reaching the poor rural strata of the population. Critical will be strategies to cope with increasing rainfall variability and its link to agricultural production, which is the dominating economic activity in many countries in the semi-arid zone, where drought sensitivity is large and economic ability to cope small. Long-term rainfall deficiency may play havoc with farmers' water security, as will be further discussed below.

In Table 1 we have structured these fundamental differences into four different categories with rather different water-deficiency challenges to address. Categories 1 and 2 are exposed to mainly blue-water problems, while Categories 3 and 4 as regards food production have mainly to address green-water problems. Category 1 is the most exposed, in the sense that irrigation – the backbone of agriculture – may be severely threatened. Category 2 will be able to manage by securing increased irrigation water use efficiency. Category 3 contains many African counties where agriculture is threatened by increasing rainfall variability. Category 4 will be particularly severely exposed due to chronic water shortage and will have to plan for a future without irrigation.

Climate change adaptation: coping with water deficiencies

Considering these four contrasting situations in terms of water predicament, we now turn attention to differences in the two particular types of water deficiencies that have to be

Table 1. Four climate change exposure categories in drought-sensitive countries.

		Water crowding	
		Low	*High*
Relative water use	*High*	**2** Low water crowding/ Large-scale irrigation	**1** High water crowding/ Large-scale irrigation
	Low	**3** Low water crowding/ Mainly rainfed agriculture	**4** High water crowding/ Mainly rainfed agriculture