Global Issues in Water Policy 25

M. Dinesh Kumar
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Management of Irrigation and Water Supply Under Climatic Extremes

Empirical Analysis and Policy Lessons from India

Springer

Global Issues in Water Policy

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Policy work in the water sector has grown tremendously over the past two decades, following the Rio Declaration of 1992. The existing volume of water-related literature is becoming dominant in professional outlets, including books and journals. Because the field of water resources is interdisciplinary in nature, covering physical, economic, institutional, legal, environmental, social and political aspects, this diversification leads in many cases to partial treatment of the water issues, or incomplete analysis of the various issues at stake. Therefore, treating a whole host of a country's water resources issues in one set of pages will be a significant contribution to scholars, students, and other interested public. This book series is expected to address both the current practice of fragmented treatment of water policy analyses, and the need to have water policy being communicated to all interested parties in an integrated manner but in a non-technical language. The purpose of this book series is to make existing knowledge and experience in water policy accessible to a wider audience that has a strong stake and interest in water resources. The series will consist of books that address issues in water policy in specific countries, covering both the generic and specific issues within a common and pre-designed framework.

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Preface

Over the past one decade or more, several publications, both academic and popular in nature, have come out from around the world on the theme of climate change and water. While some of them have focused on the global situation with regard to the impact of climate change on water availability and food production, others have focused on the likely impacts on South Asia, especially India, and China. Several academic and research studies have used Global Circulation Models (GCMs) and many Regional Climate Models (RCMs) to predict the changes in temperature and precipitation in different regions across the world.

One major limitation of these studies is their failure to capture the effect of the phenomenon of climate variability such as variability in annual precipitation and variability in the mean annual and seasonal temperature on the reliability of the predictions. This is in spite of the fact that for several centuries, many South Asian countries are historically known for severe droughts and devastating floods as a result of extreme climatic conditions. Understanding the effects of such phenomena are vital as historically many of the largest falls in crop productivity in countries like India have been attributed to anomalously low precipitation events, and greater risks to food security may be posed by changes in year-to-year variability and extreme weather events; therefore, knowing the magnitude of extreme event is more important. Most predictions that are based on average trends significantly reduce the utility of the models for regions that experience extreme variability in climatic variables between years. The reason is that many a time, the percentage change in value of the predicted variable (say, rainfall) is less than the percentage change in the annual rainfall, which the region experience, between a dry year and a wet year.

In the same way, several of the modelling studies, which tried to predict the impact of climate change on water resources at basin scales, have also failed to capture the impact of variability in precipitation and many other weather parameters on the hydrological processes and their outcomes, that is, stream-flows and groundwater recharge, in the basin. Such omissions make the predictions of hydrological impacts of climate change a futile exercise when the ratio of the annual runoff in a very wet year and that in a dry year is very high. A quick comparison between the stream flows of wet years with that of dry years of major rivers of the semi-arid regions of India, such as Godavari, Pennar, Cauvery and Krishna, will illustrate this point in ample measure. Analysis of such complex hydrological processes calls for pragmatic approaches that suit the local weather, land use and soil conditions rather than using routine models that predict average conditions that never occur in the basin in real life.

Capturing the stresses that the variations in hydrological conditions induce on the socio-economic system in terms of changes in irrigation water availability, drinking water supplies and sanitation is more important than capturing the small changes in the precipitation and its consequences on basin yield and water supplies.

In spite of the growing body of research on climate change and water in India, there is too little clarity on how reduction or increase in rainfall due to climate change in different river basins would impact basin water availability and water supply situation on an annual basis and the risks they pose to the communities which are dependent on such systems. This would require complex analytical frameworks that are compatible with real-life situation vis-à-vis weather conditions, hydrology, water resource system characteristics and socio-economic realities. This is attempted in the volume.

While most of the available scientific literature dealt with climate change issues only at the macro and national level, the uniqueness of this volume is that it addresses the same in the specific context of irrigation and water supply and sanitation, with empirical studies both at the national, provincial and local levels with case studies. In addition, practical and policy interventions are suggested to reduce the stresses induced by climate extremes on irrigation and domestic water supply and on the socioeconomic system.

We are sure that researchers working on climate impacts on water, practitioners working on climate adaptation and climate resilience in irrigation and WASH, and policy makers working on climate actions in the water sector would find this volume useful.

Hyderabad, Telangana, India — M. Dinesh Kumar
Mumbai, Maharashtra, India — Yusuf Kabir
Jaipur, Rajasthan, India — Rushabh Hemani
New Delhi, Delhi, India — Nitin Bassi

Acknowledgement

First of all, the editors of this volume would like to thank Prof. Rathinasamy Maria Saleth, one of the esteemed members of the editorial board of Global Water Policy Series of Springer who has been a friend and philosopher of the lead editor of this volume. It was because of the strong encouragement and continued persuasion from Prof. Saleth that we decided to prepare and submit a proposal for an edited volume to the series editor Prof. Arial Dinar sometime during the last year.

The initial proposal for the book had undergone several changes based on two rounds of review by the members of the editorial board, whose comments and suggestions had immensely helped improve the richness of the contents and focus of this volume. The contents proposed initially for the volume were more of empirical research on the impact of climate variability on water supply and sanitation in India. This has changed to accommodate more work on irrigation, and focus on policy aspects have been strengthened. The editors would like to express a deep sense of gratitude to all the members of the editorial board of the series for their valuable comments.

Special thanks are due to Prof. Arial Dinar who was very supportive of the idea of having a book from India on the theme.

We would also like to profusely thank Ms. Rajeshwari Chandrasekar and Ms. Isabelle Bardem, the heads of UNICEF field offices in Mumbai and Jaipur, respectively, who had not only permitted their colleagues, Yusuf Kabir and Rushabh Hemani, to be co-editors of this volume, but also encouraged their other colleagues to contribute chapters based on the outputs of the research their offices had supported on climate variability and WASH (water supply and sanitation and hygiene) to the volume.

Lastly, we would also like to express our deep sense of gratitude to Dr. Saurabh Kumar and Mr. Ajath Sanjeev of the Institute for Resource Analysis and Policy for their great assistance to bringing this volume to fruition. They helped in obtaining high-quality versions of several of the maps used in this volume. They also worked hard to check, correct and format the references of individual chapters.

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He has nearly 200 publications to his credit, including seven books, seven edited volumes, several book chapters, and many journal articles. He has published in many international peer-reviewed journals viz., Water Policy, Energy Policy, Water International, Journal of Hydrology, Water Resources Management, Int. Journal of WRD and Water Economics and Policy. He is currently also Associate Editor of *Water Policy* and Member of the Editorial Board of Int. Journal of WRD. His research works of global relevance are: integrated water resources management in river basins; water use efficiency and water productivity in agriculture; global virtual water trade; methodology for assessing global water & food security challenges; climate risk in WASH; and socio-economic impacts of large water systems.

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Nitin Bassi is a Natural Resource Management specialist (M. Phil) having nearly 13 years of experience undertaking research, consultancy, and training in the field of water resource management. Presently, he works as a Principal Researcher with the Institute for Resource Analysis and Policy (IRAP) and is based at their Liaison Office in New Delhi. His areas of work include River Basin and Catchment Assessment, Water Accounting, Institutional and Policy Analysis in Irrigation and Water Supply Management, Water Quality Analysis, Climate Variability, and Climate-induced Water Risk Analysis and Wetland Management. He has been engaged as a consultant/specialist in projects, research studies, and assignments supported by various national and international organizations. Some of these organizations include European Commission, World Bank, GIZ, DFID, WRG 2030/IFC, UNICEF, WWF, IWMI, SRTT, and SDTT.

He was involved as one of the specialists for establishing the first phase of the 'India-EU Water Partnership' between EU and Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD & GR), Government of India. In its second phase, he is engaged as one of the specialists for providing advisory services for the EU/BMZ co-financed action on 'Development and implementation support to the India-EU Water Partnership (IEWP)' and 'Support to Ganga Rejuvenation (SGR)'.

He has co-edited two books that were published by Routledge UK, and has several book chapters, and peer-reviewed journal articles. Also, he regularly reviews manuscripts for Water Policy; International Journal of Water Resources Development; Journal of Hydrology; and Journal of Hydrology: Regional Studies.

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Chapter 1
Climate Risks for Irrigation, Water Supply and Sanitation in India: Overview and Synthesis

M. Dinesh Kumar, Yusuf Kabir, Rushabh Hemani, and Nitin Bassi

Abstract This chapter will provide the overall context and setting for the volume. Based on available empirical data, it will discuss the issue of variability in rainfall and other climatic parameters in India. It will illustrate the need for assessing the impact of climate variability on water resources, by discussing its implications for the design of water management systems vis-à-vis the stress they induce on water flows and alterations they affect in the demand for water in various sectors, including domestic sector. It will also discuss the need for assessing the climate-induced risk in WASH (water, sanitation, and hygiene systems), particularly due to extreme climatic conditions and events, for designing water supply and sanitation systems that are climate-resilient, risk informed and sustainable. The chapter will also present the objectives and scope of the book, and the outline of individual chapters.

Keywords Climate variability · Water resources · Water management systems · Climate-induced risk · Climate-resilient WASH

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1.1 Context

The last nearly one and half decades have witnessed a great deal of enthusiasm among climate researchers from all over the world to work on climate change issues, particularly in the Asia Pacific region. It has its origin in the strong belief based on limited evidence to the effect that the global climate is undergoing unprecedented changes, which went unnoticed in the recorded human history, in terms of change in temperature. The monsoon weather system of the Asia-Pacific region, which is a complex system and not so easily amenable to predictions by weather forecasting models, and which has significant implications for India's climate, has also been a subject of scientific inquiry in the recent past to know what would be the impact of climate change on it. Understanding the cause of monsoon is crucial to deepening our understanding of how monsoon in India would change as a result of larger changes occurring in global and regional climate. There are contesting theories about the cause of Monsoon. Halley (1753) suggested that the primary cause of the monsoon was the differential heating between the ocean and land. This is still considered as the basic mechanism for the monsoon by several scientists (e.g. Webster 1987). In an alternative hypothesis, monsoon is considered as a manifestation of the seasonal migration of the inter-tropical convergence zone (Charney 1967). The two hypotheses have very different implications for the variability of the monsoon (Gadgil 2003).

Nevertheless, the Indian sub-continent and the ocean surrounding it is at the centre of the monsoon region (Gadgil 2003). Indian Monsoon has been a subject of intensive study for the spatial and temporal (season and annual) variations (Gadgil 2003; Pisharoty 1990). Though climate modellers have used both Global Circulation Models (GCMs) and Regional Climate Models or Regional Circulation Models (RCMs) to predict changes in monsoon precipitation for different scenarios of temperature change, the 'scientific accuracy' or robustness of such models have been a subject of debate among climate scientists in India and elsewhere. The underlying concern has been that 'how the temporal variability that exists in monsoon precipitation in different regions and the precipitation variation across space get captured in the 'climate simulation models', and how far the model predictions address these key characteristics of Indian monsoon'. 'Climate variability' has significant implications for the way climate change predictions need to be made for the sub-continent. An understanding of 'climate variability' and its impact on hydrological systems would also help understand the likely impact of the change in climate over time on the hydrological system and water resources. Unfortunately, these concerns were very narrowly addressed by the advocates of climate change, with the key contention being the increase in variability in precipitation with a greater frequency of extreme events such as floods and droughts. Much less is known about the impact that these hydrological stresses will have on the performance of irrigation systems, and on the communities in terms of risk in water, sanitation, and hygiene (WASH). That said, the rainfall and climatic variables (solar radiation, relative humidity, wind speed, and temperature) in India display remarkable spatial and temporal variation. The temporal variation includes not only inter-annual and inter-seasonal but also intra-day variations.

1.1.1 Rainfall Variability in India

India receives precipitation from two sources, viz., rainfall and snowfall. But rainfall is the major source of precipitation in terms of the geographical area which benefits from it, and also the total quantum of water produced from the precipitation. Snowfall occurs only in the Himalayas during the winter season and benefits the hydrological system through the snow-fed rivers viz., Ganges, and the Indus which originate from the Himalayas. However, in this note, we would discuss the rainfall which occurs in different parts of the Indian sub-continent.

Pisharoty (1990) discussed the characteristics of the Indian monsoon, particularly the spatial and temporal variations in the rainfall, and the rainy days, and spatial variation in potential evaporation. Analysis shows that Gujarat and Rajasthan have 11% and 42% area, respectively, experiencing extremely low rainfalls (< 300 mm); and 39 and 32%, respectively under low rainfall (300–600 mm). The other states by and large fall in the medium rainfall (600–1000 mm) and high rainfall (1000–1500 mm) regimes. In the case of Maharashtra, MP, AP, Karnataka and Tamil Nadu, a lion's share (85% and above) falls in medium rainfall regime, and in the case of Orissa and Chhattisgarh, 45 and 40%, respectively fall in high rainfall regime.

The Indian monsoon is characterized by significant inter-annual variability and more or less follows a cyclic pattern of high and low rainfall. Analysis shows that the year to year variation in annual rainfall is high in regions of low rainfall and low in regions of high rainfall. In regions such as western Rajasthan and Kachchh, the coefficient of variation in the rainfall is as high as 50% and above. In the north eastern region and in the Western Ghats region, the coefficient of variation in rainfall is very low, meaning high dependability. The Indian monsoon is also known for its erratic nature, for many regions. The regions which receive fewer days of rain coincide with those experiencing low rainfall and high evaporation and high variability in rainfall. The regions which experience many wet days coincide with those which experience high and reliable rainfall.

1.1.2 Temporal Variability in India's Climate

Climate is the net effect of the interplay of precipitation, humidity, temperature of the atmosphere, winds (speed) and rainfall. Atmospheric temperature and temperature on the surface of the earth is the effect of solar radiation. Besides rainfall, the other climate parameters also vary from region to region, influenced by their geographic positioning with respect to oceans, mountains, desert, and the latitude and longitude, and would change with change in seasons, that is, rainy season, winter and summer.

Humidity is a measure of the amount of vapour in the air, and is measured in terms of the vapour pressure of the air. While humidity itself is a climate variable, it also interacts strongly with other climate variables. The humidity is affected by winds and by rainfall. At the same time, humidity affects the energy budget and controls the movement of vapour from the surface of water bodies and transpiration from plants—the former affecting water supplies and the latter affecting water demands in agriculture.

Coastal areas are generally more humid than inland areas, so are the areas receiving higher rainfall over extended time periods. Normally, if the amount of moisture in the air remains the same, then an increase in temperature would reduce relative humidity as warmer air can hold more moisture than cold air. But, in humid tropics, an increase in temperature would also result in higher evaporation adding to the atmospheric vapour content, and hence there would be no reduction in relative humidity. Normally, in any region, the relative humidity in an area would increase during monsoon, though the variation would be much higher in hot climates.

Kumar (2018) reported the following points with regard to variation in humidity between two consecutive years, that is, 2009 and 2010: (1) the highest difference encountered in the relative humidity values between morning and evening of any day over the entire year during 2009 and 2010 is higher than the difference in relative humidity values for both morning and evening between the most humid day and the least humid day of the year; (2) relative humidity is excessively high in the range of 80–90% during the rainy season; and (3) the RH values for both morning and evening for the same day of the month can vary significantly between years.

1.1.3 Spatial Variability in Climate

Potential evaporation for a particular location is the net result of the solar radiation flux, wind speed and relative humidity experienced in that location and to a lesser extent the temperature, and is a strong indicator of the location's climate, along with rainfall. This parameter is extensively used in hydrology for estimating water losses from open reservoirs and water requirements for crop physiological processes. The variations in solar radiation, air temperature, wind speed and relative humidity across space in India ultimately result in significant variation in potential evaporation (PE). Lower rainfall, coupled with higher PE reduces the runoff potential and high evaporation from the impounded runoff, thereby increasing the dryness (Hurd et al. 1999).

Variation in these parameters with respect to space and time also results in significant variation in reference evapotranspiration values and therefore potential evapotranspiration (PET) for the same crop across regions and also within the same regions with time, respectively (Howell and Evett 2004).

A general pattern is encountered in the spatial variation of PE across India. Regions with relatively low rainfall are found to have higher potential evapotranspiration due to relatively low humidity, and a higher number of sunny days (Pisharoty 1990). Analysis of spatial data on mean annual rainfall and mean annual potential evaporation shows that regions which have very low rainfall are also the regions which experience very high evaporation and vice versa. The reason is these regions experience rainfall in very few rainy days, which increases the number of days of sunshine, increasing the temperature. The lower rainfall and prolonged days of sunshine also reduce the relative humidity. Both the factors together increase the annual evaporation rate.

1.2 Rationale for the Book

In the past couple of decades, researchers and academicians in the field of climate, water and agriculture in India have tried to predict future changes in India's climate at various scale from sub-continental level to regional level to basin level, using various assumptions about likely changes in temperature in the future and by using GCMs and RCMs. The most important predicted variable is the precipitation/rainfall. However, none of the climate models have tried to factor in variability in climate, particularly the inter-annual variability in temperature and rainfall in the model. The model predictions are based on average values, significantly reducing the utility of such predictions for regions that experience high variability in climate factors (Kumar and Rao 2012; van Oldenborgh et al. 2013). The reason is that many a time, the value of the predicted variable is less than the percentage change in the annual mean value of the variable that the region experiences between a dry year and a wet year. From a practical point of view, historically, many of the largest falls in crop productivity have been attributed to anomalously low precipitation events (Kumar et al. 2004; Sivakumar et al. 2005), and greater risks to food security may be posed by changes in year-to-year variability and extreme weather events (Gornall et al. 2010) and therefore knowing the magnitude of an extreme event is more important.

In the same way, the model predictions of the impact of climate change on water resources done at basin scales, have also failed to capture the impact of variability in precipitation and many other weather parameters on the hydrological processes and their outcomes, that is, streamflows and groundwater recharge, in the basin. Analysis of such complex processes calls for pragmatic approaches that suit the local specific context rather than using routine models that predict average conditions that never occur in the basin in a real-life situation.

From a purely utilitarian perspective, what one would like to know is the 'reference levels' to which these increase and reduction are likely to occur and how it would look like in dry and wet years (Kumar and Rao 2012). More importantly, from a water management perspective, capturing the current variations in the hydrological conditions in the basin and the stress that induces on the socioeconomic system might appear to be more important than capturing the small changes in the precipitation and its consequences on basin yield and water supplies. Currently, there is too little clarity on how reduction or increase in rainfall due to climate change in different river basins would impact basin water availability and water supply situation on an annual basis. This would require a complex modelling exercise. This is attempted in the volume, through an assessment of the climate-induced threat to irrigation water supplies, climate-induced risk in WASH faced by communities, and the public health hazards associated with climate extremes. More importantly, climate change issues have been addressed in the literature only at the macro and national levels. But this volume addresses the same in the specific context of irrigation and water supply and sanitation, with empirical studies both at the national, provincial and local levels with case studies.

1.2.1 Analyzing the Implications for Water Management Institutions

When water flow varies and the demand for water change, water management strategies also have to change. The institutions dealing with water resources management and water supply provisions have to adapt to the changing situation with regard to water availability and water demands. In the same river basin, the interventions to deal with a drought situation will be different from the one adopted during a wet year when the flows are excessively high. Hence, the approach to water management has to change to give more emphasis to institutions and market instruments such as water rights, water allocation, water pricing, etc. than mere engineering interventions that focus on resource appropriation and distribution that remain largely static, as the rules and criteria concerning water rights, water allocation and water pricing can be changed depending on the situation. However, traditional water institutions are designed to deal with either water supply provisions or flood control.

1.2.2 Implications of Regional Climate for Planning and Designing of WASH Systems

Climate and environmental conditions can significantly impact the way water supply and sanitation systems perform in a region or locality. While climatic variability affects the availability of water that can be tapped for water supply provisioning, and the water ecology of a region, in rural areas climatic conditions also influence the demand for water for domestic and livestock uses and therefore can affect the performance of the WASH systems. The environmental conditions (climate, soils, geohydrology and rainfall) influence the way onsite sanitation systems