

Climate Adaptation in the Water Sector in India

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The *Fifth Assessment Report* of the Intergovernmental Panel on Climate Change (IPCC) shows that climate change is likely to directly impact the water sector (IPCC 2014; also see Bates et al. 2008). Climate change may affect both the short-term variability of water resources through increased frequency and intensity of droughts and floods or induce long-term changes in mean renewable water supply. Climate change may also induce behavioural changes, which may in turn impact water demand. However, evidence from empirical research on climate adaptation suggests that climate change is not the only stressor and resilience is not the only concern. Instead, an approach that accounts for multiple stressors, multiple concerns, and missing linkages across scales is needed.

Impact of Climate Change in the Water Sector

Impact of Climate Change on Hydroclimatic Variables

Assessments of the impact of a changing climate on water resources typically involves the applications of chains of models through: (i)

downscaling and bias correcting the output of the general circulation models (GCMs) to project hydroclimatic variables; and (ii) evaluating the impacts of the climate projections using hydrological models.

The scholarly evidence on the impact of climate change on hydroclimatic factors can broadly be divided into two literatures: 'empirical statistical analyses' of past trends in observed precipitation, temperature, soil moisture, stream flow, and so on; and 'model-based projections' of future trends in these variables. Surprisingly, these are not always in sync.

There is reasonable consistency in temperature projections under climate change and historical trends. Maximum temperature in India has increased in most parts of south, central, and west India. The rise in annual mean temperature over India is comparable with the reported rise of global surface temperature by 0.6°C (Jones et al. 1999), although a few stations exhibit declining trends in the north and north-east (Jain and Kumar 2012; Jaswal, Rao, and Singh 2015). However, as Jain and Kumar (2012) point out, many stations are in the proximity of settled areas, so the urban heat island effect cannot be separated from the impact of global climate change. Rising temperatures may impact human demand for water. Temperature, however, also affects supply, altering the hydrologic cycle by increasing evaporation and evapotranspirative demand by vegetation.

In the case of rainfall, however, the trends remain confusing. There is some support for the hypothesis that the frequency and intensity of extreme rainfall events over India has been increasing over the last century (Guhathakurta, Sreejith, and Menon 2011; Krishnamurthy, Lall, and Kwon 2009). In the case of the Himalayan snowpack, the models and observation records both indicate a continued trend of less snow, more rain, and more evaporation under a warmer climate. Melting snow and ice contribute an estimated 70 per cent of summer flow in the main Ganges in the dry season (Xu et al. 2009). Although the processes determining the conversion of glaciers, ice, and snow into run-off and stream flow are not completely understood, climate change is expected to substantially alter flow regimes in Himalayan rivers (Xu et al. 2009). While increased melting of glaciers may initially increase stream flow, in the long run, as glaciers shrink or approach new equilibria, increasing dry-season water shortages are likely to occur downstream.

There remain, however, inconsistencies between the models and past trends when it comes to rainfall and a consistent picture has not emerged (Jain and Kumar 2012). Most climate models predict intensification of the Indian monsoon and *increases* in precipitation in many parts of India. On the subject of the Indian monsoon, the IPCC *Fifth Assessment Report* projects a general increase in seasonal mean rainfall over India, but an increase in intense rainfall events at the expense of weaker rainfall events over the central Indian region, among other areas, and longer dry spells. The extreme events are attributed to the enhanced moisture content or warmer sea surface temperatures (SSTs) in the tropical Indian Ocean. These increases are likely to be unevenly distributed. Further, while monsoon onset dates are likely to be earlier or unchanged, the monsoon retreat dates are likely to be delayed, resulting in lengthening of the monsoon season (IPCC 2014).

The problem is that even as the climate models predict increases in precipitation, many studies of observed rainfall trends suggest the opposite, that is, there has been a weakening in seasonal rainfall in some regions and a regional redistribution. These discrepancies have been attributed to local factors, such as changes in black carbon and aerosols, land use, and SSTs, that are poorly incorporated in climate models (IPCC 2014; Saha et al. 2014). This suggests that understanding the possible changes in the Indian monsoon under global warming remains a major challenge in climate science, as even state-of-the-art GCMs show poor skill in reconstructing the observed historical trends and intra-annual variability in precipitation (Saha et al. 2014).

Impact of Hydroclimatic Variables on Water Supply

Water resources planning and development requires an ability to predict the likely direction and magnitude of changes to future ground and surface water flow (Kumar 2011), but these efforts in India are stymied by our inability to generate consistent projections of precipitation.

Probabilistic assessments are central to water management and design of water systems because of the variable nature of climatic patterns. Traditionally, water resources assessments have assumed

‘stationarity’, that is, natural systems fluctuate within an unchanging envelope of variability both in terms of rainfall and stream flow. This principle was used to design infrastructure and policies. For instance, dams, inter-state water-sharing agreements, and storm water drains are all designed based on ideas of a ‘basin yield’ and a ‘100-year storm’. While it is clear that the assumption of stationarity is unlikely to hold in the future (Milly et al. 2008), uncertainties in the hydro-climatic impacts of climate change pose a challenge in river basin models. As a result, most studies merely assume more variability.

A number of studies have attempted to translate the projected changes in precipitation to changes in run-off and groundwater recharge. However, the task of determining cause and effect with respect to hydrologic behaviour is complicated in India due to sparse hydrologic records and human modifications. Lack of data not only confounds the formulation of quantitative models, but also hampers the development of conceptual models of ‘how the river basin works’. As models rarely account for human impacts, any decrease in the stream flow in the recent past is often attributed entirely to a ‘climate signal’ (Ghosh, Raje, and Mujumdar 2010), essentially precluding the possibility of proximate influences like groundwater pumping.

In the absence of reliable historical records of climate, water, and human activity, models relying on conventional data sources often make unrealistic assumptions or oversimplifications, resulting in questionable predictions. The vast majority of existing studies use off-the-shelf basin-scale models like SWAT (Soil and Water Assessment Tool) and VIC (Variable Infiltration Capacity) to test future scenarios (Narsimlu, Gosain, and Chahar 2013; Patel and Nandhakumar 2016; Paul et al. 2015). For instance, a study by Gosain, Rao, and Basuray (2006) modelled the water availability in space and time in several Indian river basins under climate change. However, the models did not incorporate any man-made structures like dams and diversions.

Indeed, operational data on reservoirs is hard to obtain and, in many cases, the data have not even been digitized. Most models do not allow for coupling of surface water to deep groundwater resources, and this effectively decouples any effects of groundwater mining from surface water responses. The cumulative impact of small-scale interventions such as check dams, farm bunds, and drip irrigation are completely neglected, despite widespread evidence that

they drastically alter stream flow and recharge regimes (Batchelor, Rama Mohan Rao, and Manohar Rao 2003; Glendenning et al. 2012).

In summary, predictions of water availability under climate change remain highly questionable. Not only are rainfall projections themselves inconsistent (across climate models and when compared with historical data), the translation of rainfall into run-off and recharge is even harder, because watersheds in India have been so drastically altered by human activity. Much more primary research is needed to fully understand the impacts of 'multiple stressors' (Lele et al. 2018). A fundamental unsolved challenge in hydrology remains in predicting the future trajectory of human actions in terms of land use, crops, technology, and infrastructure; new approaches are needed that are able to consider alternative water futures and incorporate these into models (Srinivasan et al. 2017).

Limitations of the Current Framework and Way Forward

Current framing of climate adaptation in the water sector has been largely inadequate for several reasons. To help address these, climate adaptation in the water sector should explicitly acknowledge the existence of multiple concerns and multiple stressors at the outset, and also seek ways of linking basin-scale analysis to individual actions via infrastructure and institutions where appropriate (Srinivasan et al. 2013).

Climate Resilience Is Not the Only Concern, Agencies Have Multiple Concerns

As climate change is predicted to impact extreme events, the focus of many studies has been on droughts and floods. This narrow focus may be reasonable in a temperate, developed country context, where issues of water scarcity, water quality and, to a much more limited extent, sustainability, have been largely resolved over a century of development and many decades of relatively stable populations. In the face of potentially dramatic shifts in climate, the major goal for these regions has to be to adapt and/or build resilience so as to maintain their (high) level of water availability or water service (Lele et al. 2018). This, however, does not hold true for developing countries,

where the goals of adequacy, quality, or sustainability (among others) are far from being met.

Existing problems in water provisioning in developing countries are not adequately captured by the framing of climate change as the primary driver and vulnerability/non-resilience as the primary concern. For instance, median per capita water availability in Indian cities is a mere 69 litre per capita per day (LPCD) and is highly inequitably distributed (Indian Institute for Human Settlements 2014) compared to 310 LPCD in the United States (US) in 2015 (Dieter and Maupin 2017). Groundwater resources are depleting rapidly (Shah 2010), raising concerns about the well-being of future generations. At the same time, water quality is declining. The water quality in majority of surface water bodies and water treatment infrastructure are inadequate and deteriorating, resulting in public health crises.

This poses a problem when it comes to bridging the gap between academic research and policy practice—climate adaption research cannot be separated from general water and sanitation sector debates; and there are few win-wins as often satisfying one objective occurs at the expense of another. Explicit formulation of the trade-offs and synergies between different normative goals therefore becomes critical to avoid unintended consequences (Lele et al. 2018). An integrative approach is needed that can recognize multiple normative concerns, such as developing, allocating, and managing water equitably and efficiently; ensuring resource and financial sustainability; making progress towards Sustainable Development Goals (SDGs); following good governance principles, including stakeholder participation; and ensuring environmental quality.

Climate Change Is Not the Only Stressor; Need to Incorporate Multiple Stressors

Is climate change the most important stressor acting on the water resource system, now and will it be so in the future? In economically developed, temperate countries with low population growth and relative stable land use, it does seem likely that climate may already be the main stressor. However, in India, rapid growth of urban populations combines with intensifying agriculture, industrial growth, and rising incomes that increase the demand for fresh water in multiple

ways that are far more immediate, and are likely to dominate the climate change effect, at least for now.

Human interventions are increasingly recognized as undermining the assumption of stationarity. Dams, groundwater extraction, watershed interventions, and land use–land cover change are all altering flows. While climate change will alter precipitation and evapotranspiration, human water abstraction is likely to remain the principal contributor to reduced freshwater flows globally (Grafton et al. 2013; Vorosmarty 2000;). Indeed, in India, the business-as-usual scenario, based on the recent trends in population and agriculture growth, projects a 40 per cent increase in groundwater withdrawals (Amarasinghe et al. 2007).

The problem is that acknowledgement of anthropogenic influences on water resources models (and consequently policy) in India remains rare. In many cases, even large infrastructure projects are not factored in, let alone the effects of small, decentralized anthropogenic modifications (Srinivasan et al. 2015). Yet, it is increasingly being recognized that interventions at smaller scales have significant cumulative effects at the river basin scale, once they are adopted by millions of farmers or micro-watersheds. For example, farm bunds and check dams increase water availability upstream at the expense of flows into downstream reservoirs and drip irrigation projects may reduce recharge to groundwater. Groundwater abstracted from millions of private borewells, even while buffering users against rainfall variability, is also resulting in declining stream flows. Since studies rarely account for these smaller-scale processes, there has been a tendency in the climate resilience literature to blindly count these measures as climate adaptation, even if there are deleterious impacts at larger scales of these anthropogenic modifications.

An integrative framework must also include *all* drivers of changes at all scales in watersheds; such as groundwater pumping, watershed interventions, land use–land cover change, crop choice, and irrigation technology.

Bridging Scales from the Basin to Water User Remains a Challenge

Analysing the impact of climate change at the farm or household scale requires working across very disparate scales. There remain

sharp disciplinary disconnects. Climatologists estimate climate change patterns at fairly coarse regional scales. Hydrologists are adept at downscaling these patterns and applying them to basin-scale models to predict changes in stream flow, groundwater levels, or urban flooding. However, hydrologists seldom go beyond estimating average physical availability in a basin and lack the tools in translating basin-scale water availability into water access at the household or farm. On the other hand, social science research on adaptation and resilience in urban water provisioning has focused on households and/or communities. They tend to take the hydrological resource and engineering context as a given (Lele et al. 2018), while focusing on pre-existing vulnerability.

Much of the water used in urban or agricultural contexts is delivered to water users via piped or canal infrastructure. Inter-basin and intra-basin transfers, water transport and distribution systems, and effluent treatment plants play an important role in mediating between basin-level water availability and water availability to the user. These infrastructure projects may import large quantities of water from surrounding watersheds and significantly influence water availability, thus hedging against local rainfall. In fact, creating a diverse portfolio of water sources is often an explicit planning objective. Water supplied to cities or irrigation projects generates return flows that create new (albeit polluted) flows downstream. The legal and administrative framework and political process for surface water allocation across major sectors (for example, between agriculture, domestic, or industrial users, or between states) is crucial in determining who gets how much water when there is a shortage. For instance, the ‘domestic priority’ in the draft National Water Framework Law implies that farmers bear most of the cutbacks during droughts. A significant portion of irrigation and urban water is self-supplied via borewells. Groundwater regulations (indirectly through electricity pricing or directly through licensing) play a critical role in determining access to and use of groundwater resources. As a result, developing a complete understanding of water availability at the scale of a water user necessitates understanding both the physical layout of infrastructure projects as well as the rules—formal and informal—governing their operation under different conditions of water availability.

Implementing a Multiple-Concern, Multiple-Stressor, Multi-Level Approach Requires Integration of Human Dimensions, Stakeholder Participation, and Adaptive Management

In the context of climate and anthropogenic change, our experience derived from historical records does not tell us much about the frequency and intensity of extremes in the future. Taking into account the true complexity of water systems at different scales requires fundamental changes in how we approach water resources management, in at least three ways. First, it necessitates a move from techno-economic approaches to a complete integration of human dimensions.

Most models of water resources under climate change seem to hold land use and demand patterns static or use simple extrapolations. In reality, human demand for water is highly non-linear. It depends on land, labour, and commodity markets (Patil et al. 2019). The process of urbanization, industrialization, agricultural policy, among others, all significantly influence water demand and water availability in streams and aquifers. As the Indian economy grows, there are likely to be large-scale changes to demographic and employment patterns and water resources. This requires considering multiple, alternative socio-economic pathways, while also accounting for the path-dependent, sticky nature of infrastructure investments like large dams.

Second, taking full account of complexity requires greater stakeholder participation to understand what scenarios are possible. Once we accept that humans are going to constantly shape and reshape the waterscape over the next 100 years, the question is how do we anticipate these changes? By choosing which scenarios and processes get considered, water resources modellers have a disproportionately large effect on eventual social outcomes (Troy et al. 2015). Including stakeholders in the modelling process can ensure ownership of model results and the decisions that follow (Sivapalan and Blöschl 2015; Walker et al. 2012). While stakeholder participation in the framing and shaping of alternate futures is gaining popularity elsewhere in the world, in India it remains rare. Part of the problem is that facilitating formal participation requires investments in interdisciplinary training, better communication, and building legitimacy, which Indian water resources professionals are ill-equipped for.

Third, taking account of multiple concerns requires an adaptive and flexible approach to respond to new information under

changing conditions. Given the difficulty in anticipating the exact impacts of climate change, globally accepted principles of climate adaptation in the water sector generally entail low-regret decision making and a mix of hard (infrastructural) and soft path (decentralized, institutional, pricing, behavioural measures) scenario planning (IPCC 2014). Global discourses have also shifted towards adaptive water management (Pahl-Wostl 2007), advocating a shift from traditional prediction and control towards more flexibility and learning-by-doing. However, in India, the cycle of research, policy, to action remains fairly weak. In any case, most climate adaptation research remains in the theoretical domain with limited links to policy.

Mainstream Climate and Find Synergies in Existing Initiatives

Climate change adaptation in the water sector cannot occur without considering other changes that are also impacting water availability and demand. Existing agencies in the water sector have to respond to the exigencies of providing water to all, while addressing concerns over declining groundwater, disappearing streams, and so on. If climate change is to be mainstreamed into water sector planning, climate adaptation must become a part and parcel of existing sector policies and plans.

In India, the National Action Plan on Climate Change (NAPCC) prepared by the Government of India (GoI), in 2008, tasked the National Water Mission (NWM) with tackling the challenge of climate change in the water sector. The stated goal of NWM is to 'ensure integrated water resource management helping to conserve water, minimize wastage and ensure more equitable distribution both across and within states'.¹ The NWM recommends a large number of water supply and demand management strategies, as well as institutional reform measures. In 2015, the NWM asked that state governments develop State Specific Action Plans on Water (SSAPs-Water), solely focused on state-level water management issues, including climate change adaptation (England 2018).

¹ See nwm.gov.in; accessed on 17 June 2019.

In practice, most states prepared ‘irrigation sector improvement plans’. Frustrated with the lack of a comprehensive, cross-sector approach to water, in April 2017, NWM began to shift its focus to the preparation of state water budgets, creating a template that would require states to track all sources and uses of water in the form of sub-basin-level ‘balance sheets’. Over the next several months, dozens of consultations were held and a detailed template was presented (GoI 2017). In October 2017, the then Ministry of Water Resources (MoWR) convened a workshop attended by national and state government officials, as well as non-government actors, at which state governments were advised to develop SSAPs-Water based on state-level context and requirements. Eleven states have committed to creating state water budgets as of April 2018.

Although the NWM is officially the agency tasked with climate adaptation in the water sector, water in India is a state subject; in any case, the vast majority of action needed to address climate change occurs at lower levels of government. Table 27.1 presents a mapping of normative concerns, as well as interventions to address each. In the subsequent sections, I will discuss how each of these can be implemented through actions at the local, state, and national level.

Extreme Events

Climate change is likely to alter the frequency and severity of flooding. Recent floods in Chennai and Mumbai have claimed dozens of lives. Subsequent research has suggested that the floods were not the result of intense rainfall alone, but also caused by poor or clogged drainage networks (Jamwal 2012). As low-lying areas and tanks have been filled to make multi-storey buildings and shopping malls, the natural water-holding capacity of cities has disappeared. The quantity of water falling on the city may or may not have changed, but the space for water to flow has declined, tremendously. Additionally, the very steps taken to tackle floods, such as embankments, have resulted in greater development and settlement in floodplains, worsening the impact of flooding. In the case of the 2009 Krishna basin flood, inadequate flood forecasting and improper management of reservoirs was a problem. Political

Table 27.1 Mapping of Water Concerns, Mechanisms, and Jurisdiction

Concern	Adaptation Mechanisms	Actors
Extreme Events		
<ul style="list-style-type: none"> • Flooding 	<ul style="list-style-type: none"> • Better flood forecasting, dissemination. • Improvement of storm water infrastructure in cities. • Surplus floodwater capture mechanisms. • Room for the river plans in rural areas. 	<ul style="list-style-type: none"> Disaster-monitoring agencies; state water resources departments; and urban local bodies (ULBs).
Unsustainability of the Resource		
<ul style="list-style-type: none"> • Declining inflows into reservoirs and groundwater recharge. • Decreased dry season flows and springs. 	<ul style="list-style-type: none"> • Better management of available water resources. • Revise evaporation rate tables to account for higher temperatures. 	<ul style="list-style-type: none"> Central Water Commission; Central Ground Water Board; MoWR; state water resources departments; and forest departments.
Mismatch in Demand and Supply		
<ul style="list-style-type: none"> • Agriculture: Changes in soil moisture, increased irrigation demand. • Cities: Impacts on domestic, commercial, and industrial demand (outdoor versus indoor). 	<ul style="list-style-type: none"> • Crop shifting by farmers to less water-intensive crops. • Drip Irrigation. • Climate-smart landscaping. • Water efficiency in industry. • Dietary shifts. 	<ul style="list-style-type: none"> Departments of agriculture and industry; urban water utilities; developers; industry; and citizens.
Water Quality and Environmental Health		
<ul style="list-style-type: none"> • Dissolved oxygen (DO), algal blooms. • Turbidity from extreme events. 	<ul style="list-style-type: none"> • Building of sewage treatment plants (STPs). • Change operations of STPs. 	<ul style="list-style-type: none"> Central and state pollution control boards; water utilities; and ULBs.

(cont'd)

Table 27.1 (cont'd)

Concern	Adaptation Mechanisms	Actors
<ul style="list-style-type: none"> • Water-borne disease vectors: mosquitoes. • Mobilization of pollutants due to salinity, temperature, and flow regime changes. 	<ul style="list-style-type: none"> • Better management of drainage systems. • Enforcement of pollution laws. 	
Water Conflicts		
<ul style="list-style-type: none"> • Absence of mechanisms to deal with increased variability. 	<ul style="list-style-type: none"> • Flexibility in inter-state sharing and within state reservoir operations. • Market mechanisms: insurance schemes, short-term markets (farmers giving up shares to city in exchange for payment). 	Inter-state tribunals; reservoir management boards; and state water resources departments.

Source: Compiled by author.

bias towards managing reservoirs to hold water back, rather than release water, and uncertainty over forecasts meant that no official was willing to take the risk of releasing water until the very last minute (Killada, Badiger, and Thomas 2012).

Flooding can only be proactively addressed through a participatory process of planning, enforcement of buffer zone regulations, and prevention of encroachment of storm drains and streams to create more 'room for the river', all of which would have to occur at the level of the urban local body or Panchayati Raj Institution. Once the encroachment has already occurred, the only option is the court system and increasingly, the National Green Tribunal. So, what might be required is an analysis to understand the extent to which these urban and rural local institutions comprehend and incorporate climate change considerations and if necessary, invest in communication strategies to improve them.

Unsustainability of the Resource

Climate change is expected to result in increasing variability, with more prolonged droughts and more dry days, interspersed with intense rainfall events. The only way to address increased variability, in the face of increasing demand for water, is to increase storage. The issue of storage, however, remains highly contested (Iyer 2013; Joy et al. 2008). On the one hand, the MoWR and state irrigation departments prefer centralized, top-down planning of large-scale infrastructure-based surface water management, including dams, reservoirs, and canal irrigation construction and management. On the other hand, the majority of non-government actors, including non-governmental organizations (NGOs), civil society, and industrial and farmer groups, have been advocating smaller-scale, decentralized water management practices, including rainwater harvesting, aquifer management, and small-scale surface water storage (Agarwal, Narain, and Khurana 2001). Indeed, as dam building has slowed down, in the last two decades, India's water policy has shifted to 'managed aquifer recharge' through watershed development, essentially using the massive capacity in India's underground aquifers to buffer climate variability (Shah 2008).

The problem is that increasing dependence on groundwater is depleting the buffering capacity of groundwater as shallow aquifers are drying up in parts of India (Shah 2010). Laws and administrative regulations, such as licensing, have been discussed and even piloted (Mukherji and Shah 2005); however, the logistical challenges of enforcing these on tens of millions of widely dispersed farmers (Planning Commission 2007) as well as overcoming political resistance to pricing groundwater remain formidable (Shah 2008).

The government has invested vast sums in mapping aquifers² and recharging groundwater in recent years. However, recent evidence suggests that recharge alone is unlikely to solve the problem. In closed basins, water resources are a zero-sum game; any water that recharges groundwater is water that does not flow downstream. The

² See <http://www.aquiferindia.org/>; accessed on 17 June 2019.

cumulative impacts of watershed development on reducing downstream flows has been documented by many studies (Glendenning et al. 2012). The solution is to manage groundwater recharge and abstraction simultaneously. While excellent case studies of ‘participatory groundwater management’ through *pani* panchayats exist in Maharashtra and Rajasthan, these solutions require high levels of social capital, trust, and leadership, and have not so far proved to be scalable. The GoI has recently announced the Atal Bhujal Yojana (formerly the National Groundwater Improvement Programme) to improve measurement, tracking, and management of groundwater on a massive scale.

Mismatch in Demand and Supply

Based on current projections, adaptation to uncertain resource availability is going to occur while demand for water is increasing. Water supply agencies in India are grappling with the challenge of how to match demand and supply. At present, each state, city, and gram panchayat is addressing this problem reactively, by lobbying for inter-basin transfers or drilling deeper. The fundamental problem is that the ministries that ‘control’ demand for water (such as power, agriculture, industries, and forests) are not accountable to the water resources ministry. There has to be a mechanism that ensures that annual water consumption (demand) by various sectors is within the limits of annual water availability (supply). Ensuring this remains a challenge because data on water use are largely missing. Even where such data exist, they are fragmented, inconsistent, and held by different agencies, who are reluctant to share.

In the absence of a single agency that coordinates water demand and holds the sectors accountable for excessive use—which is not politically feasible—some other approach that provides an integrated view is needed. The problem of climate change is that of allocating an increasingly uncertain pie, between multiple stakeholders. This has been recognized by the draft National Water Bill (MoWR 2016a) and the Model Groundwater Bill (MoWR 2016b), which have called for the creation of water security plans at the district and basin levels. A few states like Andhra Pradesh have been very proactive in collating data and presenting water budgets

statewide.³ The NWM's recent call for state water budgets is also based on the same idea.

The absence of data on how much water is being used is clearly not helping. Only time will tell if the data interventions being suggested will lead to more rational, fair allocation of water, or simply more contestation.

Water Quality and Environmental Health

Increased temperatures are likely to speed up bacterial activity in nutrient-rich rivers, resulting in decreases in dissolved oxygen and therefore aquatic life (Rehana and Mujumdar 2012). There is also a concern that declining flows will reduce the dilution capability of rivers. However, while climate change may exacerbate water quality, the main problem is the excessive pollution (mostly domestic sewage) itself. The solution, of course, is to ensure that sewage is treated and disposed safely. Thousands of crores have already been spent through the Ganga Mission alone in reducing sewage pollution in just one river, without making a significant dent in the problem. There is an ongoing debate in the water and sanitation sector on how to address the problem and whether on-site sanitation and septage management or conventional sewerage systems should be the goal. While climate change is marginal to these debates, there is one emerging area of overlap. Energy recovery through biogas from human excreta is increasing becoming feasible (Muralidharan 2017) and may represent a potential 'win-win' solution in the future.

Water Conflicts

Conflicts over water resources have been increasing in recent years, occasionally precipitating constitutional crises. In India, most inter-state rivers are governed by tribunals under the Inter-State Water Disputes Act, with inter-state river-sharing agreements instituted through negotiations over years, sometimes decades. Yet, contestations over inter-state rivers continue. The problem is that the tribunal agreements have typically focused on evolving a 'formula'

³ See apwrims.ap.gov.in; accessed on 17 June 2019.

for sharing. This entails determining how much of the 'basin yield' (measured at some specific reservoir) should be allocated to each riparian state. The agreements' focus is on timing and releases at specific reservoirs. The tribunals are poorly suited to addressing the threat of climate change and are, in general, not suited to adaptive approaches. They largely do not account for links between surface and groundwater and thus the fact that basin yield itself may change with increased groundwater abstraction. They also lack 'shortage-sharing' allocation mechanisms in dry years and do not account for future changes to climate.

This chapter makes three core arguments. First, the future of water resources is about 'everything change'; climate is only one of the many stressors and resilience is only one of the many normative concerns the sector must grapple with. Second, climate and socio-economic futures are inextricably interlinked as they affect supply and demand, respectively, and they are constantly evolving. This requires a participatory, adaptive management approach. Third, climate change adaptation cannot occur in isolation. It must be mainstreamed into planning processes at each scale of government and this necessarily involves coordination across agencies.

This is a daunting challenge. Yet, the prominence of climate change in national and international discourses suggests that even if climate change is not the biggest current threat to water resources in India, it offers an opportunity for transformative change in the water sector. Where governance in the water sector has remained highly fragmented with between 20 and 30 departments addressing some part of the problem, climate change offers the opportunity to create agencies that can drive inter-agency coordination. Perhaps the biggest hope lies here.

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