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GEOGRAPHY AND YOU
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Access to tap water, water rights, water conflicts and many such issues are now significantly impacting the quality of life.

GnY
GEOGRAPHY AND YOU

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COVER PHOTO
EARLY MORNING SOJOURN TO THE CANAL, CHAMPARAN, BIHAR, BY PRASAD

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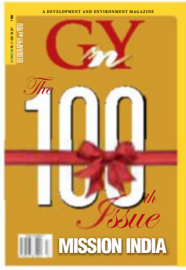

JANUARY-FEBRUARY 2017 ISSUE: I congratulate the entire editorial team of G'nY for coming out with a splendid 100th issue. The selection of articles in under the theme 'Mission India' is impeccable and has a interesting blend of information on scientific, economic, social and resource chronicling. The article on public schooling by Prof. Sachchidanand Sinha is an eye opener. Our basic education which is the foundation of nation building is in shambles. The government must take note of it and initiate a meaningful intervention at this basic level. —SUJATA PANDEY, New Delhi *Via e-mail.*

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HAVING READ YOUR web article on National Geospatial Policy made me aware of all the damages we have been doing to the environment. It being clearly worded and properly researched, helped me understand the issue, and intrigued me to further study about it. I was probably most surprised to hear about the EPA's finding regarding dirty air at home. With healthy adults exchanging up to 70,000 liters of air a day, it seems like a reason for worrying. How can we expect to stay free of illness, no matter how well we try to live and eat, if we're steadily breathing in chemical pollution and contaminants?
—RIC SMITH, VIA WEBSITE

THANKS TO G'NY online for publishing about age-old techniques of water conservation. I was happy to read about eri tanks of Tamil Nadu. These tanks have a long historical background and have contributed a lot to Tamil Nadu. Unfortunately, now many eri tanks are being converted to use for real estate, and while people want water, they are not ready to save water. Such techniques are important to avoid water-related conflicts in the future.
—RAJENDRAN, VIA WEBSITE

I CAME ACROSS THE G'nY magazine in my college days and still go through it years later. The quality of articles has been a drawing point for me. Thanks to G'nY I now have know-how about a wide variety of topics. I would like it very much if the magazine can be made available more frequently.
—YASH, VIA FACEBOOK

YOUR WEBCAST ON International Women's Day, March 8, covered a lot of issues that women face in the contemporary time -from violence to falling work participation rates. Thank you for such a nice conversation.
—MANGULU CHARAN, VIA LIVE WEBCAST

I WATCHED THE entire live webcast on Women's Day. Dr Sachidanand Sinha, the expert panelist was a delight indeed. I would like to know from him, however, what are the solutions for the falling work participation rates for women despite the fact that they are better educated today, as compared to a decade ago. Maybe G'nY could help us with an in depth article on this.
—AVINASH CHAURASIA, VIA WEBSITE

I ENJOY GOING to your website every few days to catch up on latest geographical events and news. However, G'nY should incorporate more quizzes for us to learn from!
—SOWMAY, VIA REVIEW FORM

I HAVE BEEN A G'nY subscriber for six months now and check the posts on a regular basis. My favourite, however, is the weekly quizzes in the media section. It made me realise the vastness and diversity of this country and made me curious about exploring the country further.
—SUMIT KUMAR, FACEBOOK

YOUR 100TH ISSUE on Mission India is a real gift for all the environment lovers. The articles are properly articulated and contain relevant information for the benefit of readers!
—A RAVI KRISHNA, VIA EMAIL

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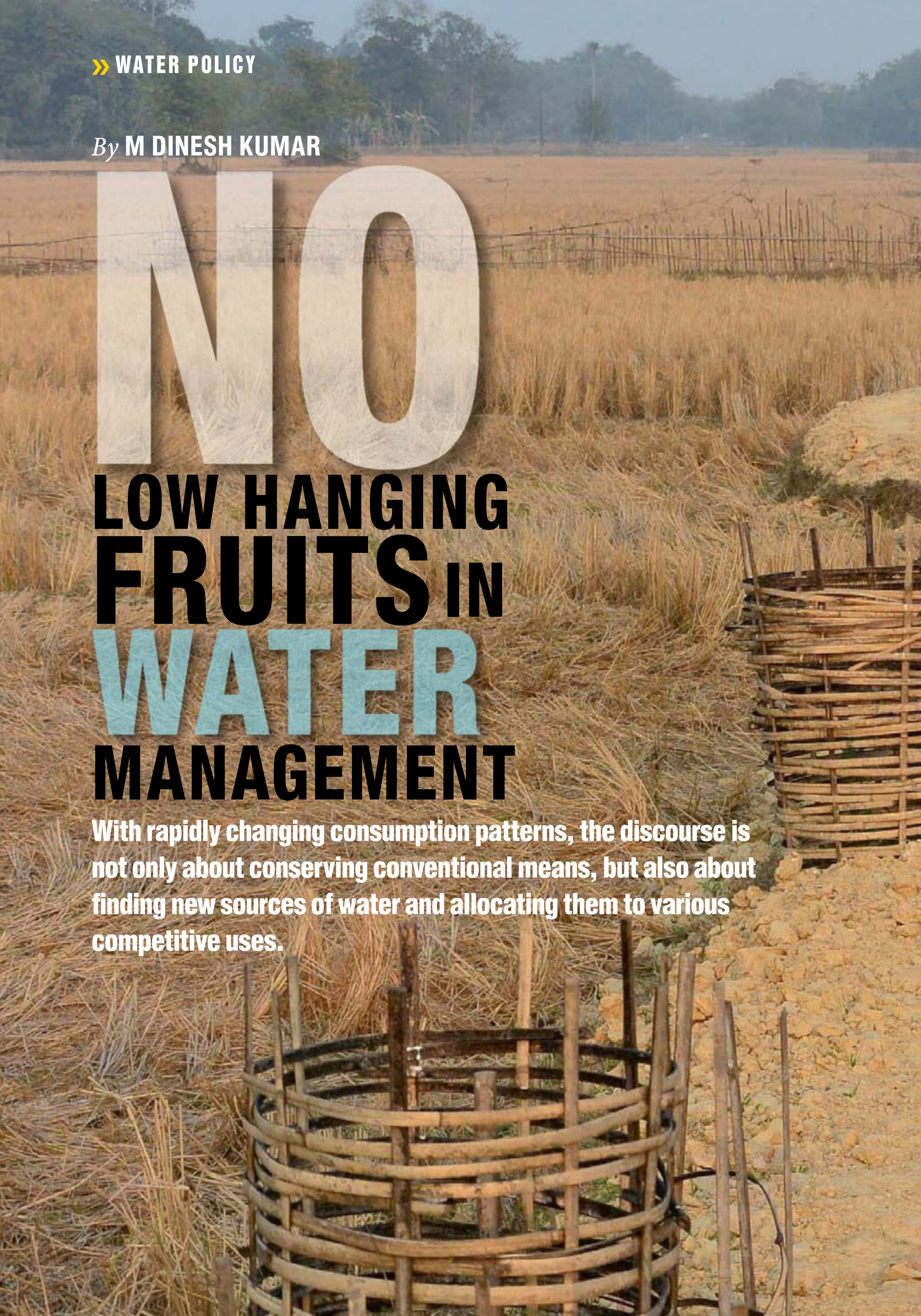
TO CONTRIBUTE AN ARTICLE: Kindly send the abstract of your article in not more than 200 words to submissions@geographyandyou.com. The abstract will be reviewed by our guest panelists. Once selected we shall respond for the procurement of full article. The length of the final article may range from 1000 to 1500 words. Please also mention if you can contribute relevant high resolution photographs. *The Editorial Advisor.*

Dear Readers,

Water has been a subject of favoured discourse for many years now. We have heard doomsday prophesies about how exacerbated conflicts related to rising scarcity of water can lead to wars much worse that the world has ever seen. India is a water-endowed country - and the monsoon in the last few decades has been 'normal' to a great extent. So how close are we to such prophesies?

In a sense, very close – especially if one considers the level of pollution in surface and groundwater – the latter still considered 'pure' in many instances. However, with awareness about the various water pollutants gaining widespread attention, a need to gain access to clean water is also showing sharp upward trend. Whether it is the State's responsibility to ensure free access to clean water or should it be priced, particularly when one considers that the poor are compelled to pay more?

We have visited the domain of water rights in this issue to understand whether water should indeed be a free resource. Should the farming sector be allowed to get away with inefficient water usage systems? The answer would necessitate the political and social contest of wills of common good and productivity goals. Nevertheless such questions and more are increasingly pertinent and seek urgent interventions at a policy level.



By M DINESH KUMAR

NO LOW HANGING FRUITS IN WATER MANAGEMENT

With rapidly changing consumption patterns, the discourse is not only about conserving conventional means, but also about finding new sources of water and allocating them to various competitive uses.

There is a need to manage water as a primary resource of the nation with utmost care. Dry canal running through a post harvest farm in a rural-location in Assam.

PHOTO: GNA

Inter-sectoral water allocation requires greater use of sound economic principles for efficient pricing, introduction of water use restrictions and more. Water resource management needs an understanding of ecological sciences and environmental economics. It is obvious that our water sector institutions have to be equipped with more technical manpower, with greater competence and with people from multiple disciplines. Water resource management and resolving conflicts over water use also calls for new institutions for basin wise water allocation and action.

Water being a state subject, most of the reforms has to be initiated at the state level through consensus. The role of different agencies such as Central Water Commission (CWC), Central Pollution Control Board (CPCB) and Central Ground Water Board (CGWB) is limited to hydrological monitoring of rivers, flood forecasting, groundwater survey and assessment of water quality. In other words, their role is advisory in nature and they have no direct stakes in the outcomes of their decisions. It is quite possible that one state has to forego some of its economic interests for the benefit of another. As a result, in the current institutional set up, the state may show no interest in such plans as they are not statutory in nature.

Institutional arrangement

The committee set up in November 2015 by the Ministry of Water Resources on 'Restructuring of Central Water Commission and Central Ground Water Board', which was to come out with specific recommendations for restructuring the CWC and CGWB seems to have ignored these basic facts. The Committee's Report 'A 21st Century Institutional Architecture for India's Water Reforms' made several recommendations, based on its own diagnosis of the ailing sector (Government of India, 2016). Some of the problems identified by the Committee are: low efficiency - about 35 per cent in public irrigation schemes; a mounting gap between potential created and potential utilised in the irrigation sector to the tune of 26 million ha; unsustainable use of groundwater, which accounts for 2/3rd of India's irrigation; declining of proportion of area irrigated by canals and lack of scope for further development of surface water in the country.

The Committee's recommendations, however, are rather mere reflections of the strong ideological bias and position of its members from the civil society collectively. Some of them are—plucking the 'low hanging fruit' of 26.0 million ha of additional irrigation by filling the gap between irrigation potential created and potential utilised; water demand management through promotion of water users associations (WUAs) in irrigation commands; participatory groundwater management through nation-wide aquifer mapping to be completed on a war footing; river rejuvenation; and integrated water resources management taking river basin as a unit for planning.

The Committee went on to suggest CWC and CGWB to work under a single umbrella body which is the 'National Water Commission (NWC)'. It is assumed that such an institution can promote integrated water resource management (IWRM) planning at the basin level for both surface water and groundwater. What has been ignored is that the lack of integrated planning is not because of the absence of coordination and data sharing, but due to inability to foresee how future development of the resource is going to take place in different sectors. Also the lack of control is perceptible, which lies in the hands of the concerned state departments.

Issues of concern

Contrary to the claim that this would mark a major paradigm shift in India's water sector and would have long lasting impacts, most of it can only bring about cosmetic changes. The larger concern continues to remain: can the two central agencies (CWC and CGWB) be held responsible for the perceived poor state of affairs in the water sector and also held accountable for implementing the new water management paradigm? The Committee Report does not provide any analytical base to establish the link between the two. Firstly, the proposed paradigm shift is not based on a proper analysis of the problems. Secondly, the two agencies whose work is under review are neither linked to the problems identified by the Committee, nor are parties for implementing the consequent recommendations for solving them, as it is made out to be.

First of all, the efficiency in public irrigation is far higher than what is being reported, if one assesses it at the basin scale. An efficiency level of 25-35 per cent in public irrigation schemes, as noted by the Committee, means nearly 70 per cent of the water released from the reservoirs or diversion systems would be lost. This works out to be around 280 billion cubic metres of water, annually. This 'wastage' should end up in the natural sink that is the rivers and the oceans. If we acknowledge that the large irrigation systems are located in the water scarce states of India such as Gujarat, Maharashtra, Andhra Pradesh, Tamil Nadu, Karnataka and Telangana, most of this water should appear at the last drainage point of the rivers in these states. However, this does not happen. Most of these rivers have no significant amount of water draining out in normal years (Government of India, 1999; Kumar, Patel, Singh and Ravindranath, 2008), as noted even by the Committee. Hence, the efficiency argument is completely flawed.

Secondly, as regards the Committee's remarks on the large gap between 'irrigation potential created' and 'potential utilised', they are only the administrative lexicons of India and not used in irrigation science. Moreover, the way estimates of 'irrigation potential created' are arrived at is misleading. These figures are often unrealistic as they are based on estimates of quantum of water available in the reservoir and a 'design cropping pattern' which never happens in reality. Water inflows into reservoirs can change depending on the amount of rainfall in the catchment and many upstream developments. Also, farmers shift to water intensive crops once irrigation water is made available, shrinking the area further. As regards the potential utilised, there is heavy under-reporting of the actual area irrigated by canals. There is no account for water lifted from canals and drains by engines and the area irrigated by wells which benefit from the canal seepage and return flows from gravity irrigation. This also means that we need to review the way data on canal irrigated area are collected. In sum, there is no 'low hanging fruit'. Every drop of water in these water scarce basins is captured and used within the basin though some scope exists for reducing non-beneficial uses of water such as evaporation from barren or fallow land.

Surely, this takes up to the next point that water users associations (WUAs) will have too little role in achieving water demand management except taking care of the distribution issues to some extent at the level of tertiary canals. Water demand management requires efficient pricing of water in

An efficiency level of 25-35 per cent in public irrigation means nearly 70 per cent of water from the reservoirs is lost.

irrigation and other sectors and water rationing or fixing volumetric entitlements. These are long overdue. Only such measures can bring about improvements in water use efficiency through optimal use of irrigation water for the crops or allocation of the available water to more efficient crops or saving water in the existing uses and selling it to alternative uses at a high price. These decisions need to be executed by the respective state agencies.

The Mihir Shah Committee used statistics to confuse and mislead readers when it compared surface irrigation with well irrigation. It used figures of 'percentage of net area irrigated by different sources' to show that canal irrigation had declined and well irrigation went up consistently. But if one looks at the gross irrigated area by different sources, it clearly shows that the gross canal irrigated area after steadily going up, has stagnated in the recent years. Though well irrigated area in India is much higher than that of canal irrigated area at present, the same type of stagnation has happened to well irrigation as well after a steady growth for nearly four decades.

The Committee does not make a mention of the fact that large reservoirs (most of which were primarily built for irrigation, excluding those for hydropower) today supply water to several large cities. A recent analysis involving 301 cities/towns in India shows that with increase in city population, the dependence on surface water resources for water supply increases, with the dependence becoming as high as 91 per cent for larger cities (Mukherjee and Shah, 2008). Many large cities depend almost entirely on surface water from large reservoirs. Some examples are Bangalore, Ahmedabad, Chennai, Rajkot and Coimbatore,

There is a need to understand how participatory aquifer mapping will get translated into participatory groundwater management in India, especially in ecologically sensitive areas such as the Sunderban.

with contribution ranging from 91 per cent to 100 per cent (ADB, 2007). This factor would have been considered by any scholar who makes an objective assessment of the sector. Not doing that shows the professional bias against public irrigation.

On the groundwater side, it is a well-established fact that the two major reasons for over exploitation of aquifers are the absence of well defined water rights in groundwater and inefficient pricing of electricity supplied in the farm sector. The problem is surely not due to lack of sufficient information about occurrence of groundwater and its flows. The farmers as well as official agencies know that the resource is fast depleting in many pockets. Participatory aquifer mapping can do nothing to halt this on-going menace. Neither is the Committee able to visualise how the participatory aquifer mapping will get translated into participatory groundwater management under the much touted National Aquifer Management Programme with a budgetary allocation of INR 3539 crore under the 12th Five Year Plan.

Challenges ahead

As a matter of fact, we already have sufficient information to start initiating management action in the problem areas. But those actions are going to be institutional in nature and what we lack is the political will of state governments. The experiences of developed countries such as the United States, Australia, Mexico and Spain, dealing with issues of groundwater management, clearly show that the solution lies in creating robust institutions—which can clearly define water rights of individual users and enforce them or put tax on groundwater use based on volumetric withdrawal. On the other hand, programmes like participatory aquifer mapping can have serious negative consequences on equity, with the rural elite using aquifer maps for their benefits—say for instance to buy land in areas where there is good amount of water lying underneath.

The problem today is that most of the basins in the naturally water-scarce regions are 'closed', with no water going uncaptured. But agriculture

growth is suffering in these regions due to lack of sufficient amount of water to meet the high irrigation demands owing to the presence of large amount of arable land and high aridity. Telangana, Rayalaseema and western Rajasthan are just a few examples. Cities located in these basins are not getting adequate amount of water to supply to their rapidly growing population. The rivers in these regions need water to maintain the ecological health. While the Committee discussed about 'rejuvenation of rivers' at length, it failed to offer any practical suggestions on the ways to achieve it except taking platitudes about integrated surface and groundwater development. But to get water back in the river and to maintain the base flows from aquifers, we need to cut down water withdrawals drastically. The only way we can achieve these multiple objectives is through inter-basin water transfers from water abundant basins, which is already happening in limited ways in different basins that are characterised by sharp differences in resource endowments.

A much larger and more sophisticated water infrastructure for inter-basin water transfers is needed to store, divert and transfer water from water rich basins to distant regions with water shortage. Therefore, capacity building of state and central level institutions has to be in multiple disciplines such as hydrology, groundwater modelling, water engineering, river morphology, dam safety, ecological and environmental economics and water law etc. to take up the new challenges.

Endnote

As the cost of production of water touches astronomical heights, water demand management has to receive great attention in the coming years. There cannot be two paradigms in one country. The paradigm which the states choose to follow will always be dominant as they have statutory mandate. Hence this exercise is a recipe for face- off between the centre and the state.

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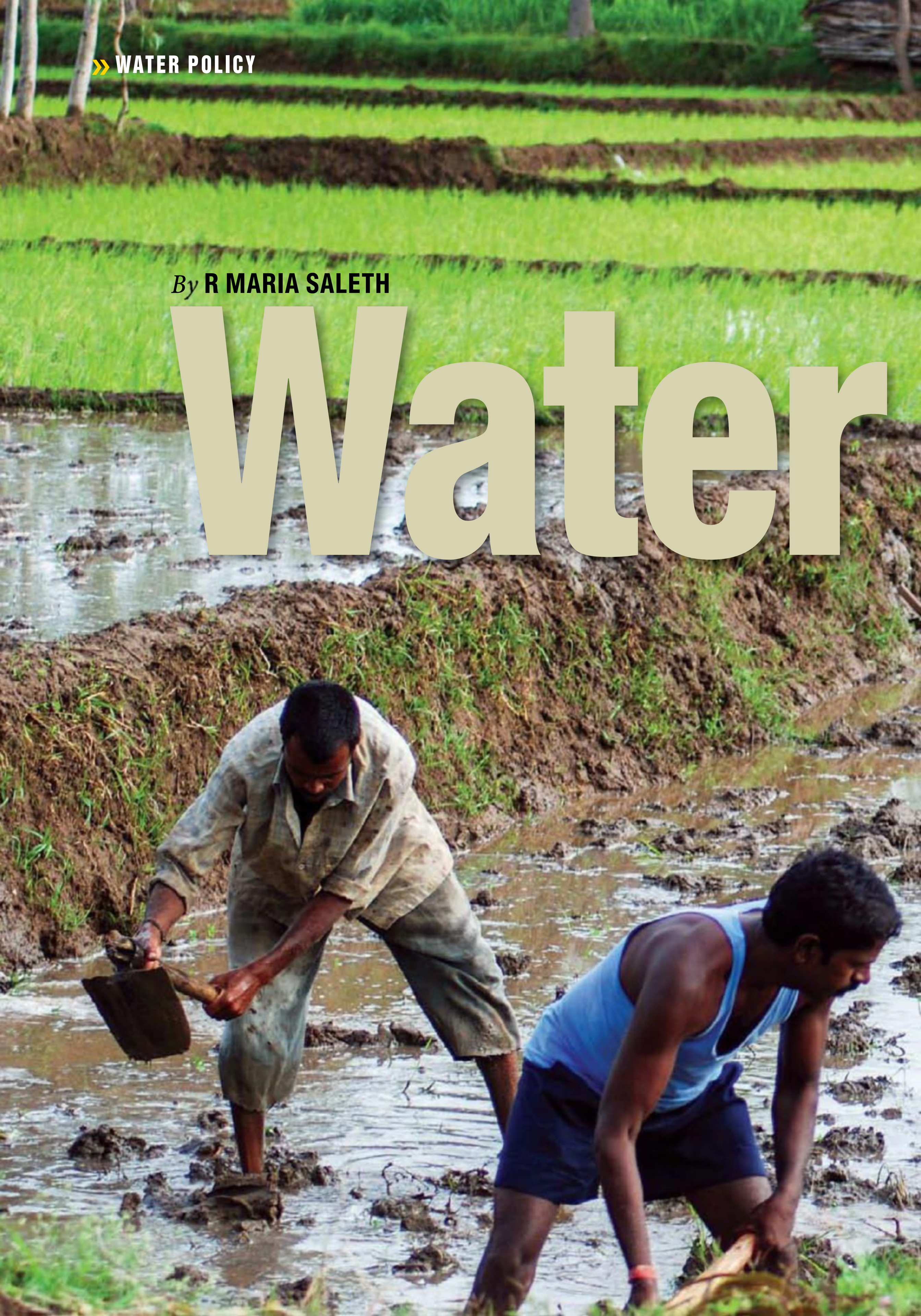
By **R MARIA SALETH**

Water



Unbridled use of water requires a upper cap to manage water judiciously, Rice Farming in Mysore.

Rights SYSTEM FOR INDIA

Water scarcity in India cannot be tackled without establishing binding water withdrawal limits through a system of enforceable water rights at various scales.

PHOTO: PRASAD

The persistent and widespread symptoms of an imminent water crisis across India are a clear evidence for the failure of our water-related policies and institutions. It is urgent to seek for more durable, but politically harder and technically challenging options such as the institution of a water rights system. Why do we need a water rights system in the first place? What is the status of the issue of water rights in current policy? What are the legal, economic and physical characters and requirements that a water rights structure should satisfy? Do we have enough institutional and technical potential for instituting a water rights system? This article attempts to shed lights on these and related questions.

Why do we need a water rights system?

While legal reforms are needed in all spheres of environment and natural resources, water reform is particularly urgent in view of the special role that water plays in human survival and progress (Singh, 1991). Water not only caps the absolute needs of human beings (and also of animals, plants, etc.), but also forms the basic input for producing other basic needs such as food and fish products as well as other needs such as power generation and navigation. Since existing water-related laws, policies and organisations are unable to tackle current and future challenges of the water sector, there is need for creating a new water institution rooted in a system of water rights.

With an efficient and transferable water rights system, markets for water will emerge to guide water allocation and use at the individual, sectoral, and regional levels. Since the water rights system can be designed to establish withdrawal/use limits at the individual level, to address distributional needs of within and across groups and regions and to confirm with the overall sustainability limits, it is a rare policy instrument that can simultaneously advance three social goals, i.e., economic efficiency, social equity and resource sustainability.

Water rights issue in policy and literature

Although most colonial and post-colonial laws have ascertained the absolute rights of the state over water and other natural resources, policy-makers have, time and again, underlined the need for something resembling a water rights system (Government of India, 1976 and 1992). For instance, the National Commission on Agriculture (1976) has proposed to allocate groundwater rights in proportion to land ownership. The Model Groundwater (Control and Regulation) Bill 1992 has postulated a kind of water permit system. Similarly, the National Water Policy of 1987 and that of 2002 have recognised the need to establish some upper limit on individual water withdrawals. While the economic and equity significance of water rights system is clear, it is still considered by many as an administrative nightmare and a political impossibility. Fortunately, this perception is steadily changing because the opportunity costs (i.e., the foregone socio-economic benefits) of status quo are exceeding fast the political/administrative costs of instituting the system. Besides, with technological progress and development of institutional and technical capacities, the costs of transacting the reforms are also on a constant decline.

Water rights system: technical and institutional requirements

At the outset, it is necessary to dispel the commonly held view that the fugitive character of water is an insurmountable obstacle for defining water rights. Complete physical control over an object is not at all necessary for establishing an ownership system for ownership to an asset implies only a bundle of *circumscribed* user rights. That is, it is rights, not objects, which are owned (Coase, 1960; Dales, 1968). Property rights over water, once established, can yield tremendous net social benefits. The full realisation of such benefits depends on the technical and institutional potentials and capabilities, which are critical to establish, enforce and administer the water rights system in the field.

The most immediate requirement for a water rights system is to establish water balance, i.e., the demand for and supply of water for each appropriately defined hydro-geological unit. To enhance decision-making under uncertainties, water balances have to be established under a variety of alternative climatic/technical conditions, disaggregated by uses and sources. Given an uneven regional distribution of water demand and supply, it is also necessary to form 'water grids' that could provide a framework to promote inter-basin water transfers.

As to the *modus operandi* of water rights systems, three issues qualify for immediate attention: (a) unit of measurement, (2) criteria for rights distribution and (c) enforcement and monitoring mechanisms.

Volumetric measure: An ideal unit of measurement will be independent of both time and space. This demands a volumetric rather than a flow-based measure. This has been suggested long before by the 1972 National Irrigation Commission and also endorsed by the 1976 National Commission on Agriculture (Government of India, 1976). It is the volumetric measure that could provide the much-needed economic incentive for maximising output per unit of water, instead of the usual practice of maximising water per unit of output. The Model Bill of 1992 has suggested the mandatory installation of water meters for all users (Government of India, 1992).

Criteria for rights distribution: As per Coase Theorem, as long as water rights are transferable or rentable, economic efficiency is independent of the criteria used in the distribution of initial water rights. However, from an equity or income distribution perspective, the choice of criteria is important because water rights assignment amounts to asset transfer. While one can think of a variety of approaches including a bidding procedure, for rights allocation, one can consider two familiar criteria: one proportionate to land ownership, as suggested by the 1976 National Commission on Agriculture (Government of India, 1976: 45) and the other proportionate to family size, irrespective of land ownership as adopted actually in the *Pani Panchayat* system (Thakur and Pattnaik, 2002). It is also possible to follow a hybrid model wherein certain amount of water, which is reserved for landless persons, is apportioned in accordance with the *Pani Panchayat* model and the remaining is distributed among land owners in proportion to land ownership.

Enforcement and monitoring mechanisms: To begin with, the government, as a grand trustee of water resources, owns the resource and also has the responsibility to establish the overall legal, policy, and organisational framework for an equitable water rights system. The usufructuary rights vest with individual users. However, the enforcement and administration of the rights system established thus should be left to local trustees who can be either Panchayats or other village-level or outlet-level user groups. Such a decentralised arrangement will be the effective means of enlisting people's participation in water management as the water rights system would have created a stake for their direct involvement. Despite their weakness, the local governance organs and the existing water/irrigation cooperatives and outlet-level user associations do indicate the existence of a fair amount of institutional potential at the grassroots level that could be tapped to develop effective and flexible mechanisms for the administration and enforcement of the water rights system.

It is a commonly held view that the fugitive character of water is an insurmountable obstacle for defining water rights.

Hierarchical and dovetailed framework of water rights

The 'public trust' framework noted above has both a hierarchical structure, where the use and regulatory rights of the users, communities and state are organically linked as well as dovetailed structure, where the allocation and use rights of individuals, sectors and regions are operationally linked. Such a framework, besides being an institutional synthesis of centralised and decentralised decision-making mechanisms, has also other desirable integration properties.

While the right of the state or community is essentially a legal one related more to its duties in establishing, enforcing and monitoring water allocation and use, the individuals' use rights are not only legal, but also physical in nature in the sense that these user rights specify a fixed quantity of water along

> **Water rights system is a critical institutional requirement for addressing the prime goals of sustainable development.**

with legal duties involved in its utilisation. Thus, the hierarchically structured water rights system could ensure internal legal consistency and also satisfy the basic economic requirement.

By assuming a decentralised decision-making structure that is endowed with sufficient economic and technical information, it is possible to visualise the following dovetailed structure of water rights. First, the quantity of water and its priority for different sectors are established at a given geographical and decision-making context (e.g., river basin and village) preferably on an annual basis to enable periodic revision. Second, within the sectoral allocation pattern established above, water quantity and its priority for uses within each sector are established. And, finally, having sorted the water allocation across communities, the amount of water available to each individual member (i.e., individual water rights) of the community is determined based on the distribution criteria. If the legal framework of the water rights system is designed within this dovetailed context, then it is easy to achieve internal physical consistency among the water rights of various sectors and uses.

Endnote

The economic rationality and urgency for a water institution based on a water rights system are vivid and obvious. Water rights system is indeed a critical institutional requirement for sustainable development for it is one of those rare policy instruments that can simultaneously address three critical goals of sustainable development. These are ecological security, economic efficiency and social equity. The desirable practices like conjunctive use, supplemental irrigation, water-saving technologies, water transfers and water recycling cannot all happen in an economic vacuum. Strong economic incentive could emerge only when users perceive water as a constraint which, in turn, can happen only with quantified water rights.

The existence of various forms of incipient systems of rudimentary water rights in different parts of the country and the ability and maturity of our farmers to manage water allocation by themselves, as revealed by the spontaneous emergence of groundwater markets and the growth of farmer-managed irrigation systems, do indicate that farmers and individuals could very well adapt themselves to the institution of water rights. It is time, therefore, not to enumerate the administrative difficulties, technical snags or political problems, but to identify ways and means by which these problems could be managed to make an efficient and practical water rights system as one of the indispensable institutions for promoting sustainable water management in India.

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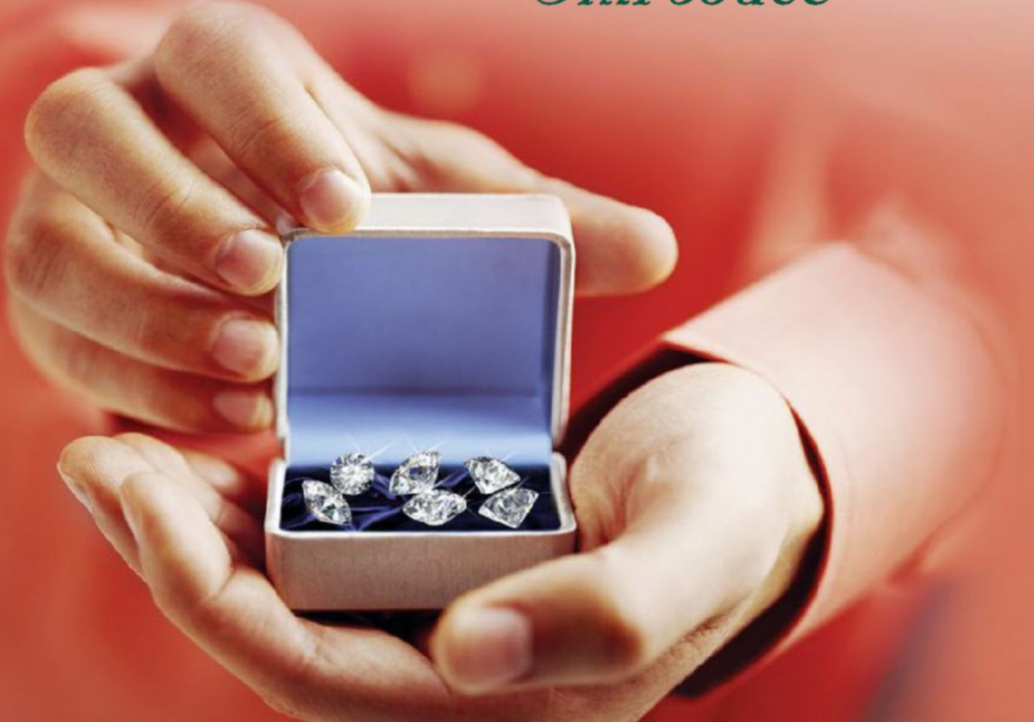

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WATER IN INDIA: MANAGING UNCERTAINTY

By **H N ADAM, S BOSE, U GHOSH, L MEHTA** *and* **S SHILPI**

Water is a deeply contested resource because of its multiple uses, meanings and governance regimes. Its fluidity makes it hard to govern and manage. Old and new challenges need to be confronted as climate change uncertainties amplify and shape water access and water use in India.

Uncertainty is part and parcel of every dry landscape in villages of Thar Desert.

PHOTO: PRASAD

Water resources and their management form an integral part in India's everyday life and planning. In both folklore and policy, water is the embodiment of life and key to sustaining livelihoods and food security. However, it is a contested resource and there is no consensus regarding how best to govern and manage it. From time to time, a variety of institutional arrangements has been put in place, plans formulated and large infrastructure projects kicked off to provide for and augment its physical availability and 'improve' access and distribution. Though the actual outcomes are disputed, these efforts reveal the highly political nature of water governance—ranging from inter-state water disputes, movements against large dams and the ambitious project of interlinking of rivers to issues of equity and access to 'safe' water.

In the last three decades, the increasing focus on climate change has also put water related uncertainties into sharp focus. Scientific projections by the Intergovernmental Panel on Climate Change (IPCC) premise that the incidence of droughts, heat waves or extreme precipitation events are likely to become more frequent and intense. This adds a layer of challenges to those already existing within the realm of water and development as impacts on the hydrological cycle become more uncertain and unpredictable. While an analysis of observed rainfall data for the 131 year period (1871–2001) suggests no clear role of global warming in the variability of monsoon rainfall over India (Kripalini et al. 2003), the Indian monsoon remains notoriously difficult to predict and understand. This is important because in recent years, scientific studies have highlighted increasing vulnerabilities of regional water resources towards climatic changes. Adding to these complexities are the competing demands from various sectors, rapid urbanisation and wider questions on the political economy of development.

Ecological events such as droughts, including what was experienced in parts of eastern, central and southern India in 2016 such as Maharashtra, Odisha and Karnataka to name a few, are not new. However, climate change is changing the intensity, predictability and ability of local people to cope with rainfall variability. Water related uncertainties exist regarding what future impacts mean at the local level, how they play out in their day-to-day lives and how government and society can respond to them.

Uncertainty—as a phenomenon, where we do not know enough about impacts and outcomes—is not new per se and has historically been experienced, particularly by rural people all over India, especially with respect to water availability (Mehta 2005). Responses to weather and related water vagaries have tended to draw on an intricate mix of strategies, which include accessing traditional knowledge regimes, community institutions and social networks or, if required, a shift in livelihood strategies.

Dominant development approaches tend to seek to 'control uncertainty' instead of trying to embrace or understand it. Such top down efforts often fail miserably when one looks at recent cases such as flooding in Chennai or the inability of Mumbai to deal with chronic flooding. In addition, they can be elite driven projects that exclude marginal people and local communities. These gaps in the understanding between the 'above' and 'below' raise a number of complex questions with respect to water governance. What impacts do these uncertainties have and on whom? How do communities respond and what opportunities can be explored? As part of a research project on 'Climate Change, Uncertainty and Transformation', these questions in different ecological, geographic and social contexts namely arid Kutch, urban Mumbai and the deltaic Indian Sundarban have been explored. The research has involved qualitative data collection comprised of interviews and literature reviews over a time period from 2015-2017. Respondents were policymakers, scientists, NGOs and local people involved in policy-making, planning, mediation and community development initiatives that look at issues of water and climate change.

It is also important to understand how climate change intersects the other drivers of change. These are some of the issues we highlight in the three regional cases presented below.

Mumbai

One of the most devastating flooding events of urban India took place in the coastal city of Mumbai in 2005. Extreme precipitation, to the tune of 944 mm over the span of just 24 hours, inundated large swathes of the city and led to debilitating loss of life, property and livestock. Residents and slum dwellers who live in low lying areas and on marginal lands suffered disproportionately. Termed as an extremely rare event, it also laid bare challenges and deficiencies in urban water governance in India, in particular the accentuated danger that flooding poses to urban agglomerations. Residents and city planners were caught totally unaware, with the latter blaming factors beyond their control, but also climate change for the damages caused. While the role of climate change remains under scrutiny, it is political and governance issues that reign supreme. The systematic neglect of ecological and geographical dimensions and the fragmented nature of urban planning combined with the influence of private interests, specifically construction mafias play a decisive role in creating an urban space that is prone to flooding—even during normal rainfall. Chennai's suffering a similar fate only showed that it did not learn lessons from Mumbai's experience. As other cities across India continue to grow exponentially, it is important that they adapt and manage present and extreme rainfall events in a way that protects and is inclusive of all their residents. This approach of managing the present variability can also be a first step when dealing with future climate uncertainties. Similarly, the admirable ability and resourcefulness of deprived sections to cope with adverse events should not lead to an entrenched status quo, instead efforts should be directed towards preventing and mitigating the onset of flooding disasters and support more long term thinking.

Scientific studies have highlighted **increasing vulnerabilities** of regional water **resources** towards climate change.

Kutch

Uncertainty is writ large in the dry landscape of Kutch, the border district in Gujarat on the north-western coast of India. Droughts and water scarcity have always been common features of this district. However, climate related changes now pose new challenges. While in the past, people were able to 'predict' normal and bad years of rainfall by relying on indigenous knowledge systems such as observing the direction of the wind and lunar calendars, etc., the increase in erratic rainfall and unprecedented rise in temperatures is beginning to disrupt this rhythm in Kutch. The flash floods of 2011 which took everybody by surprise are a testament of this. What do these changes mean for local people and how do they affect access to water? The coastal areas in Kutch face the prospect of sea level rise. Salinity ingress has become a major challenge to contend with and poor monsoon rains only exacerbate this situation. The village ponds that supplied enough water about a few decades ago now dry up during late winter and summer. Wells have been made redundant due to increase in salinity levels. This translates into long hours of drudgery and wait for women who now have to make on an average five to six trips to the well on a regular summer day. Though piped water supply has eased the situation in some areas of the district, the supply is still intermittent and unreliable in remote areas. Rapid industrial development has also added pressure on water resources of this region. Fire fighting strategies for drought mitigation which are usually top-down in nature fail to take into account the dynamics of this ecosystem.

Sunderban

The Sunderban is the world's largest active mangrove delta in the southern end of both Bangladesh and West Bengal. It is shaped and at the same time challenged by geo-climatic and geographical conditions including sea level rise and disappearing islands. Amidst these changes, the water scenario faces manifold challenges ranging from the drying up of fresh water ponds, increasing salinity, depleting ground water level due to overuse, destruction and the contamination of tap water due to frequent flooding. These issues combined with local customs such as bathing and cleaning the vegetables etc. in the local ponds have made the local population susceptible to water borne diseases and skin infections. Predominantly women and children suffer from adverse health effects as they mostly choose to bath in the neighbouring ponds and women are responsible for cooking and cleaning. Water scarcity was not very prevalent in the Sundarban until recently. According to a World Bank report (World Bank, 2014) only 30 per cent of the non-deltaic population has access to safe water whereas about 23 per cent of the deltaic population in the islands has access to safe drinking water. The main challenge is increasing water salinity due to fresh water depletion in the upstream, compounding with rising sea levels. Salinity ingress is also affecting the livelihood of the islanders and in some cases it has increased beyond the safe threshold for agriculture (World Bank, 2014). By and large, most areas lack the required number of taps. Some initiatives by the West Bengal government with reverse osmosis based desalinisation plants, solar pumps and raised tube wells have successfully recharged aquifers with rainwater and helped reduce salinity. But these are exceptions and rare. Limited understanding of the islanders' way of life and culture have also led to divergences in policy making and implementation.

West Bengal's initiatives with reverse osmosis have successfully recharged aquifers with rainwater, reducing salinity.

Endnote

Various uncertainties related to governing water and its availability, access and distribution are evidently on the rise and climatic changes make it more challenging. These changes are also intertwined with existing development issues that are sometimes difficult to separate and ultimately embedded within the existing socio-political regimes.

An inclusive and equity focussed approach would, at the outset, require a realisation of the existence of different framing and perspective on water and its linkages with climate change. There is growing acknowledgement that those most affected by inequitable access to water and events such as droughts and flooding are also amongst the most excluded from decision-making on resource use and access (Arora-Jonsson, 2011; Mehta, 2005). It is imperative that policy makers include problems of growing water related uncertainties in their programmes, prioritising the needs of the most marginalised people who live at the interface of these climate stressors and shocks.

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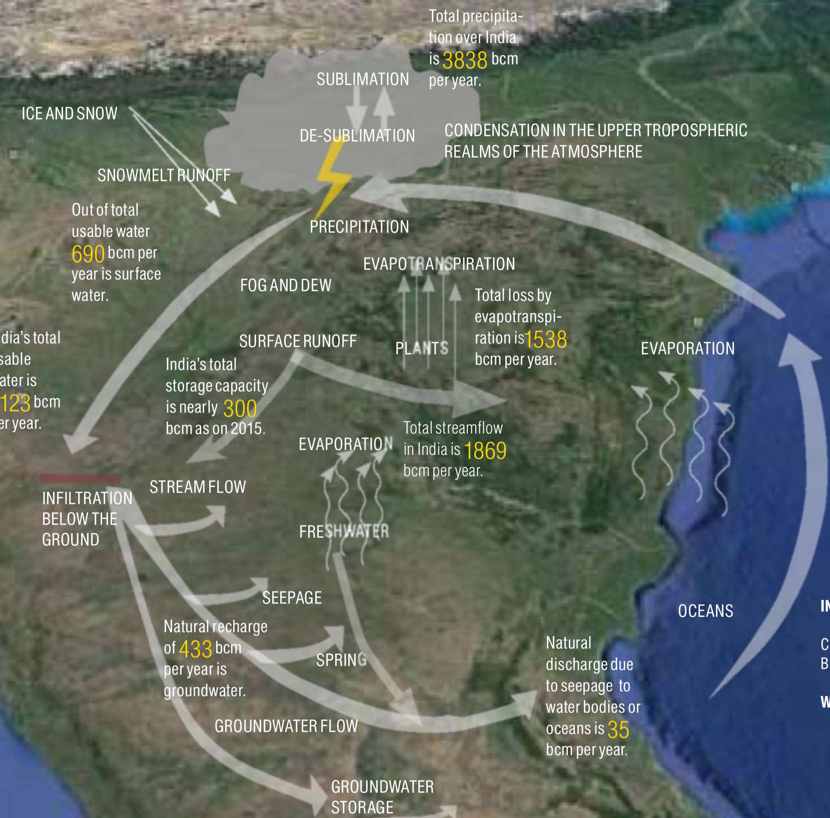
PER CAPITA AVAILABILITY OF WATER: *India had per capita availability of 5177 cu m water in 1951. Since then, it has been decreasing continuously with rising population. Per capita water availability was 1816 cu m in 2001 and it decreased within the decade to 1544 cu m in 2011. India will face drastic water scarcity with this ever growing demand. It has been predicted that per capita water availability will go down to 1341 cu m in 2025 whereas it will be 1140 cu m by 2050.*



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CU M: CUBIC METER
BCM: BILLION CUBIC METER

WATER BALANCE EQUATION:

PRECIPITATION = STREAMFLOW + GROUNDWATER + EVAPOTRANSPIRATION + ERROR

EQUATION APPLIED TO INDIA:

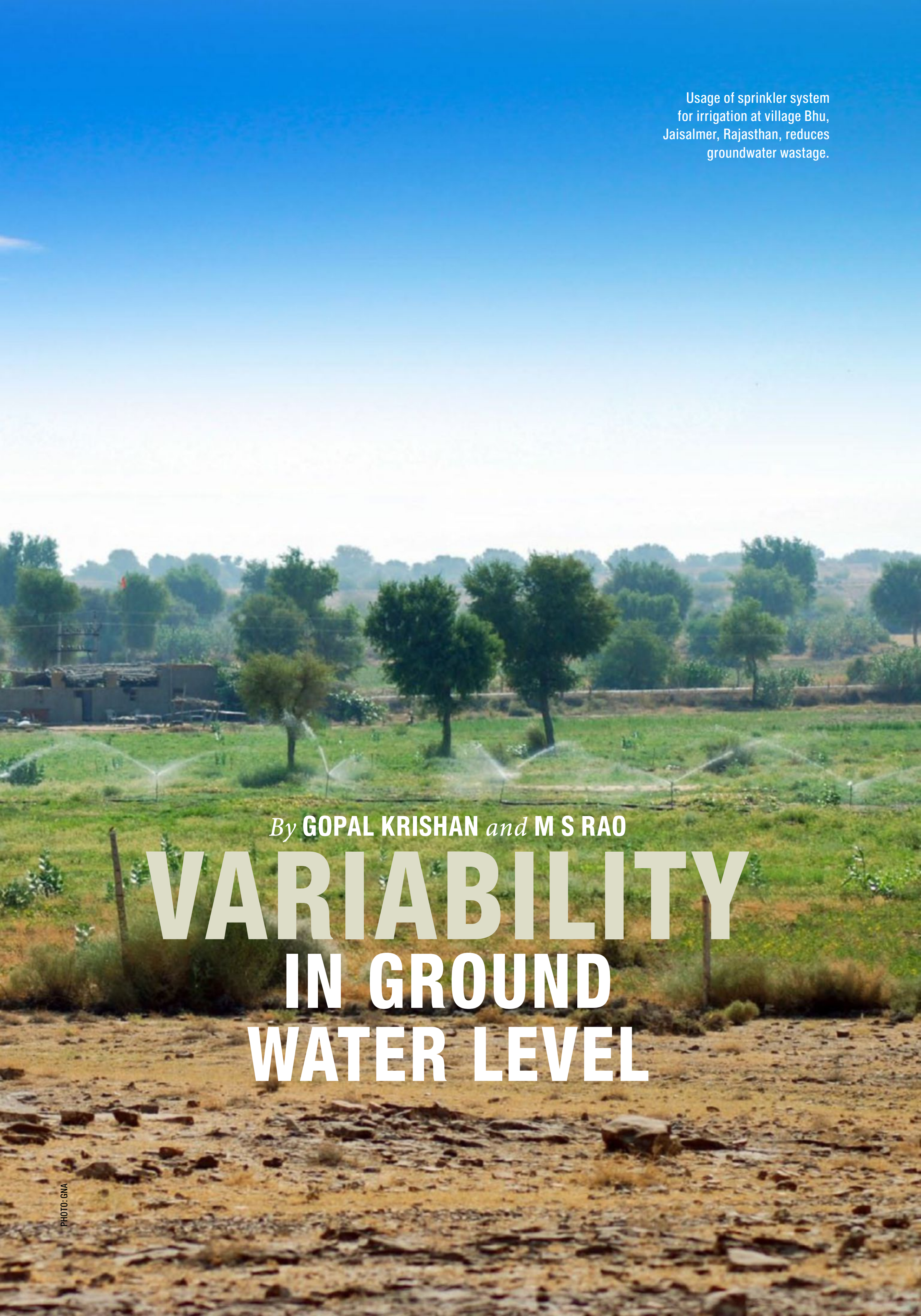
PRECIPITATION (3838) = STREAMFLOW (1869) + GROUND WATER (433) + EVAPOTRANSPIRATION (1538) + (-2) (ERROR)

* ERROR SHOULD BE ZERO, BUT PRACTICALLY IT IS NOT

WATER CYCLE: INDIA

Water flowing into the sea constitutes a major portion of India's water balance. There is a need to efficiently conserve the resource.

Groundwater is the largest freshwater storage, but its high abstraction rate for fulfilling the demands of ever increasing population, industrial and agricultural sectors has been leading to its significant depletion.



Usage of sprinkler system for irrigation at village Bhu, Jaisalmer, Rajasthan, reduces groundwater wastage.

PHOTO: GNA

By **GOPAL KRISHAN** *and* **M S RAO**

VARIABILITY IN GROUND WATER LEVEL

Groundwater is a part of the water cycle and exists underneath the earth's surface almost everywhere—hills, mountains, plains, deserts, coasts and even sometimes below the sea and ocean beds. Nearly 98 per cent of earth's fresh water, in liquid state, is groundwater. On a global scale, nearly half of the population draws on groundwater for their drinking needs and worldwide, 2.5 billion people depend solely on groundwater to satisfy their basic daily water needs (UNWWDR, 2015). Water below the surface of the earth is found as soil moisture if it is less than 100 per cent of saturation or as groundwater at 100 per cent saturation. Groundwater flows through aquifer (water saturated sediment zone), weathered rocks and through crevices and cracks in rocks as a saturated flow from its recharge to discharge area. Approximately 22.6 million cubic km of groundwater exists in the upper 2 km of the continental crust. Of this, volume of the dynamic groundwater (<50 years of age) is 0.1-5.0 million cubic km (Gleeson et al., 2016). In a recent research, Oliver Warr and his group discovered 2 billion year old water in the Precambrian rocks of Ontario, at a depth of 3 km below the earth surface (Romuld, 2016).

The present article is a brief overview of groundwater resource, the mapping techniques, identification of variability in the groundwater resource in space and time, data interpretation and management measures to safeguard depleting groundwater for sustainable use.

Mapping of groundwater and aquifers

Formation of groundwater in a region is controlled by several factors including topography, terrain slope, lithology, rainfall pattern and surface water bodies etc. Mapping of the resource involves the investigation of hydro-geological setting, aquifer and its characterisation. These investigations are usually done by airborne electromagnetic survey (AEM), surface investigation methods (time domain or frequency domain electromagnetic survey, GPR's, proton magnetic resonance survey or electrical resistivity imaging technique, etc.) and through sub-surface investigation (borehole geophysical loggings, chemical and isotopic tracer techniques etc). State geology maps and accompanying description of lithologies of tube-well logs can also be integrated to prepare 2D and 3D hydro-lithology and aquifer permeability maps across the country. Adopting a similar approach, Central Ground Water Board (CGWB) is integrating information on hydrology, geomorphology, geology, hydrogeology and hydro-chemical data to prepare aquifer and vulnerability maps of India at 1:50,000 scale for quantity and quality of groundwater under the National Aquifer Mapping and Management (NAQUIM) programme. The programme is integrating data over 3171158 square km area. In its first analysis, the Board has demarcated the Indian groundwater system into 14 principal aquifers and 42 major aquifers (Dhiman, 2012).

Groundwater availability, monitoring and observations

It may be noted that groundwater availability is the physically available groundwater in that region and is different than the groundwater accessibility which relates to how easily the groundwater can be tapped. While rainfall and the interacting surface water sources recharge the groundwater, draught and groundwater pumping cause groundwater to decline. The two reservoirs - surface water and groundwater are inseparable. While, the spread of surface water area in the recharge zone contributes in recharging the groundwater, at the discharge zone, the base flow contributes to stream flow and maintains its discharge during the non-rainy periods. Thus, the depleting groundwater can result in reduction in stream flows. The recharge/extraction process keeps the groundwater in a state of dynamic condition.

Data loggers

The fluctuating level of groundwater over different time scales (diurnal, seasonal, annual decadal etc.) is monitored using manual or semi-automatic or automatic loggers. These loggers are installed in the piezometers and observation wells and the high frequency data are downloaded. The automatic water level loggers measure the overlying water head pressure (total pressure minus the barometric pressure) and convert it in the units of water level. Increasing and decreasing levels of groundwater are interpreted in terms of groundwater recharge (from rainfall and other surface water sources) and draft respectively. Annual deficit or excess of groundwater balance can be viewed from the long term record of groundwater level trend (also termed as groundwater hydrograph). For interpretation, along with the groundwater data, rainfall and stage of the interacting surface water sources are also recorded.

Interpreting data

The data collected from other agencies can also be interpreted to see the water level changes over a period of time, which can be correlated with the precipitation. Asoka et al. (2017) have reported estimated changes in the groundwater well depth using CGWB data for 1996-2013 and observed decreasing trend in north India in monsoon as compared to non-monsoon season (Fig. 1), while increases in water level are observed in majority of wells in South India with some exceptions. For example, Shadnagar from hard-rock region of Andhra Pradesh depicts rising level of hydrograph in response to the rainfall recharge and falling thereafter due to adjustment with regional groundwater level and/or due to local groundwater withdrawal (Briz-Kishore and Bhim Shankran, 1981).

Sometimes, raw groundwater data show a misleading picture of rising or falling trend due to varying rainfall pattern. A proper mathematical analysis is, therefore, used to get pure trends due to natural and anthropogenic effects. Various methods used by researchers are cross-correlation analyses (Liu et al., 2015; Hsiao, 2017).

The temporal variation of groundwater balance in a basin helps identification of variation in recharge, draft and base flow conditions. Paucity of data for basin scale hydrological modelling can be overcome by using satellite based data. Large amount of satellite based global scale hydro-meteorological data, gridded to few km resolutions over time intervals from daily to annual period, are available from various sources. For hydrological modelling, the required parameters from these sources can be downloaded, down-scaled to the regional scale and the data available at local levels are integrated to regional scale. Temporal data are analysed for high and low frequency trends and their changing amplitudes. The futuristic models extend the resultant time series by incorporating population growth, economic reforms and developments, changing rainfall and temperature pattern, food productivity and its requirement etc. over the required time scales. Based on such models, suitable steps can be taken up to recoup, use and manage the groundwater aquifers.

Groundwater level and hydrological evaluations

Groundwater flow direction visualisation using groundwater level: Groundwater flow is usually visualised in a region by plotting groundwater level contours in units of meter above mean sea level. From the contour map it is possible to visualise regional flow pattern, rapid and slow flow paths, recharge (concentrated mounds) and discharge (depressions) zones, zone of influence of surface water with the nearby groundwater etc. As an example, a case of groundwater flow pattern of northern part of Punjab falling within the interfluves region of Beas and Satluj Doab region is shown in Figure 2.

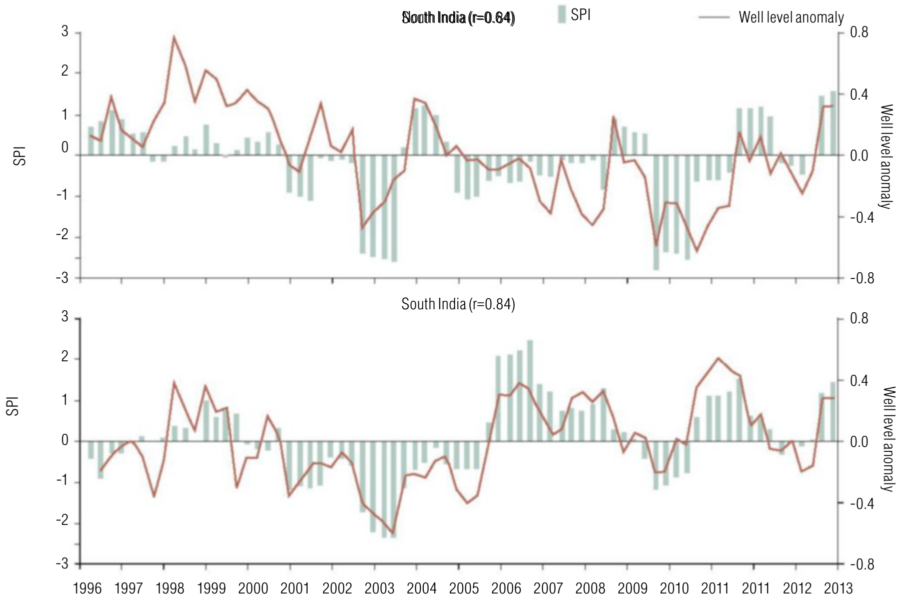
The contours of groundwater level clearly show flow of groundwater along the direction northeast to southwest direction. The shaded region in the northeast is Siwalik Hills which acts as a regional zone for the groundwater recharge. The contours are concentrated near the hill indicating higher rate of groundwater flow. The flow becomes parallel to the surface flow near the rivers Beas and Satluj. The gap between the contours increases towards southwest direction indicating decrease in groundwater flow rate.

Since the groundwater movement is very slow, a perturbation in the form of heavy recharge or extensive long term draft can be captured in the contours in the form of local mounds or depressions. However, as time passes after the recharge or discharge, these local perturbations smoothen out.

Groundwater resource estimation and management: Groundwater level time series have been widely used in groundwater resource evaluation and its management. The variability analysis using additive and multiplicative models of groundwater levels is done to pool long-term groundwater levels and correlating them with rainfall and climatic cycles which help in the long term planning of groundwater utilisation.

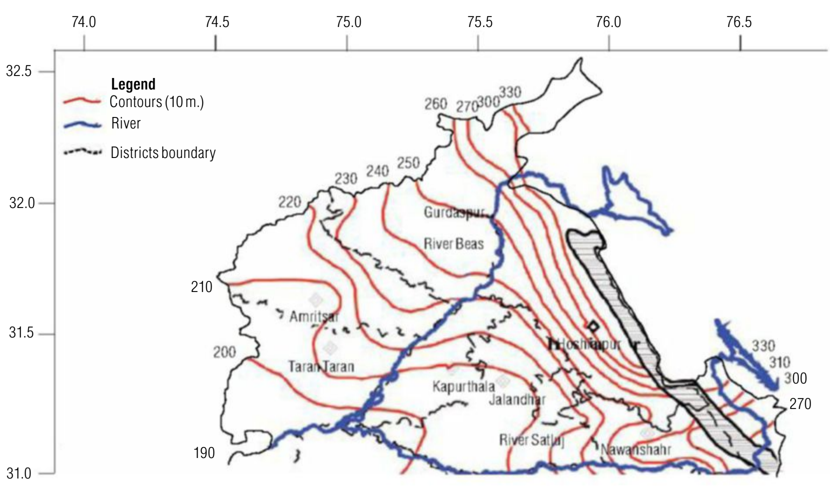
The groundwater trend in a country like India

Fig. 1: Relationship between groundwater fluctuations and precipitation during 1996–2013



In general, the trend of precipitation and groundwater level shows a positive correlation.

Fig. 2: Groundwater flow pattern in northern Punjab



Source: CGWB, 2007

Map not to scale

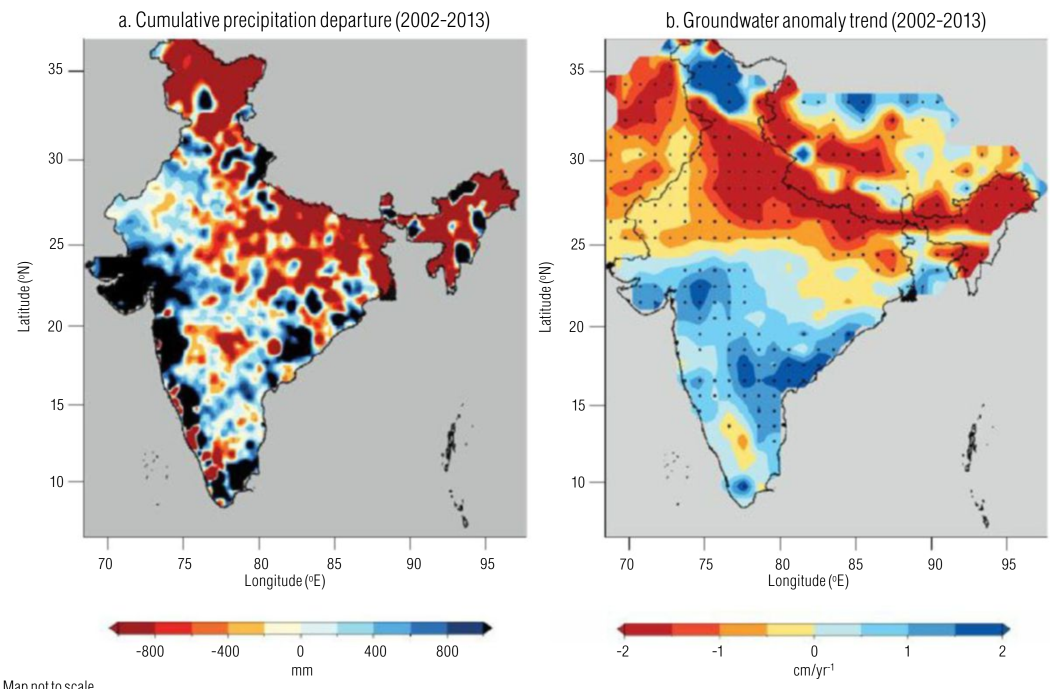
Groundwater flows from northeast to southwest following higher levels to lower level contours. Siwalik Hills act as regional zone for the groundwater recharge.

is complicated because of several parameters such as population growth, changes in land-use, agricultural practices and vegetation cover, recharge measures, developments of dams, reservoirs and canal structures, inter-basin water transfer, changing rainfall pattern and climate change etc. Of these, climate change indirectly affects the groundwater resource. The change in climate modifies the rainfall and temperature pattern influencing surface water sources and food productivity, which in turn affects the groundwater recharge/withdrawal pattern having a bearing upon the groundwater resource.

Annual deficit leading to falling groundwater levels and excess balance leading to rising groundwater levels requires management measures to avert risk of drying groundwater resource and water logging problem, respectively. Aquifers in the hard-rock regions usually have low permeability and poor regional inter-connectivity. Thus in these aquifers, local recharge or withdrawal takes a long time to adjust with regional groundwater levels. Therefore, the local groundwater level

Rainfall and temperature affect surface water and food productivity in a changing climatic scenario.

Fig. 3 a & b: Cumulative precipitation departure and groundwater anomaly trend during 2002-2013 using GRACE data



Source: Asoka et al 2017

GRACE data shows a decline in precipitation over northern India is positively correlated with groundwater decline.

Installation and collection of data using data loggers.

contours may develop mounds and depressions, more prominently compared to alluvial aquifers. At global scale, changes in the distribution can also be detected by satellite based measurement on changing mass distribution around the planet. This is available from the Gravity Recovery and Climate Experiment (GRACE) satellite data since 2002, which provided immense information on the depletion rate of groundwater over northern India (Rodell et al., 2009), California (Famiglietti, et al. 2011) and in other parts of the world.

The decline in rainfall can also affect the groundwater storage as observed by Asoka et al (2016) who reported a decline of 2 cm yr-1 due to substantial reductions in precipitation in north India. Researchers have found that the decline in precipitation in monsoon season over the Gangetic Plain resulted in increased frequency and intensity of droughts and this significantly contributed towards enhanced abstraction of groundwater simultaneously reducing recharge of groundwater (Fig. 3 a and b).

The groundwater crisis is making several countries to develop comprehensive management plans. In recent years, focus is also on transboundary aquifers which connect and pass groundwater from a country to its neighbouring country located in the downstream (MacDonald et al., 2016). These transboundary aquifers are managed by international laws or through the transboundary groundwater sharing treaty developed on the basis of data and through dialogue and communication between the countries.

Endnote

The fluctuating level of groundwater over the years should be regularly monitored with a more in-depth analysis done to pool long-term groundwater levels and their correlations with rainfall and climatic cycles. A proper mathematical analysis should be used to get the trends due to natural and anthropogenic effects. The futuristic models extend the resultant time series by incorporating various dimensions such as population growth, economic reforms, changing rainfall and temperature pattern etc. over the required time scales. Based on such models, suitable steps can be taken up to recoup, use and manage the groundwater aquifers. It is further recommended that the sectors working on water resource should consider the establishment of rainfall recording equipment close to the water level monitoring recorders. This would enhance the reliability of the correlation between rainfall and water level fluctuations. Groundwater level records contain important information on the long-term behaviour of aquifers that have not been studied in any great detail, but could provide valuable information in future that will be beneficial to the managers of the national water resources.

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Water and Employment

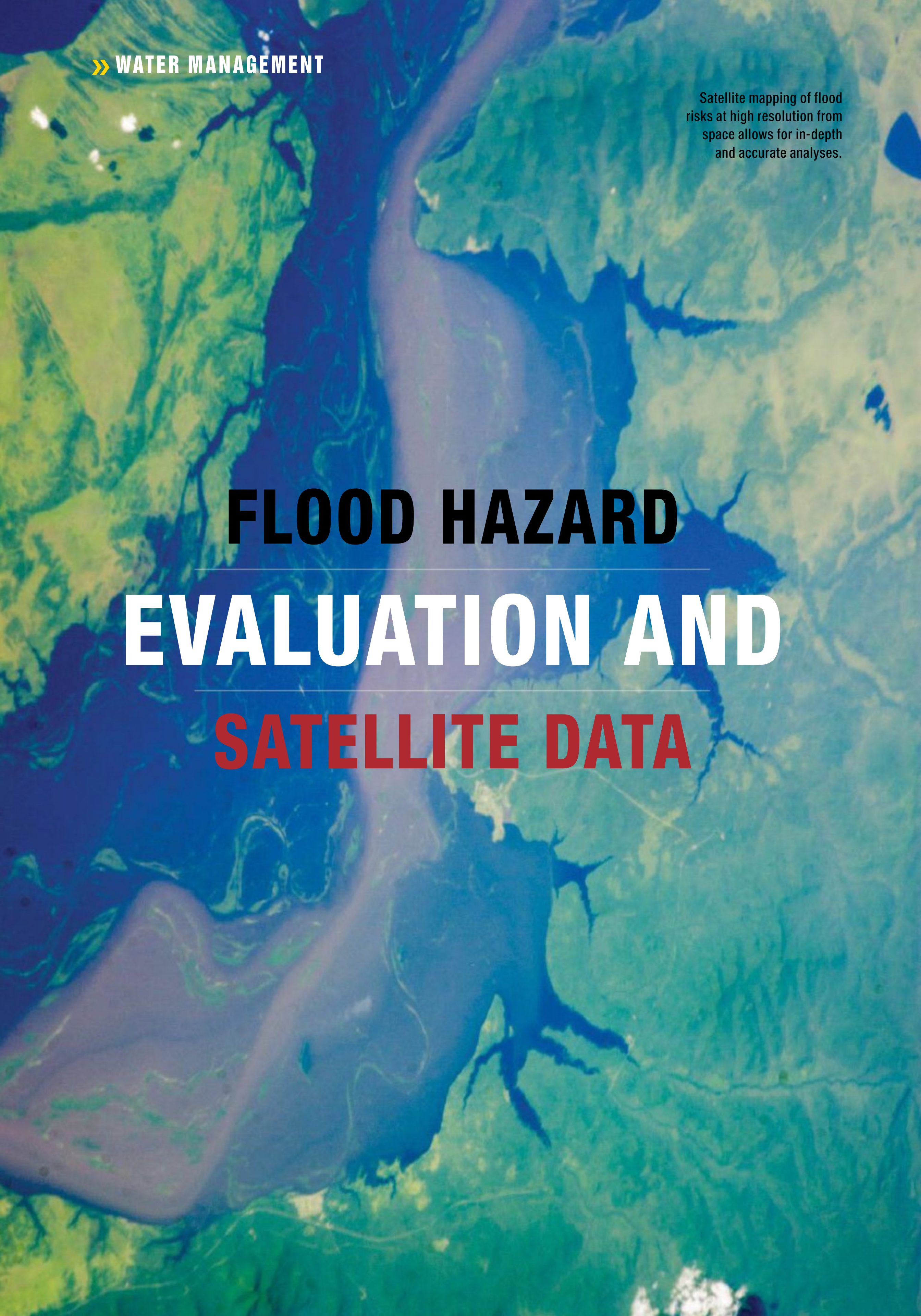
The United Nations World Water Development Report 2016 talks about the little explored interlinkage between water and employment. The Report shows how many jobs in the global workforce depend on water and how water stress and the lack of decent work can add to security challenges. The underlying core message is about the importance of water interlinked through various dimensions of working lives of human beings and the need to preserve, protect and rehabilitate water resources.

According to the Report, over one billion jobs, representing more than 40 per cent of the world's total active workforce, are heavily water-dependent. Another billion jobs, representing over one third of the world's total active workforce are likely to be moderately water-dependent. This implies that about 80 per cent of the global workforce is dependent upon having access to an adequate supply of water and water-related services that includes sanitation as well. As such, jobs in the water sectors themselves comprising of integrated water resources management, ecosystem restoration and remediation, management of water infrastructure and the provision of water-related services such as water supply, sewerage and waste management help to create an enabling environment for the creation and maintenance of decent jobs across most other sectors of the global economy.

Water scarcity can tacitly trigger other work-related aspects. For example, India is one of the countries where wages are highly sensitive to rainfall shocks. Droughts that last longer may lead to persistent unemployment leading to migration as a coping strategy, particularly so if off-farm employment opportunities are absent or meagre. One of the purposes within the Mahatma Gandhi National Rural Employment Guarantee Act and the wage employment programme in India was to arrest such movement of people from rural areas by providing productive green jobs to 52.5 million households in 2009 and 2010.

These few examples point towards the inescapability of taking water and its management seriously for the well-being of humankind.

Excerpts from the United Nations World Water Development Report 2016, Water and Jobs.



Satellite mapping of flood risks at high resolution from space allows for in-depth and accurate analyses.

FLOOD HAZARD EVALUATION AND SATELLITE DATA

By **P MANJUSREE** AND **G SRINIVASA RAO**

Flood hazard zonation is one of the most important non-structural measures, facilitating appropriate regulation and development of floodplains and thereby reducing the flood impact. Satellite remote sensing data have the capability to 'provide comprehensive, synoptic and multitemporal coverage of large areas in near real time and at frequent intervals' over the flood-affected regions.

Floods are the most common and widespread among all natural disasters in India and more prominent in the Brahmaputra and Ganga basins which include the states of Assam, Bihar, Uttar Pradesh and West Bengal. Floods also hit the states of Odisha, Andhra Pradesh, Maharashtra, Gujarat and Telangana. About 40 million ha of area in our country is flood prone, according to the National Flood Commission. Floods cause damage to crops, public utilities, industries and property resulting in huge losses in financial terms besides disrupting of telecommunications network and transport network. If the losses are to be minimised, it is imperative to take necessary long and short term measures encompassing prediction, prevention, warning, monitoring and relief. Various structural and non-structural measures have been adopted by the Central and State Governments and considerable protection has been provided to the people. However, there is a need to put in place a techno-legal regime to make structures flood-proof and regulate the activities in the floodplains of the rivers. Flood hazard zonation is one of the most important non-structural measures, facilitating appropriate regulation and development of floodplains and thereby reducing the flood impact. A flood hazard map is considered as a preliminary, yet necessary input for all regional development policies. Flood hazard maps help the administrators and planners to identify areas of risk and prioritise their mitigation efforts.

Satellite remote sensing-based approaches offer quick and cost-effective information on the spatial extent of flood inundated areas for different

PHOTO COURTESY: NASA

magnitudes of floods and flood mitigation activities (Liu and Liu, 2002, Bhatt, Rao, Manjushree and Bhanumurthy, 2010). Since the advent of remote sensing technology, satellite images because of their capability to 'provide comprehensive, synoptic and multitemporal coverage of large areas in near real time and at frequent intervals' of the flood-affected regions, have become an integral part of flood disaster management (Roy, Bhanumurthy, Murthy and Chand, 2008).

> **Satellite-based information can assess severity of the flood damage to provide disaster footprints of higher accuracy.**

Satellite-based mapping and flood hazards

Flood hazard zonation assessment broadly involves data preparation of satellite images, geometric correction of satellite images, delineation of flood inundation layer using algorithms, generation of annual flood inundation layer, calculation frequency of flood inundation, estimation of intra-annual flood variations using flood peaks, computation of flood hazard index and finally integration with administrative boundaries to compute flood hazard statistics, generation of district-wise flood hazard zonation maps and identification of villages in various hazard categories.

The first satellite based Flood Hazard Atlas was prepared for Assam and released by Government of Assam during the year 2011 (Indian Space Research Organisation, Undated). Multi-temporal satellite images acquired in optical and microwave spectrum regions from satellites IRS-1C, 1D, RESOURCESAT-1A &2A, RISAT-1 and RADARSAT-1&2 capturing flood events from 1998 to 2010 were analysed. The frequently flooded villages in the state of Assam, the flood hazard severity in different districts based on flood hazard category, flood hazard area and intra-annual flood variations were generated. In addition, the Atlas was updated during 2016 using about 215 satellite datasets acquired during floods at different magnitudes, spanning last 18 years from 1998 to 2015.

Further, Flood Hazard Atlas for Bihar was released during 2013 by the Government of Bihar (Bihar State Disaster Management Authority, Undated.) and the severity of flood hazard in Bihar is assessed using 128 decadal historical satellite images acquired at different flood magnitudes from 1998 to 2010. The satellite-based observations have been analysed in conjunction with the hydrological data for assessing the frequency of inundation as well as severity of flood hazard and cropped land. The spatial distribution of flooding is investigated, and a systematic flood hazard database is created, which can be analysed from a spatial dimension in GIS.

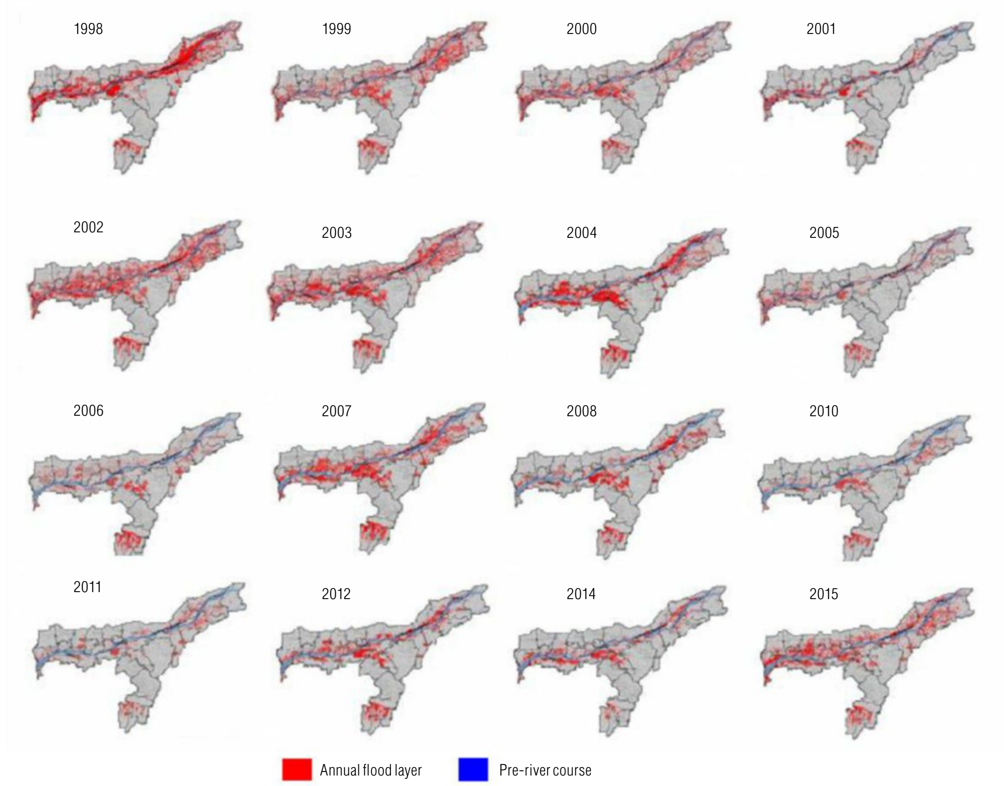
In addition, the information on flood hazard is also generated for the flood prone states of Odisha and Uttar Pradesh using satellite data. All the hazard information can be viewed on ISRO Geoportal called "Bhuvan" (National Remote Sensing Centre, Undated).

Assessment of flood risks

From the satellite data analysis, it is estimated that about 28.75 per cent (22.54 lakh ha) of land in Assam state is affected by flood during 1998-2015 and about 1.55 lakh ha of land falls under high (inundated 13-15 times) to very high (inundated 16-18 times) category where floods are hazardous. It is observed that about a maximum of 14.58 lakh ha of cropped area is under various categories of flood hazard. Out of which about 1.10 lakh ha of land falls under very high to high flood hazard zones. Figure 1 shows the annual flood inundation layers of Assam draped over a terrain image for the years 1998 to 2015.

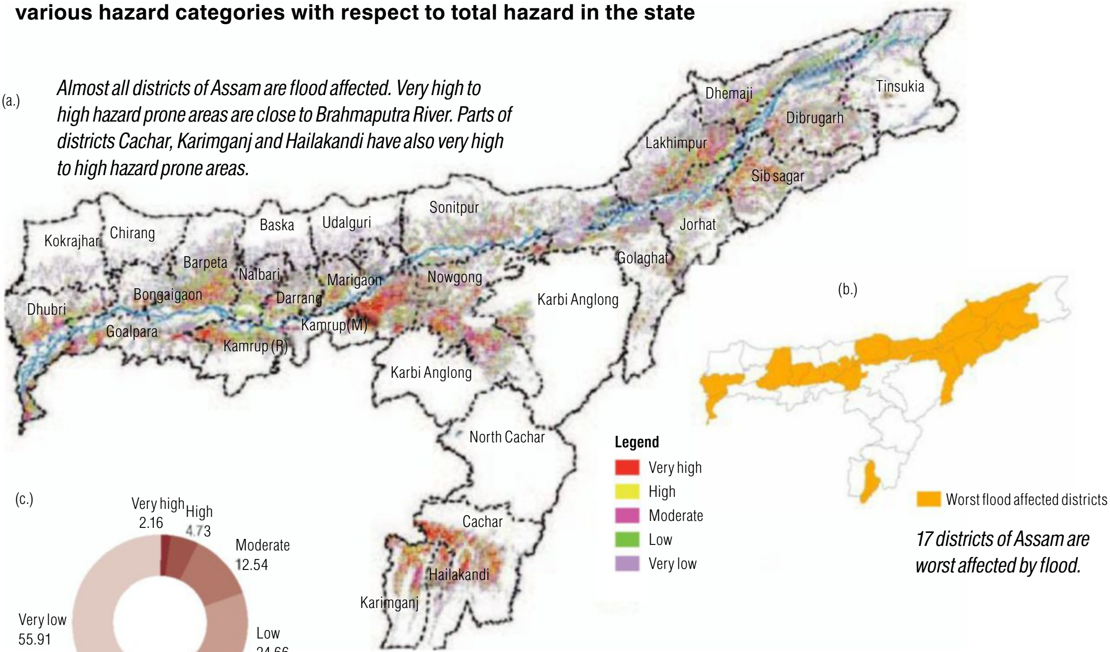
Figure 2(a) shows the flood hazard map for Assam. Marigaon, Dhemaji, Darrang, Sibsagar, Charaideo, Sonitpur, Biswanath, Dhubri, South Salamara, Kamrup, Jorhat, Lakhimpur, Barpeta,

Fig. 1: Annual flood layers of Assam draped over a terrain image for the years 1998 to 2015



Flood patterns are oscillating in Assam with many parts getting regularly inundated each year during 1998 – 2015. About 1.55 lakh ha of lands in Assam is under high to very high flood risk.

Fig. 2: (a) Flood hazard map of Assam (b) Worst 17 flood affected districts in Assam (c) Percentage of various hazard categories with respect to total hazard in the state

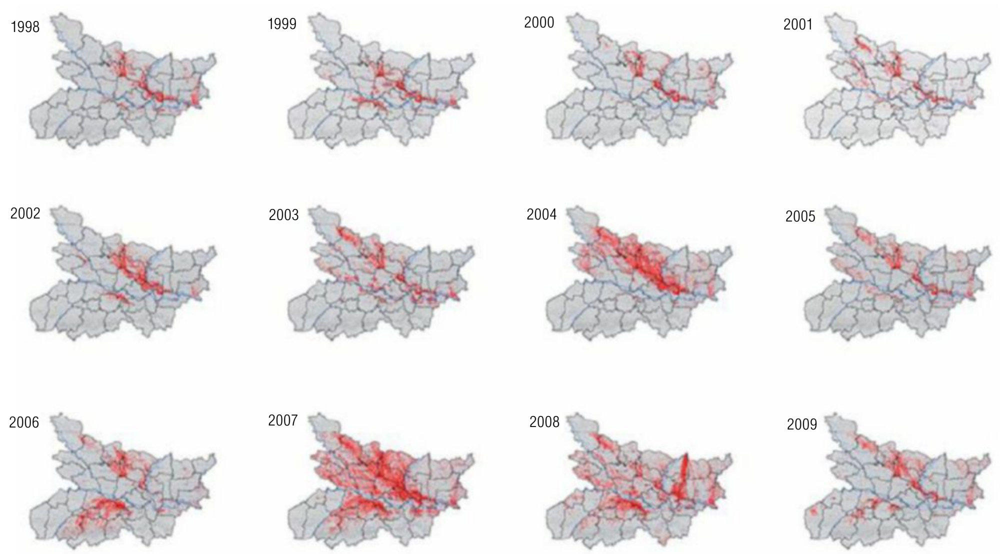


Almost all districts of Assam are flood affected. Very high to high hazard prone areas are close to Brahmaputra River. Parts of districts Cachar, Karimganj and Hailakandi have also very high to high hazard prone areas.

17 districts of Assam are worst affected by flood.

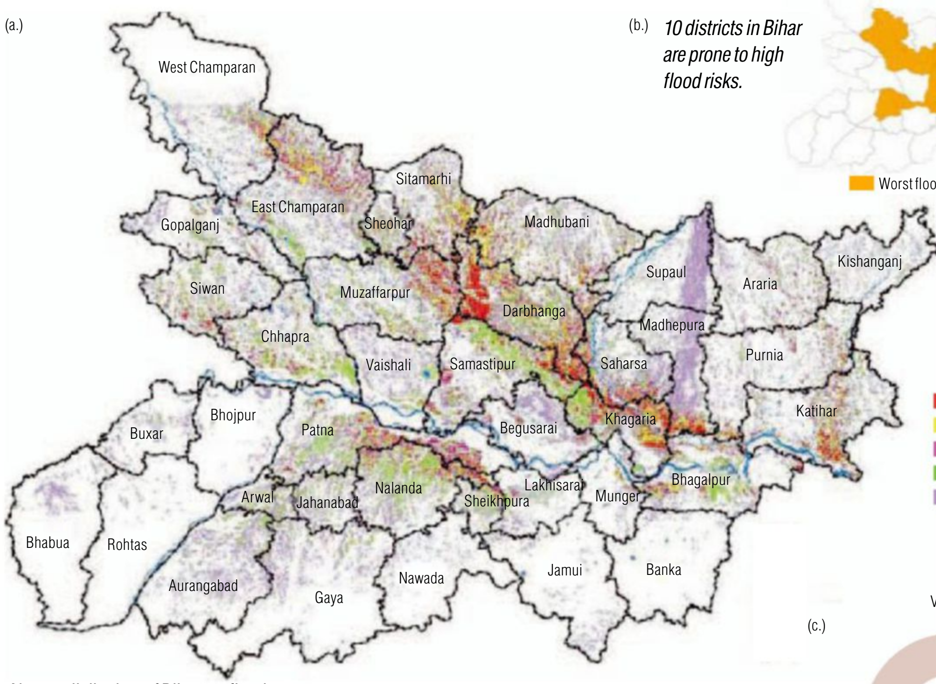
About 7 per cent land falls in very high and high categories. 80 per cent of land falls in low to very low and rest 13 per cent into moderate category.

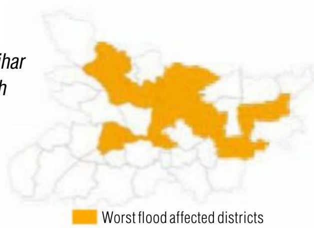
Figure 3: Annual flood layers of Bihar draped over a terrain image for the years 1998 to 2009



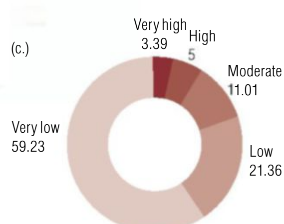
Flood patterns shows that worst flood affected years were 2007 and 2004. About 2.05 lakh ha of land comes under very high to high flood hazard zones in Bihar.

Figure 4: (a) Flood hazard map of Bihar (b) 10 Worst flood affected districts in Bihar (c) Percentage of various hazard categories with respect to total hazard in the state





Almost all districts of Bihar are flood prone. Very high to high flood prone area are concentrated in districts of East Champaran, Darbhanga, Muzaffarpur, Saharsa, Sitamarhi, Madhubani and Khagaria.



About 8 per cent land falls in very high and high categories. 81 percent of land falls in low to very low and rest 12 per cent into moderate category.

Dibrugarh, Golaghat and Hailakandi districts are the 17 worst flood affected districts in Assam as shown in Figure 2(b); the graphical distribution of area under different hazard categories is shown in Figure 2(c).

Figure 3 shows the annual flood layers of Bihar draped over a terrain image for the years 1998 to 2009. In Bihar, it is observed that about 26.09 per cent (24.56 lakh ha) of land is affected by flood during 1998-2009 out of the total state geographical area of 94.16 lakh ha.

Out of total 24.56 lakh ha of flood affected area, about 0.83 lakh ha of land fall under very high flood hazard category, 1.24 lakh ha under high, about 2.70 lakh ha is under moderate flood hazard category, whereas 5.24 lakh ha under low hazard and about 14.56 lakh ha under very low flood hazard as shown in Figure 4 (c). It is observed that out of 24.56 lakh ha of the state's flood affected area, about 15.85 lakh ha of the cropped area are vulnerable to flood hazard.

The ten districts of Bihar that are more vulnerable to flooding are Darbhanga, Khagaria, Samastipur, Muzaffarpur, East Champaran, Patna, Madhubani, Saharsa, Bhagalpur and Purnia as shown in Figure 4 (b).

Endnote

Satellite-based flood inundation information have become a very important input for assessing the severity of the flood situation and flood damage and remains a rich source of information that can provide disaster footprints of higher accuracy and useful for taking up flood mitigation activities. Using the flood hazard information it is possible to carry out the flood vulnerability and risk analysis using the multi-hierarchical decision support tools. With Geo-spatial technologies encompassing Remote Sensing (RS), Geographic information System (GIS), Web technologies, GPS etc, it is possible to minimize the vulnerability to floods and the consequent loss to lives, livelihood systems, property and damage to infrastructure, so as to build a safer India.

Acknowledgement

The author would like to thank the guidance provided by Director and Associate Director, NRSC. The encouragement provided by DD (RSA), NRSC is duly acknowledged. The author would like to thank the Scientists of DMS Group for their support.

The first satellite based flood atlas was prepared for Assam in 2011.

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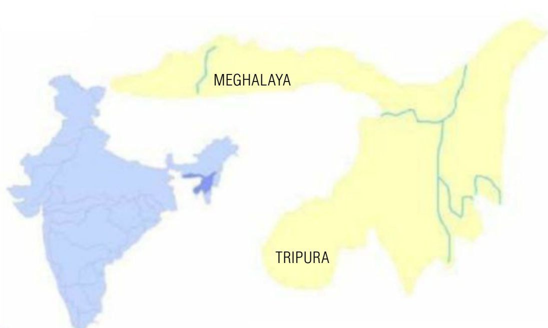
RIVER **BASINS** OF INDIA

2a Ganga
Origin: *Gangotri glacier*
Total Length: *2,525 km*
States: *Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal*
Falls in: *Bay of Bengal*
Principal tributaries: *Yamuna, Chambal, Banas, Kali Sindh, Parbati, Sind, Betwa, Dhasan, Keri, Gomati, Sarda, Ghaghara, Gandak, Son, Damodar and Hooghly, Ramganga and Mahananda*
Few valleys: *Chambal, Doon, Tons and Valley of Flowers*

1 Indus (within India)
Origin: *Around Mansarover Lake*
Total Length: *1114 km in India (2880 km)*
State: *Jammu and Kashmir*
Falls in: *Arabian Sea*
Principal tributaries: *Shyok, Jhelum, Chenab, Ravi, Beas, Satluj and Ghagghar*
Few valleys: *Bangus, Betaab, Gurais, Lidder, Baspa, Bhakra Nangal, Chamba, Karsog, Sangla, Nubra and Zanskar*

2b Brahmaputra
Origin: *North from Kailash ranges just south of the lake Konggyu Tsho*
Total Length: *2,900 km (916 km in India)*
States: *Assam and Arunachal Pradesh*
Fall in: *Bay of Bengal*
Principal tributaries: *Lohit, Dibang, Subansiri, Jiabharali, Dhansiri, Manas, Torsa, Sankosh, Teesta ,Burhidihing, Desang, Dikhow, Dhansiri, and Kopili*
Few valleys: *Dibang and Yumthang*

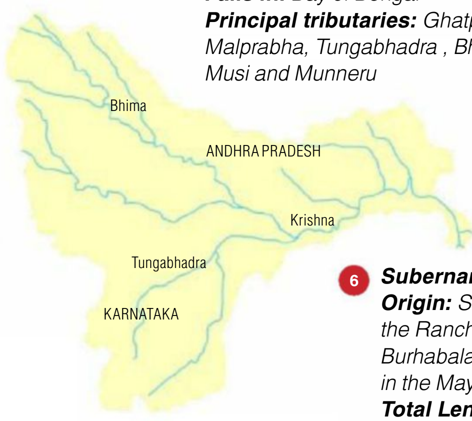


2c Barak and others

Origin: *South of Mao in Senapati district of Manipur*
Total Length: *564 km in India*
States: *Barak-Manipur, Mizoram and Assam*
Fall in: *Bay of Bengal*
Principal tributaries: *Jiri, Chiri, Modhura, Jatinga, Harang, Kalain, Gumra Dhaleswari, Singla, Longai, Sonai and Katakhal*

3 Godavari

Origin: *Trimbakeshwar in the Nashik district of Maharashtra*
Total Length: *1,465 km*
States: *Maharashtra, Telangana*
Falls in: *Bay of Bengal*
Principal tributaries: *Pravara, Manjra, Purna, Penganga, Wardha, Wainganga, Indravati and Kolab*



4 Krishna

Origin: *Jor Village of Satara district of Maharashtra*
Total Length: *1,400 km*
States: *Maharashtra, Karnataka, Telangna and Andhra Pradesh*
Falls in: *Bay of Bengal*
Principal tributaries: *Ghatprabha, Malprabha, Tungabhadra , Bhima, Musi and Munneru*

6 Subernarekha & Burhabalang

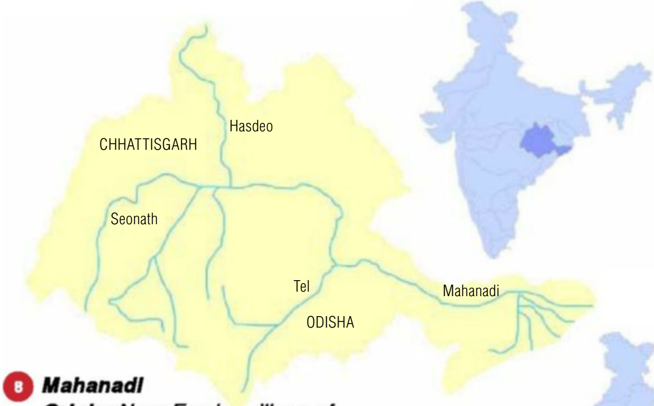
Origin: *Subernarekha - Nagri village in the Ranchi District of Jharkhand*
Burhabalang - South of Similipal village in the Mayurbhanj district of Odisha
Total Length: *Subernarekha - 395 km, Burhabalang - 164 km*
States: *Subernarekha - Jharkhand, Odisha and West Bengal*
Burhabalang - Odisha
Falls in: *Bay of Bengal*
Principal tributaries: *Subernarekha - Kanchi, Karkari and Kharkai*

5 Cauvery

Origin: *Talakaveri on the Brahmagiri range near Cherangala village of Kodagu district of Karnataka*
Total Length: *800 km*
Falls in: *Bay of Bengal*
States: *Karnataka and Tamil Nadu*
Principal tributaries: *Harangi, Hemavati, Shimsha, Arkavati, Lakshmantirtha, Kabbani, Suvarnavati, Bhavani, Noyil and Amaravati*

7 Brahmani-Baitarni

Origin: *Brahmani - Nagri village in the Ranchi District of Jharkhand, Baitarni - Dumuria village in the hill ranges of Kendujhar district of Odisha*
Total Length: *Brahmani - 799 km, Baitarni - 355 km*
States: Brahmani- *Jharkhand, Chattisgarh and Odisha,*
Baitarni - *Jharkhand and Odisha*
Falls in: *Bay of Bengal*
Principal tributaries: *Brahmani - Karo, Sankh and Tikra Baitarni - Salandi and Matai*



8 Mahanadi
Origin: *Near Farsiya village of Dhamtari district of Chhattisgarh*
Total Length: *851 km*
States: *Chhattisgarh and Odisha*
Falls in: *Bay of Bengal*
Principal tributaries: *Seonath, Hasdeo, Mand, Ib ,Ong, Tel and Jonk*

9 Pennar
Origin: *Chenna Kasava hill of the Nandidurg range, in Chikkaballapura district of Karnataka*
Total Length: *597 km*
States: *Karnataka and Andhra Pradesh*
Falls in: *Bay of Bengal*
Principal tributaries: *Jayamangali, Kunderu, Sagileru, Chiravati, Papagni and Cheyyeru*

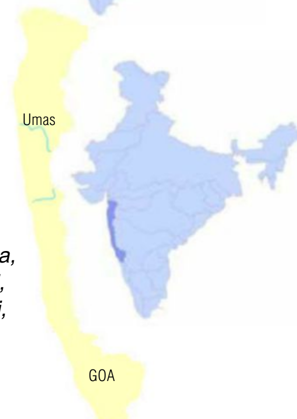
10 Mahi
Origin: *Near village Bhopawar, Sardarpur tehsil in Dhar district of Madhya Pradesh*
Total Length: *583 km*
States: *Madhya Pradesh, Rajasthan and Gujarat*
Falls in: *Arabian Sea*
Principal tributaries: *Som, Anas and Panam*

11 Sabarmati
Origin: *Near village Tepur in Udaipur district of Rajasthan*
Total Length: *371 km*
States: *Rajasthan and Gujarat*
Falls in: *Arabian Sea*
Principal tributaries: *Wakal, Hathmati, Vatrak and Sei*

13 Tapi
Origin: *Near Multai reserve forest in Betul district of Madhya Pradesh*
Total Length: *724 km*
States: *Maharashtra, Madhya Pradesh and Gujarat*
Falls in: *Arabian Sea*
Principal tributaries: *Suki, Gomai, Arunavati, Aner, Vaghur, Amravati, Buray, Panjhra, Bori, Girna, Purna, Mona and Sipna*

12 Narmada
Origin: *Maikala range near Amarkantak in Anuppur district of Madhya Pradesh*
Total Length: *1,312 km*
States: *Madhya Pradesh, Maharashtra and Gujarat*
Falls in: *Arabian Sea*
Principal tributaries: *Burhner, Banjar, Sher, Shakkar, Dudhi, Tawa, Ganjal, Kundi, Goi, Karjan, Tendoni, Barna, Kolar, Man, Uri, Hatni and Orsang*

14 West Flowing Rivers from Tapi to Tadri
Many rivers in the basin do not meet into one forming a major stream
Falls in: *Arabian Sea*
Independent Rivers: *Purna, Ambika, Damanganga, Vaitarna, Ulhas, Amba, Savitri, Vashishti, Kajvi, Vaghotan, Gad, Mandavi, Kalinadi, Gangavali and Tadri*



15 West Flowing Rivers from Tadri to Kanyakumari

Many rivers in the basin, but they do not meet and a major stream is not formed.

Falls in: *Arabian Sea*

Independent Rivers: *Varahi, Netravati, Payaswani, Valapattanam, Chaliyar, Kadalundi, Bharathapuzha, Periyar, Muvattupula, Minachil, Pamba, Achankovil, Kallada and Vamanapuram*

16 East Flowing Rivers between Mahanadi and Pennar

This has three river systems: *1) river systems between Mahanadi and Godavari 2) river systems between Krishna and Pennar and 3) a small area between Godavari and Krishna drained mainly by the small stream of Palleru*

Fall in: *Bay of Bengal*

Independent Rivers: *Rushikulya, Bahuda, Vamsadhara, Nagavali, Sarada, Varaha, Tandava, Eluru, Gundlakamma, Musi, Paleru and Manneru*

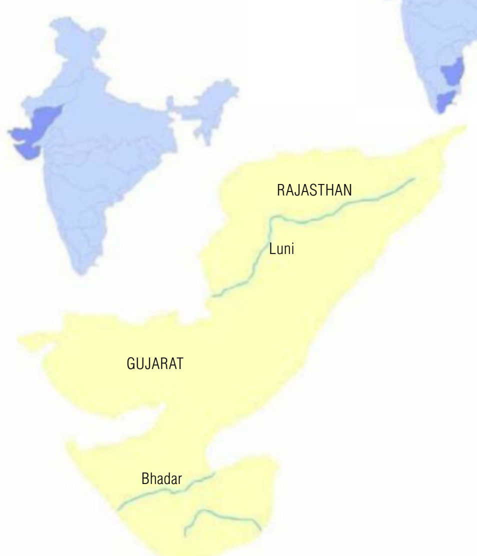
Valley: *Araku*

17 East Flowing Rivers between Pennar & Kanyakumari

This has two river systems: *1) River system between Pennar and Cauvery and 2) between Cauvery and Kanyakumari*

Fall in: *Bay of Bengal*

Independent Rivers: *Kandleru, Swarnamukhi, Arani, Korttalaiyar, Cooum, Adyar, Palar, Gingee, Ponnaiyar, Vellar, Varshalei, Vaigai, Gundar, Vaippar and Tambraparni*



18 West Flowing Rivers of Kutch and Saurashtra including Luni

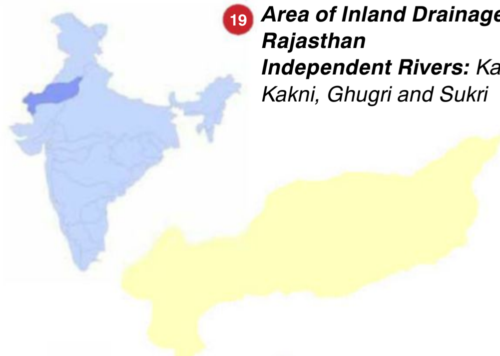
Origin: *Luni is the major river system of the basin, originates from western slopes of the Aravalli ranges, in Ajmer district of Rajasthan*

Total Length: *511 km*

Fall in: *Arabian Sea*

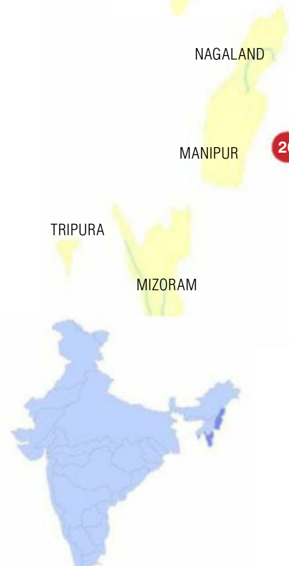
Principal tributaries: *Luni - Lilri, Guhiya, Bandi, Sukri, Jawai, Khari Bandi, Sukri Bandi, Sagi and Jojri*

Independent Rivers: *Shetrunji, Bhadar, Machhu, Rupen, Saraswati and Banas*



19 Area of Inland Drainage in Rajasthan

Independent Rivers: *Kantu, Kakni, Ghugri and Sukri*



20 Minor Rivers draining into Myanmar (Burma) and Bangladesh

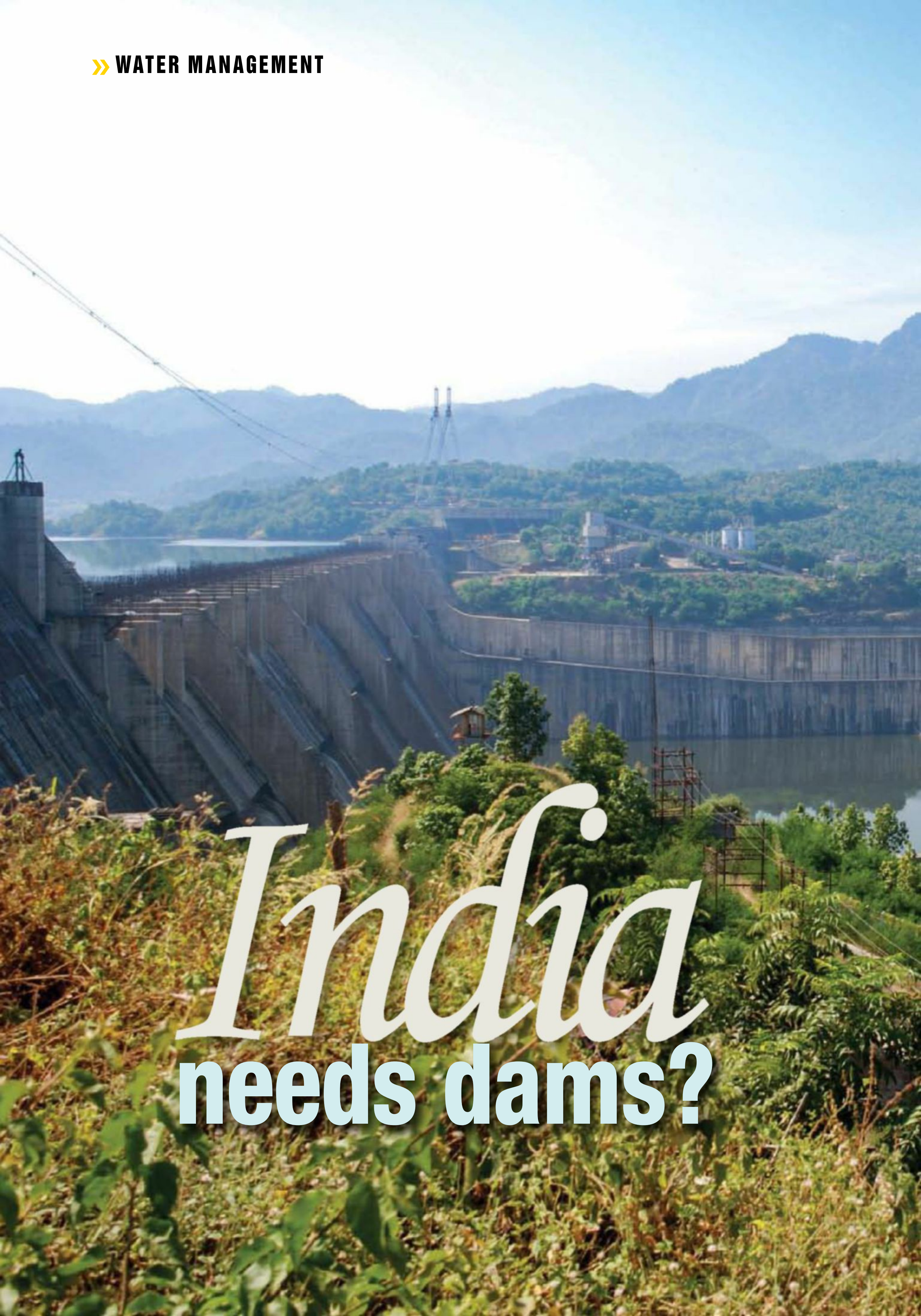
Origin: *Major river Imphal originates from Kangpokpi in Senapati district of Manipur*

Total Length: *511 km*

States: *Imphal River - Manipur*

Falls in: *Chindwin river system of Myanmar*

Principal tributaries: *Iril, Khuga and Chakpi*



India needs dams?

Sardar Sarovar dam has been controversial and its potential to do good has been contested by many.

PHOTO: PRASAD

By **SHARAD K JAIN**

Dams are an important component of water resource development, particularly needed for a country like India. However, these are to be constructed and managed in such a way that the adverse impacts are minimised.

A dam, a barrier built across a river to impound and regulate water, serves three main functions. The first is to store water in the reservoir behind the dam to even out fluctuations in river flow and match the availability with demand. The second function of a dam is to create a hydraulic head of water (difference in height between the water surface in reservoir and the river downstream) in the reservoir—used to generate hydroelectric energy. Due to this gravitational head, water can also flow to cropping areas by canals. Thirdly, dams also protect population, infrastructure and property from flood damages as they temporarily hold high flows within the reservoirs, which are gradually released after the high flow period is over.

Due to the large size, the dam projects are capital intensive—they require huge amounts of money, manpower, land and other resources. Dams significantly impact the environment, population and economy of the region in which they are constructed. Moreover, once the dams are in place, it is not easy to undo or partially offset their harmful impacts. After construction, the benefits that can be reaped largely depend upon how well the dams are operated. Due to these reasons, it is necessary that dams are planned and constructed with utmost care.

The International Commission on Large Dams (ICOLD, undated) has details of the world's large dams. The Asian continent accounts for nearly two-thirds of dams all over the world and China has built most of them.

Why do we need dams in India?

We need dams for many reasons. In India, rainfall occurs only in a few monsoon months (June to September) and that too in a few spells of heavy rains. Therefore, unless a sizable portion of flow, generated from rainfall in this short period, is stored, water cannot be utilised for various beneficial purposes over the rest of the year and will go waste. Reservoir water is also sent to faraway places which do not have another water source. At the same time, large river flows may also cause flood damage on their way to the sea. Clearly, conservation of water entails storing it when the availability exceeds the demand and using it when the situation reverses. Water conservation is also one of the guiding principles enshrined in India's National Water Policy. Thus, it is important for India to create as much storage space as feasible so that adequate quantity of water can be conserved and converted into utilisable resource.

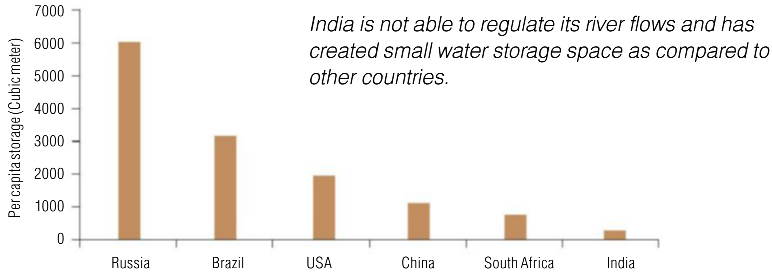
Further, mighty rivers flowing over steep mountain slopes can be harnessed to generate hydroelectric power. Hydropower is a clean source of renewable energy since the fuel is free and no greenhouse gas is emitted. Indians dams have contributed in generating cheap hydropower and the current installed capacity is about 30,000 MW (Central Electricity Authority, 2017). This is only about 35 per cent of India's hydropower potential and thus very large portion remains unutilised.

From the Figure 1, it can be immediately noticed that India has created a small storage space as compared to other countries of similar characteristics. Precipitation is far more evenly distributed in many countries compared to India, but despite this, such countries have a higher ability to regulate stream flows. With varied topographic, climatic, demographic and agricultural settings, India needs more ability to regulate rivers to combat recurrent floods and droughts. Keeping in view the temporal variability of surface water availability, a Committee of the Planning Commission has estimated the required live storage capacity for the country at about 450 BCM (Planning Commission, 2009). However, significant enhancement of water storage capacity appears to be progressively difficult in view of great opposition to dams on various grounds.

Figure 2 shows the storage capacity of reservoirs in selected river basins in India in terms of the number of days with average flows that can be stored. For example, the value of 220 for Tapi river means that mean flow of 200 days can be stored in the reservoirs in Tapi basin. It can be seen that in the Colorado Basin (USA), reservoirs can store mean flow of about 2.5 years (Jain, Agrawal, and Singh; 2007). Clearly, the storage capacity in Indian River basins is much smaller compared to many basins in other countries.

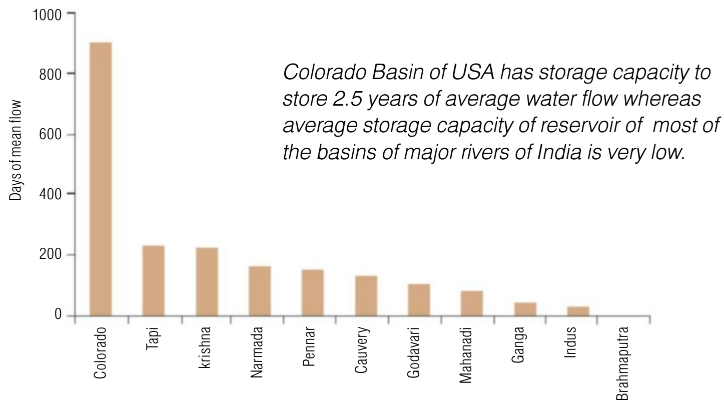
More than 80 per cent of annual flows in rivers in India takes place during the monsoon months which is also the period when floods cause damages. Many Indian reservoirs are operated for flood management. For instance, the Hirakud

Fig. 1: Per capita reservoir storage space in selected countries of the world.



Source: Jain, Agrawal and Singh, 2007

Fig. 2: Number of days of average flows that can be stored in reservoirs in selected river basins in India; the data for Colorado River is for comparison



Dam on Mahanadi River has considerably mitigated floods in fertile Mahanadi delta. A series of dams in the Damodar Valley have substantially controlled flood menace in the Damodar Basin and Bhakra Dam has largely controlled floods in Satluj River. Surat, a prosperous town in Gujarat used to suffer recurrently from floods which are now moderated by the Ukai Dam. Floods in many rivers are moderated by the storage space available behind dams.

Dam engineering in India

South Asia has a long history of dam building. At the turn of twentieth century, there were 42 dams in India. During 1901 to 1950, about 250 dams were added. After independence, there was a spurt in dam construction activity and about 700 dams were constructed, bringing the total number of dams to nearly 1000 by the year 1970. The dam building further intensified during the next two decades and at the end of 1990, the total number of Indian dams crossed 3000. Due to slow economic growth and other reasons, only about 115 dams could be added in the next 15 years (Jain, Agrawal, and Singh; 2007). Currently India has more than 4500 large dams. It is noted that with the passage of time, the dams are aging and their maintenance and rehabilitation need attention.

There are large regional disparities in development of storage dams in the country. In Satluj, Beas, Ravi in north-west, Krishna, Pennar and Cauvery in south and Mahi, Tapi and Sabarmati, more than 80 per cent of the water potential is already developed. However, the tributaries of Brahmaputra and Barak have less than 2 per cent of storage potential. On the tributaries of Ganga, Yamuna, Mahanadi, and Lower Godavari, less than 30 per cent storage potential has been developed so far. There is no large storage project on

View of construction and spillway in Chamera dam, Himachal Pradesh.

Ghaghra, Gandak, and Kosi rivers which have huge water as well as hydro-power potential in India and Nepal. Among the states, Andhra Pradesh, Madhya Pradesh and Maharashtra have created large storage capacity to utilise water resources.

The irrigation potential developed from surface and ground water sources through major, medium and minor irrigation schemes is over 100 mha whereas the ultimate irrigation potential is 140 mha. The actual utilisation is about 80 mha. Impressive progress in creating irrigation facilities along with other inputs has contributed in tremendous increase in agricultural products and making India self sufficient in foodgrains. In fact, in the recent past, India has exported considerable quantities of foodgrains and other agricultural products.

Dams: Boon or Bane

Public opinion about dams is sharply and intensely divided. Many people believe that dams are an essential component of water resources development, particularly for India. Dams including Bhakra, Chambal, Ujjani, Tungabhadra, Nagarjuna Sagar, Hirakud, Almatti and Tehri provide water to irrigate crops and are essential for food security. Bhakra, Pong, Srisailam, Tehri, and Balimela generate electricity at very low price. Super thermal power stations in Uttar Pradesh depend on storage of Rihand reservoir for their water supply. A large part of water supply of Mumbai, Pune, Hyderabad, Bhopal, and Warangal cities depends on reservoirs such as Vaitarana, Tansa, Bhatsa, Khadakwasla, Panchet, Majira, Singur, Kolar and Sriramsagar respectively. Sardar Sarovar Dam is a mighty water resources project under construction. Worldwide, dams generate one-sixth of world's electricity and irrigate one-seventh of food crops. They also help control floods. In many places, dams have helped rejuvenate ecosystems.

In contrast, a section of the society views the dams as evils. One of the reasons behind the opposition is displacement of population. Dams in India have flooded land areas ten times the size of Haryana. According to the author's estimate, Indian dams have displaced population which is about the same as that of West Bengal (about 90 million). Many of the displaced people have not got timely and adequate compensation and were subjected to great hardships. Submergence of forest and agriculture land, historical monuments and eco-sensitive areas by dams/reservoirs is another reason that dams are opposed. Construction of dams also causes fragmentation of rivers which means that the movement of aquatic life and sediments is hampered. Due to this, the environment and biodiversity suffers and dams pose a threat to freshwater ecosystem by extinction of species.

It is noted that any water resources development activity will impact environment. However, water resources have to be developed to meet the water, food, energy, and other needs of the society. There is a trade-off between development and conservation and each country needs to find the appropriate course of action looking at the demand and supply of resources.

Views of world commission on dams

The World Commission on Dams (WCD) was constituted in 1997 to examine environmental, social and economic impacts of large dam globally. In their report submitted in 2001, the WCD concluded that dams have made an important and significant contribution to human development and benefits from them have been considerable. At the same time, in too many cases an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms by people displaced, by communities downstream and by taxpayers and by environment. Lack of equity in distribution of benefits has called into question value of many dams in meeting water and energy development needs when compared with alternatives. WCD felt that conditions for a positive resolution of competing interests and conflicts can be created by bringing to table all whose rights are involved and who bear risks associated with different options for water and development of energy resources. Negotiating outcomes will greatly improve development effectiveness of water and energy projects by eliminating unfavourable projects early and by offering as a choice only those options that key stakeholders agree as the best ones.

More than 80 per cent of annual flows in rivers takes place during monsoon-a period when floods cause most damages.

Endnote

In view of the climate, geographic location and topographic conditions, India needs to create enough storage space so that the rivers can be regulated to conserve and manage our water resources to meet the needs of the society. Of course, we also need to protect our environment. Thus, a proper balance between water resources development and conservation of biodiversity and environment needs to be ensured.

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Cauvery dispute can be traced to a colonial past which continues to torment the riparian states even today.

PHOTO: GNA

IN *Quest* OF COOPERATION

INTER-STATE RIVER WATER CONFLICTS IN INDIA

By **NINA SINGH**

The threat of scarcity, distribution and quality of water, a finite, natural resource, has made its relationship with conflict. This is an area of continued interest and debate in both the policy literature and popular press.

River basins seem to be the natural units for dealing with issues of water sharing, investment and management. However, they have been the focus of conflict rather than cooperation in India. Constructing efficient and equitable mechanisms for allocating river flows thus has long been an important issue. Why are the states, particularly the neighbouring ones, in conflict with each other? What is the nature of interstate river water disputes? Why do the disputes remain intractable? Is there any way forward? We may explore answers to some of these questions.

Conflicting tendency of Indian states

Complex in their anatomy and articulation, interstate water disputes have their roots in the origin and making of India's democratic and federal structure. In addition, some of these disputes are a manifestation of the reproduction of colonial and imperial power relations (D'Souza, 2006; Chokkakula, 2012). For instance, incorporation of the historical agreements of 1892 and 1933 between the erstwhile states of Hyderabad, a princely state and Madras - a British presidency, was one of the ways of internalising the colonial power relation, leading to the Krishna river water dispute. The Cauvery dispute, which has seen violence erupt in Karnataka and its spread to Tamil Nadu, too inherited similar historical conditions.

The pre-independence story of creation of the states may also give an insight into the conflicting tendency of Indian states (Krishan, 2000). The provinces of British India were not shaped by any rational planning but 'by the military, political or administrative exigencies or conveniences of the moment' (Government of India, 1918).Very often heterogeneity was created to discourage the sentiment of provincial solidarity. For instance, the Madras province—a conglomerate of Tamil, Telugu, Kannada and Malayalam speaking areas, was one such unwieldy administrative entity formed without regard to its internal linguistic, cultural, economic and physical unity.

It is seen that the linguistic reorganisation of the states in India has given rise to a number of inter-state water disputes owing to new states succeeding the parties to the previous agreements. A noted example is the dispute between Punjab and Haryana for allocation of Ravi-Beas waters. The distribution of its waters between Jammu and Kashmir, Rajasthan, and composite Punjab were effected through an inter-state agreement in 1955. In 1966, Punjab was reorganised on linguistic grounds and Haryana was formed. Under the Indus Waters Treaty with Pakistan, surplus waters of the Ravi and Beas rivers became available in 1970 for utilisation in India. Haryana claims a share of these surplus waters which Punjab is disputing. Thus it can be seen that politicisation of interstate water disputes in India is inevitable fallout of the historical and structural conditions that obtained at the time of forming the Indian union (Chokkakula, 2014).

The root cause of conflicts: increasing demand of water

The conflicts arise when the demand of the co-riparian states exceed what is available in the rivers in the lean season. India may not be among the most water-stressed countries of the world, but the national aggregates and averages could be misleading as freshwater is a very unevenly distributed natural resource, both temporally and spatially. Timely water supply for agricultural uses and regular and all-season non-agricultural water requirements are to be met. Also, both drinking and industrial water needs are growing along with the increase in urbanisation and population growth. When several states are jointly dependent on the same river system, disputes among the states regarding allocation and utilisation of interstate river waters are common in a federal set-up, particularly when large areas of the country are relatively arid.

Federal mechanisms and nature of inter-state disputes

Many disputes involve large river basins. The major contentious issues relate to validity, interpretation and implementation of agreements made prior to or after reorganisation of states on linguistic basis. Arguments over prior appropriation and equitable apportionment, as has been the case with Krishna and Godavari basins, riparian rights of a lower vis-à-vis an upper co-basin utilisation of Cauvery water or vice-versa and inter-state utilisation of untapped surplus water along Krishna-Godavari basin are some of the examples. Other cases, to name a few, include the intrusion of newer competing use in Rihand sub-basin of Sone basin, inequitable operation of common facilities at control points in Yamuna and Chambal basins and seismic risk and safety of Tehri dam.

A large number of states—Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh, Odisha, Kerala, Karnataka, and Tamil Nadu are engulfed in such issues. Disputes that have been referred to Tribunals relate to Krishna, Godavari, Narmada, Cauvery, Indus (the Ravi-Beas waters) basins. No agreement has also been the outcome in several major disputes e.g., Cauvery and Ravi-Beas. Article 262 of the Constitution and the Water Disputes Act of 1956 as amended in 2002 provide for adjudication, which may be seen as the last resort to find solution to a dispute and which even could be to explore possibilities of an agreed settlement. It finally culminates in an award by the tribunal. However, it has been observed that arbitration by tribunals is not binding. Sometimes even the courts have not succeeded. There have also been instances of direct intervention by the Centre , but that too has not been able to resolve the most intractable cases such as the sharing of the Ravi-Beas waters among Haryana, Jammu and Kashmir, Rajasthan, and Punjab.

It has been observed that one of the essential features of Indian federalism is constant involvement of coalition construction to create a government at the centre. This also means a substantial ground for explicit or implicit 'horse-trading' among the Centre and the states that are important partners of a central coalition. Water could be an important element of bargaining. There have been cases where the Central government has taken very long in appointing tribunals and has dragged on negotiations. Many a times the inter-state water disputes have got entangled with other Centre-State conflicts and further political manoeuvring (Richards and Singh, 2002).

Are disputes intractable?

Does it all mean that the issues cannot be resolved? Two cases may be cited here—that of Cauvery and Ravi-Beas. These are one of the most disputed and litigious rivers in India. The Cauvery dispute has been adjudicated with the notification by the Indian Government at the instance of the Supreme Court through the Cauvery Tribunal's Final Order of February 2007, notified in the official gazette in February 2013. It was merely the culmination of a process of adjudication which began in 1990. Having been resolved only legally, it remains still unresolved as the conflict continues 'in other and different forms' (Iyer, 2013). Karnataka had violated the spirit of federalism by not releasing water to Tamil Nadu in September 2016 even at the intervention of the Apex Court. It contended to give water to Tamil Nadu at its choice and not when it was needed.

> **Interstate water disputes have their roots in India's democratic and federal structure.**

Most recently, the Supreme Court declared that Punjab has gone back on its promise to share the waters of rivers Ravi and Beas through SYL Canal with neighbouring states such as Haryana by unilaterally enacting the controversial Punjab Termination of Water Agreements Act of 2004. It held that a State Legislative Assembly "cannot through legislation do an act in conflict with the judgment of the highest court which has attained finality" (The Hindu, 2016). Such acts have resulted in demands for a review of the norms drawn for sharing of river water under the emerging ground realities (Mangat, 2016).

In these and many other cases, various agreements, accords, tribunals, commissions and water sharing formulas have been worked out from time to time, but the problem still remains unsolved. An unambiguous institutional mechanism for settling inter-state water disputes does not exist. Does it mean that interstate river water disputes are intractable? The answer seems to be in the affirmative as long as politics remains an important and all-pervasive factor in shaping the nature and outcomes of such disputes. The increasing contestation and politicising of issues surrounding water-sharing etc. require focusing on creating institutional spaces for discussion (Chokkakula, 2014).

Way forward

How can interstate water disputes be amicably and efficiently resolved? What types of policy recommendations can one make? There are no easy answers to these questions, but we must continue to explore possibilities of reducing the conflicts if not completely amending them. However, political will to resolve the issue is necessary for any systems to work in its proper perspective.

Beyond politics and difficult posturing by incumbent governments and violence leading to tremendous loss of life and property, long term comprehensive adaptive strategies for basin management are needed in order to protect the livelihoods of millions and the environment (Janakarajan, 2016). For the planning itself to be sustainable, it should be carried out for a larger ecological system of which rivers are a part. The question of how to reconcile the large, centralised, 'top-down', technology driven projects and local, decentralised, community-based, people-centred alternatives need to be adequately addressed. Moreover, the Centre can mull setting upstanding institutional basin-level arrangements for resolution of inter-state river-water disputes, which whether by agreement or adjudication, has not to be a one-time settlement, but a continuous process of conformity to the spirit of the settlement (Iyer, 2011).

Endnote

In an administrative-political context where the institutional framework is weak and regulations are easily circumvented in resolving the inter-state river water conflicts, there is particularly a need for openness, transparency and strong regulatory oversights (Molen and Hildering, 2005). Last, but not the least, universities and research agencies can substantially contribute to the mitigation of water-related conflicts in at least three major ways—acquire, analyse, and coordinate the primary data necessary for good empirical work; identify indicators of future water disputes and/or insecurity in regions most at risk and train future managers in an integrated fashion.

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ACCESS TO TAP WATER

By **STAFF REPORTER**

The profile based on 2011 Census suggests that access to tap water, presumably a safe source, is a distant dream to many as only 44 per cent of population can avail it.

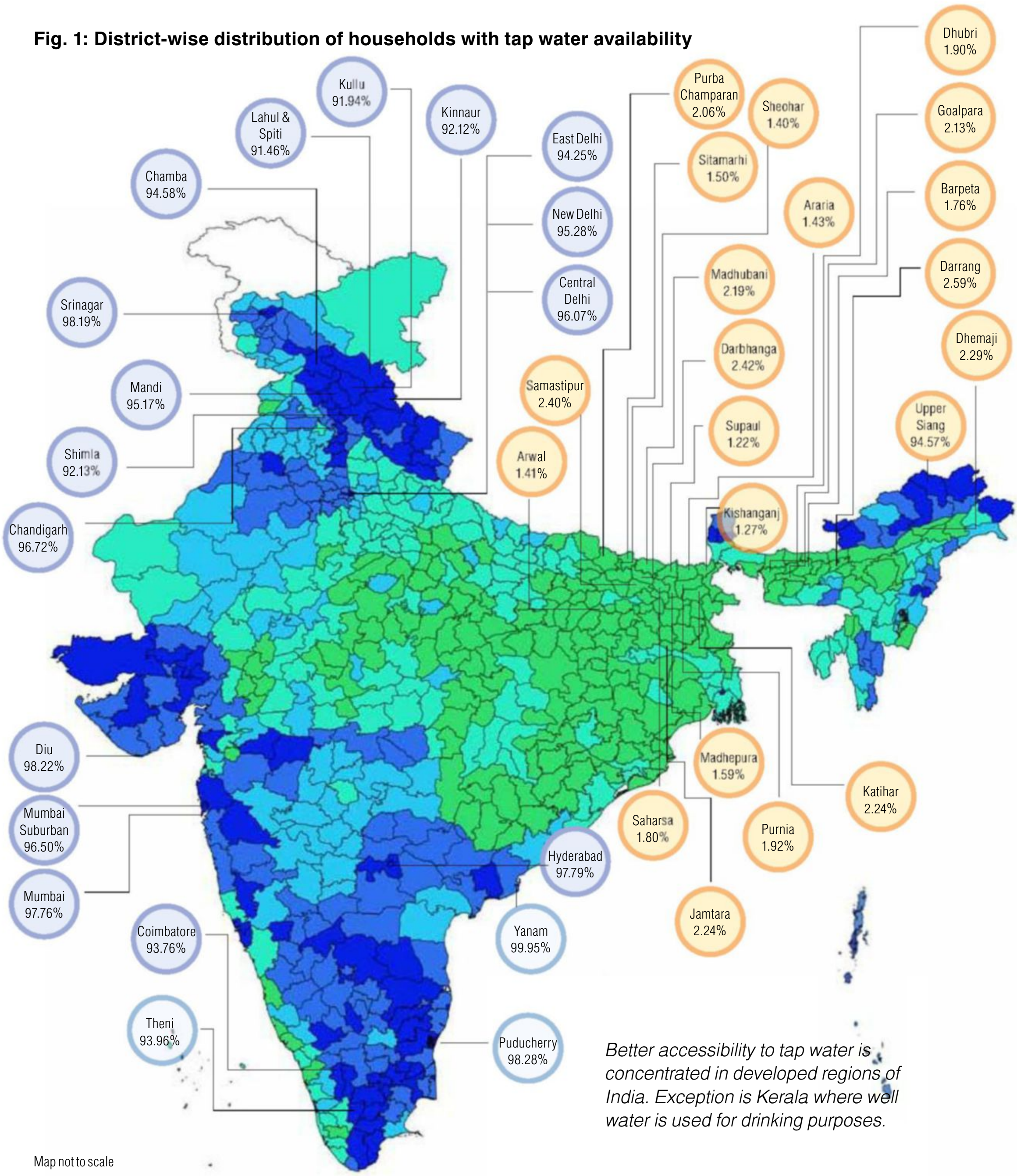
As per the 2011 Population Census, there are 246,740,228 households in India out of which 107,426,831 households which works out to be less than half (44 per cent) have access to tap water. The rest are dependent on water from covered/uncovered well, hand pump, tube well/borehole, spring, river/canal, tank/pond/lake and other sources. From these 44 per cent of the households, about one third (32 per cent) get treated tap water whereas around one tenth get untreated water (12 per cent). It may be pointed out that despite problems related to the safety of tap water, which varies tremendously across the country by cities and small towns, rural-urban locations and developed and developing contexts, the present analysis assumes that tap water is generally safer as compared to other sources. Figure 1 shows the district wise distribution of households having access to tap water.

There are wide variations as far as access to tap water is concerned. Most of the households, about 68 per cent, are located in rural areas out of which only 30.81 per cent households have tap water supplies. Out of these, a little more than half (about 58 per cent) get treated water as compared to those who have to contend with untreated water. As one would expect, the urban situation is much better where around 71 per cent of household have access to tap water; as high as 88 per cent of the urban households are supplied treated tap water.

Tap water availability is not the only problem in India. Even its location may be a cause of concern. Slightly less than one fourth of total households in India (about 38 per cent households having access to tap water) have no direct tap water available within their premises. These households have to fill water from taps available nearby—within a radius of 100 m in urban areas and 500 m in rural areas or away from premises. Once again, about 17 per cent of rural households having access to tap water are dependent on tap water available outside their premises. Nearly one tenth (13 per cent) of these households have tap water near the premises whereas about less than one tenth (3 per cent) of the households have to bring tap water from more than 500 m away. About 17 per cent of the urban households, despite having better access to tap water, are still dependent on tap water available outside their premises.

In an effort to capture the spatial variations, 20 worst and best districts each, were compared (Figure 1). As was expected 14 districts of Bihar, the poorest in terms of tap water accessibility, emerged at the top, followed by five districts of Assam and one of

Fig. 1: District-wise distribution of households with tap water availability



Better accessibility to tap water is concentrated in developed regions of India. Exception is Kerala where well water is used for drinking purposes.

Legend

Percentage of households with tap water accessibility

- No data (1 District)
- 0-20 (200 districts)
- 20-40 (135 districts)
- 40-60 (95 districts)
- 60-80 (117 districts)
- >80 (93 districts)

Top ranking districts · Bottom ranking districts

Fig. 2: Change in access to tap drinking water by location between 2001-2011

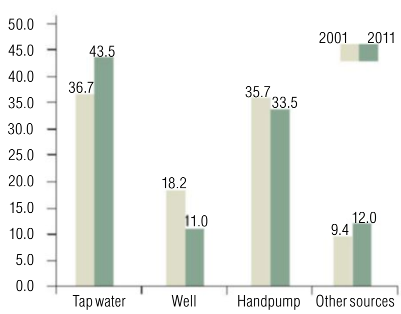
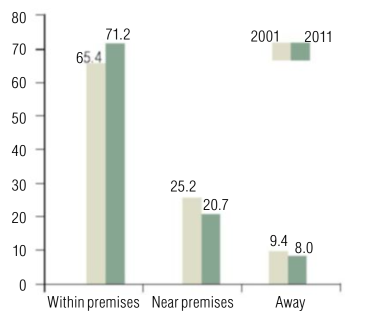


Fig. 3: Change in distribution of main water drinking sources from 2001-2011



Jharkhand. There are total of 9325135 households in these districts, but only about 2 per cent i.e., 180804 households have access to tap water. In contrast there are a total of 6622164 households with tap water availability in the top 20 districts that have better tap water accessibility. Almost every household in these districts (about 96 per cent) have access to tap water. Interestingly only 5 per cent of total households in these districts access tap water from untreated sources.

A comparative analysis of changes in main drinking water source shows that there is an increase of 6.8 per cent from 2001 to 2011 in tap water accessibility in India. Slight change in use of hand pumps can also be noticed with an increase of about 2.2 per cent. It is good to notice that use of drinking water from wells has decreased considerably, about 7.2 per cent (Fig. 2).

Similarly, access to tap water within premises has increased from 65.4 per cent in 2001 to 71.2 per cent in 2011. A reduction of about 4.5 per cent households accessing tap water near the premises has occurred between this period. But only a small decline has occurred in households bringing water away from their premises (Figure 3).

Availability and access to improved source of drinking water is a basic indicator for human development. Safe drinking water has many influence as it reduces diseases and deaths, cuts off the health expenditures, saves money and improves human productivity and quality of life. In India, demand for clean water which is essential, is less than 1 per cent of the total water demand (Das and Mistri, 2014). But as per the report by WaterAid 2016, a not-for-profit outfit, India ranks on top on the list of countries having people without access to safe drinking water followed by China and Nigeria. About 75,777,997 (75.8 million) people i.e. at least 5 per cent of its 1.25 billion population have no access to safe drinking water and annually 140000 children die of diarrhoea. This inaccessibility to safe drinking water can be depicted from the spatial distribution of tap water availability in India as shown in Figure 1. It clearly indicates that the states in the south and west have better tap water accessibility as compared to other regions of India; an overlapping of development status and availability of tap water is indicated whereas developing states such as Assam, Bihar, Chhattisgarh, Jammu and Kashmir, Madhya Pradesh, Rajasthan and Uttar Pradesh have districts with severe shortage of tap water. Kerala is an exception, despite being a developed state in terms of other parameters such as health and social attributes, accessibility to tap water is low and most of the households (62 per cent) use wells for drinking water. One of the possible reasons may be presence of backwaters which makes laying of the water pipes an intricate exercise. Lack of piped tap water in Kerala has also been attributed to sustainability, technology choice and design optimisation resulting in source and system failures (Khambete, 2015).

> Despite **increase** between 2001 to 2011, a majority of people **still** do **not** have **access** to tap water.

Endnote

Despite some increase in access to tap water between 2001 to 2011, a majority of people are still deprived of the basic amenity. A small decline has occurred in households bringing water from near or away from the home premises.

Availability and access to improved source of water is a basic indicator for human development for which India has a long way to go.

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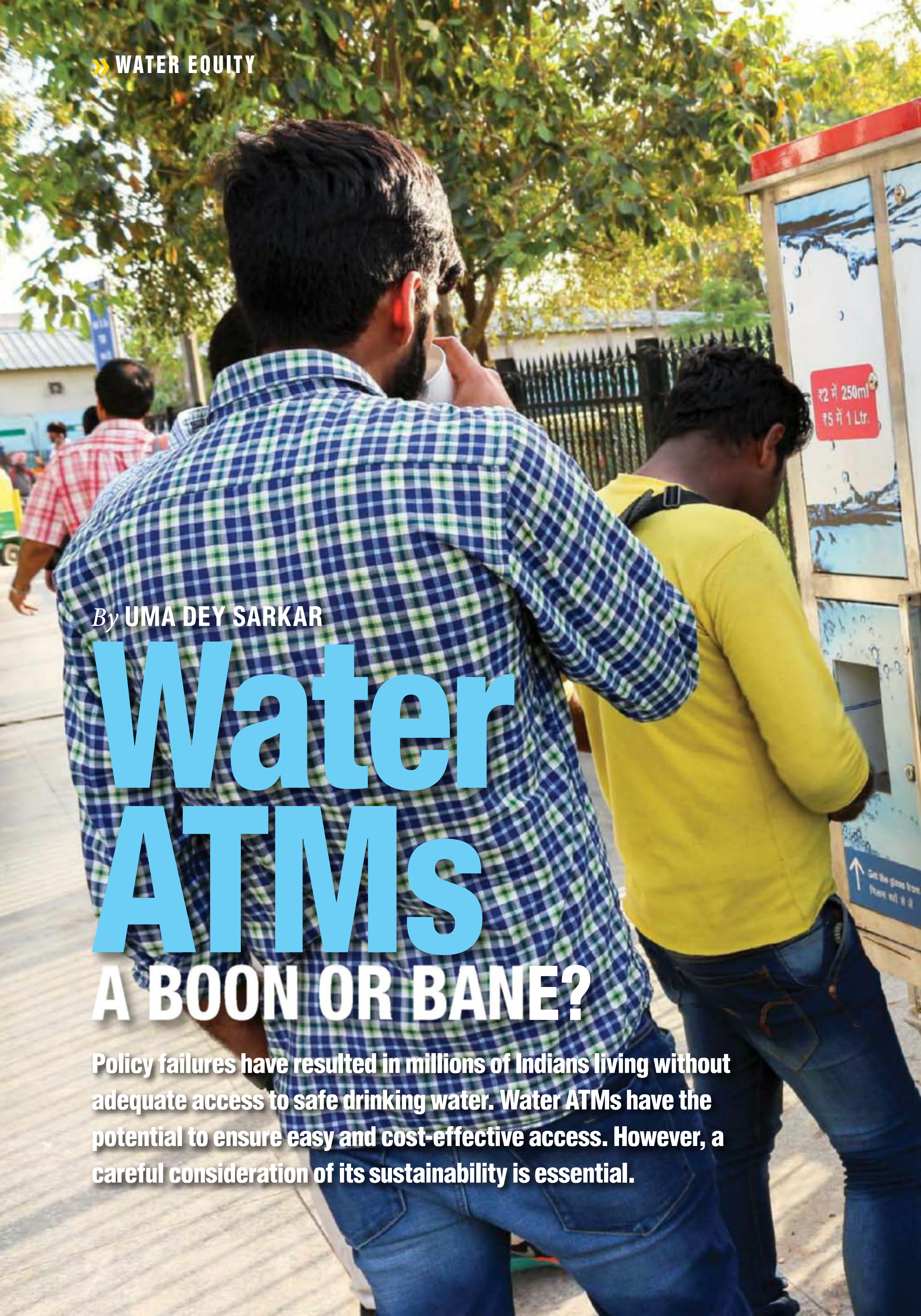

By UMA DEY SARKAR

Water ATMs

A BOON OR BANE?

Policy failures have resulted in millions of Indians living without adequate access to safe drinking water. Water ATMs have the potential to ensure easy and cost-effective access. However, a careful consideration of its sustainability is essential.

Water delivered through paid automated kiosks questions the basic premises of water being a free resource, INA Colony, New Delhi.

PHOTO: PRASAD

Access to safe water is central to living a life of dignity and paves the way for a healthier and better society. As such, the United Nations Committee on Economic, Social and Cultural Rights (UNCESC) adopted the right to water in 2002 (vide General Comment No. 15) in terms of sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses. The United Nations General Assembly has recognised and reaffirmed access to safe water as a basic right and indispensable for realisation of all human rights in the year 2010. Even though access to improved sources of drinking water has increased in India, WaterAid, a non-profit charitable organisation established in 1981, estimates that the country has 75.6 million people without access to clean water which is the highest in the world in terms of absolute numbers (Burgess, 2016). The absence of adequate arrangements by the state for safe and secure access to water has resulted in mushrooming of water vendors in both rural and urban areas of the country. With a focus on fulfilling the Millennium Development Goals and patronage of several organisations such as the World Bank and Asian Development Bank, water ATMs have gained prominence in the past decade as a solution to ensuring safe water in many countries of the global South.

The model of water ATMs in India

Water ATMs are essentially market-based solutions to the problem of insufficient access to drinking water, leveraging the benefit of modern technology and operating mostly on the idea of social entrepreneurship in India. Such ATMs are low-cost, self-contained automated water vending machines that store clean water, ensure access to drinking water at a nominal charge, in the required quantity and at any hour convenient to the consumers. There are several variants of dispensing units such as stand-alone dispensing units, container booths and delivery vans with dispensers. Such wide variety in distribution modes enables such units to function in varied settings, ranging from public spaces (such as railway stations and parks), slums and resettlement colonies to the most remote rural areas without any source of water or electricity.

The vending machines are either fitted with small-scale purification devices using the technology of reverse-osmosis or are regularly filled with water from purification units where more sophisticated technologies such as UV-filtration or silver ionization are used. The water in the vending machines is usually monitored on a 24x7 basis by means of cloud-based systems which detect not just the quality of water being processed, but also monitor the functioning of the devices, thus helping in reducing operational time in case of system failures.

While most ATMs can accept currency coins issued by the Government of India, thrust has been toward exclusive usage of prepaid RFID (radio frequency identification cards, especially in areas where purification and vending units have been established on a permanent basis). There can be more than one card in a family and there are no upper caps in drawing water from the ATMs as long as the cards have the balance. These cards can be topped up at the vending units and give one access to water and credit information when swiped at the water ATMs.

There is no record, even as a rough estimate, as to how many ATMs are functioning in the country. Available figures do not cover all the areas. Moreover, in addition to formally registered ATMs, those which are being operated by religious organisations as in Varanasi, make it further difficult to assess their spread.

One of the crucial differentiating factors of Water ATMs as a model of water vending vis-à-vis other informal water vending mechanisms (such as local packaged water business) is its low coast, while ensuring that the model is financially viable and generates its own revenue. One of the primary means of ensuring that such costs can be maintained at a low level is partnering with business conglomerates who install water ATMs as a part of their corporate social responsibility (CSR) initiatives. Such initiatives abound all over the country e. g., Maruti Suzuki sponsored the setting up of water ATMs in Gurugram with WaterLife being the implementing partner or HDFC Ergo partnering with Piramal Sarvajal to install a water vending machine in Peeth, a small village in Rajasthan (Sarvajal, Undated). In most cases, local bodies have stepped in such as Delhi Jal Board partnering with Piramal Sarvajal to install water ATMs in four resettlement colonies in Delhi or the Government of Rajasthan partnering with Cairn India to provide safe water through vending machines in several villages of Rajasthan. In such cases where local government bodies are involved, the land and water requirements are fulfilled by the local bodies. However, with water business booming and increasing acceptance of water ATMs as one of the modes to access water, smaller firms engaged in the business of water vending machines have been looking for local individuals. They are from communities or localities with inadequate access to water; such individuals can then act as franchisees. This promotes the idea of local stewardship of resources while also ensuring creation of job opportunities and can act as a potentially profitable venture.

Water ATMs are **market-based** solutions to the problem of **insufficient access** to drinking water.

Impact of water ATMs on waterscapes

Water ATMs act as a significant intervention in India's waterscape where clean and safe drinking water is not accessible to the vast majority of the population. While it is still considered a novel idea in the Indian scenario, it has made noteworthy impact in the African states of Kenya, Zambia and Uganda. Water ATMs have the potential of changing the way water affects the lives of millions of people in the country.

In a country where 1.7 million children die of diarrhoea and 37.7 million people are affected by waterborne diseases annually (Khurana and Sen, 2007), it can significantly reduce the burden of diseases. It can also have a positive effect on household income by reducing the time required for water collection which can be utilised for other productive purposes and by reducing out of pocket expenditures on health care. Given that fetching and managing water are primarily considered as women's duties, it can reduce their burden of carrying water and consequent health problems such as prolapsed uterus. Water ATMs can also significantly improve access to safe water in parts of the country where groundwater has high fluoride content such as in northern India or arsenic contamination in eastern India. The relatively low cost of water (approximately INR 0.50 per Litre) and reduction in plastic waste are two factors which give water ATMs an edge over other means of water vending.

While the benefits of such an intervention in the waterscape cannot be denied, it needs careful examination in terms of its capacity to deliver. First is the issue of acceptance of a pay-per-use mechanism for an essential service such as water which has always been a free good and requires behavioural change on the part of consumers. This is particularly difficult for poor and marginalised communities for whom the cumulative cost of such minimal charges may be a burden on their meagre incomes and these are the communities who are most in need of access to safe drinking water and suffer most from water-borne diseases. The household registration for RFID cards for water ATMs operated by Safe Water Network in Telangana ranges from 93 per cent in Pochampally to 18 per cent in Mahabubabad (Safe Water Network, Undated). In Uttar Pradesh, the number of households which have registered for such cards is far less and average around 30 per cent for the three stations that they operate in the western part of the state (Safe Water Network, Undated). Thus, the model is yet to be widely accepted and unless it is more widely accepted, net effect on improving the overall health or income levels in communities would always be suspect. Similarly, another pertinent issue related to registration is the translation of registered users into active users. For some consumers, water from such vending machines is a secondary source of water which is resorted to only when the primary sources (such as water tankers or community taps) fail to deliver. In such cases, off-take may be less and even registration may not result in financial viability of such systems. This is seen in Katrapally (Telangana) where the household registration is as high as 59 per cent yet the operating margin for the company is only 7 per cent. Since such water ATMs are being run by organisations on a for-profit basis, unless the financial viability is secured, the future of such systems are rather uncertain.

Even though water ATMs are considered to be environmental-friendly systems, most purification units which cater to water ATMs usually dispose the waste water either via open drains or is pumped back into aquifers. Since the efficiency of such systems usually range between 50 to 65 per cent, a lot of water is wasted when it is allowed to flow down the drains and in case it is used to recharge the groundwater, it further contaminates the ground water because of excessive TDS (total dissolved solids) in the wastewater (Paliwal, 2013). This ensures that local water aquifers become unsuitable for either drinking or agricultural usage without further treatment and furthers dependence on technology which may not be equally affordable to all in a community.

Importantly, one needs to carefully consider the equity aspects of establishing such systems. Instituting such systems bring about changes in the hydro-social contract wherein the poor and marginalised depending on water ATMs become mere consumers instead of citizens who are entitled to equal service levels as people who are provided with such services by the State. Even though the charges for water ATMs are nominal, per-unit charges are much higher compared to piped water supplied by public utilities. Establishing water ATMs also leads to commodification of water and use of a common property resource such as ground water for profit by corporates. Since there are no legal or regulatory frameworks in which water ATMs are operating at present, they are prone to being (mis)used by other water vendors. It is seen that wherever local bodies have partnered with private entities to establish such kiosks (such as in Bengaluru or Delhi), the land and water is provided free of cost to benefit the poorest. But it is common to see water kiosks selling it to middle-men who resell it at much higher price or other business ventures instead of exclusively focusing on serving the community (Deepika, 2016). Lastly, since water is a basic human right and the State is obliged to arrange for its provisioning, one needs to question the ethical aspect of the state relegating its duties or private entities profiting off a life-giving force.

Endnote

Interventions such as water ATMs are laudable initiatives given that they ensure wider reach of clean and safe drinking water at minimal monetary costs. However, in areas where regular piped-water supplies or community water taps are yet to reach, they should be only treated as a stop-gap arrangement and should not be treated as a replacement of piped water. Regulatory mechanisms should be framed to monitor the establishment and functioning of such ATMs so that environmental externalities (such as increasing salinity of soil due to recharge of wastewater) can be minimised, quality of the water is to be strictly supervised and subsidies (such as free land or water provided by local bodies) need to reach the poorest instead of being siphoned off by middle men. For ensuring that basic rights to water are fulfilled, it is expedient to look beyond water ATMs as a panacea for treating decades of faulty policies which have excluded people from universal access to water to seeing such initiatives for what they are- a merger of the state and corporates to profit off public resources under the guise of "social entrepreneurship"!

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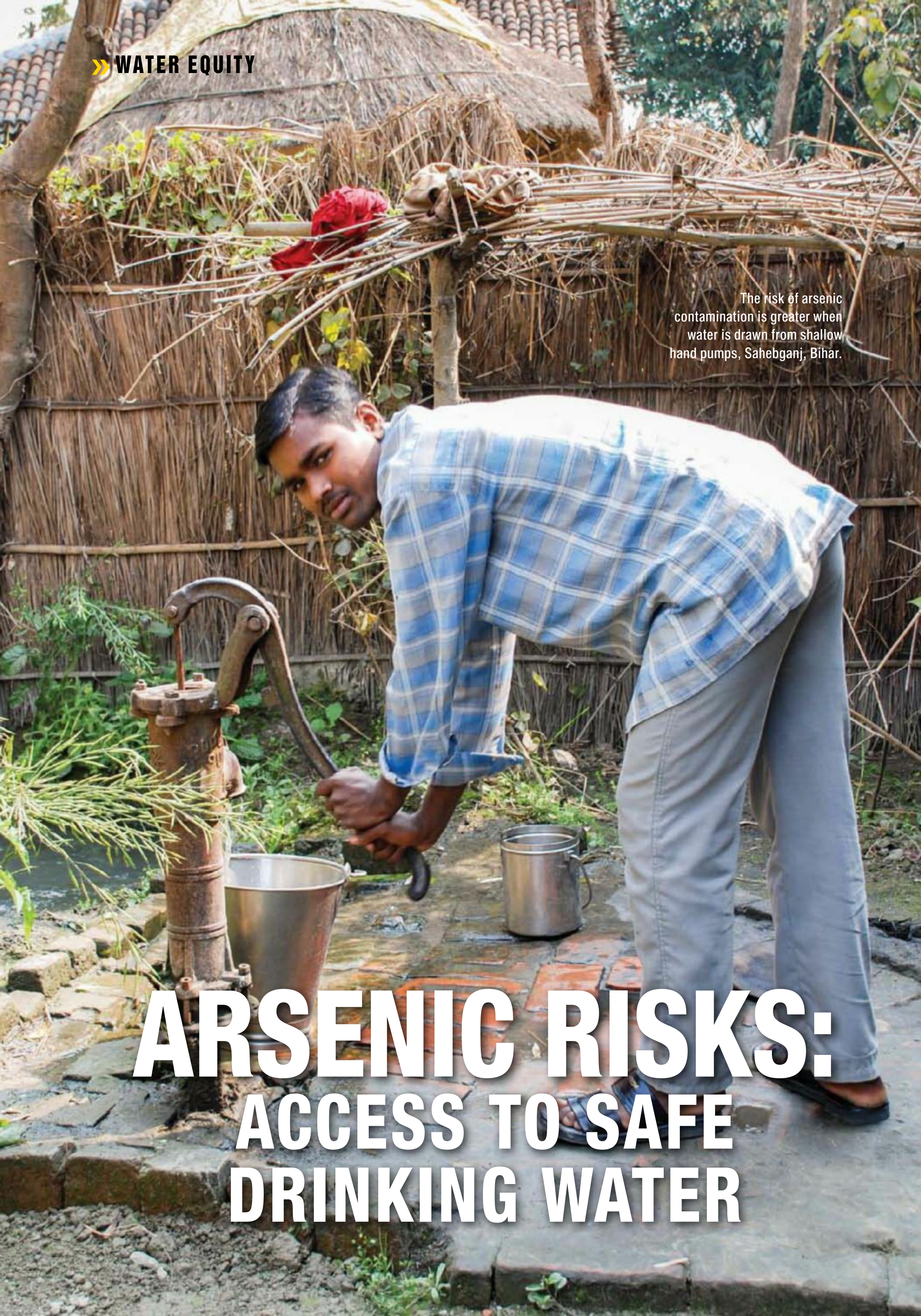

The risk of arsenic contamination is greater when water is drawn from shallow hand pumps, Sahebganj, Bihar.

ARSENIC RISKS:
ACCESS TO SAFE DRINKING WATER

By **MANISH MASKARA** *and* **SAFA FANAIAN**

Groundwater has increasingly been reported to include largely geogenic and anthropogenic contaminants such as iron, bacteria, arsenic, fluoride, nitrates etc. Over the decades, there has been a growing concern about arsenic contamination due to its severe health consequences.

Bangladesh was among the first to identify and initiate its struggle against arsenic although many districts in the Terai region of Nepal, India and Pakistan also have arsenic contamination. It is a complex challenge because it is dangerous even in minute quantities (>10 μgl1) although WHO recommends 10 μgl1 while India and Bangladesh allow up to 50 μgl1. It is neither visible, nor does it affect smell or taste. Further, poisoning symptoms appear overtime and involve complicated testing and diagnosis. In India 86 districts located in Bihar, West Bengal, Assam, Punjab, Karnataka, Haryana, Jharkhand, Uttar Pradesh and parts of Manipur and Chhattisgarh are affected (Fig. 1) (Central Ground Water Board, 2014).

Extent, sources and effects of arsenic contamination

Arsenic contamination is mostly present in shallow aquifers, which results from the holocene aquifers, originating from Himalayan sediments in the fluvial plains of Ganga-Brahmaputra in India. Though arsenic contamination in the Gangetic plain dwindles after a certain depth, it is not always the case for other geographies (Chakraborti et al 2009). Drinking water through shallow tubewells is one of the important pathways along with its entry into human bodies through the food chain (Chaurasia, Mishra and Pandey, 2012; Kundu, Pal and Majumder, 2012).

The population exposed to arsenic in West Bengal is from the lower socioeconomic strata and is prone to liver and cardiovascular diseases as well as skin manifestations in children from exposure to arsenic above 50mg/l in ground water. Incidences also vary with dose and duration of exposure, ethnicity and nutritional status of children. It is shown that the children exposed to arsenic toxicity have lower IQ scores as compared to normal children (Das et al., 2012; Majumdar and Mazumder, 2012). Pigmentation, keratosis, arsenicosis, chronic respiratory disease, liver fibrosis, peripheral vascular disease and cancer are other possibilities (Mazumder et al. 2010). Several studies have also reported of different kinds of arsenical skin lesions from affected villages of Jharkhand, Bihar, Uttar Pradesh and Chhattisgarh.

Response to the problem

Only recently, in March 2017, the Central Ministry of Water Resources, Government of India, has launched a sub-mission for arsenic mitigation. Post the inter-ministerial meeting in 2015, West Bengal, Assam and Bihar have put in place a Master Plan for arsenic mitigation. Other affected states are operating on a 'need-to-do' basis with a provision for water supply through treatment plants.

The Master Plan has short/immediate, medium/intermediary and long-term interventions. The short-term action plan includes mapping of arsenic affected sources, painting contaminated tube wells and setting up of deep tubewells. Medium/intermediate term step involves installing treatment and filtration units. Long-term plans take care of construction and setting up of treatment plants and piped water supply schemes from surface water bodies. The main responsibility for water supply in these affected regions is that of the Public Health and Engineering Department (PHED) under the state government, which is also responsible for

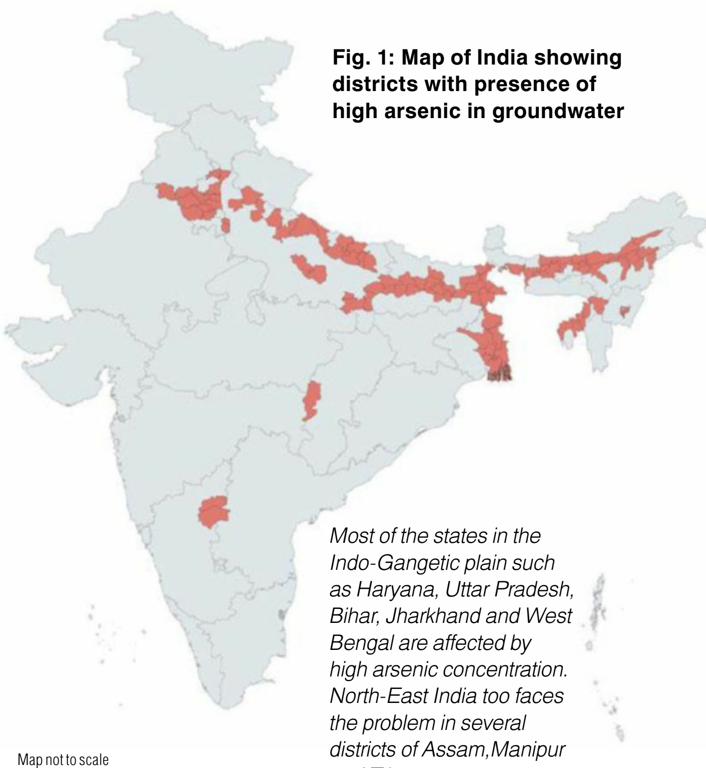

Fig. 1: Map of India showing districts with presence of high arsenic in groundwater

Most of the states in the Indo-Gangetic plain such as Haryana, Uttar Pradesh, Bihar, Jharkhand and West Bengal are affected by high arsenic concentration. North-East India too faces the problem in several districts of Assam, Manipur and Tripura.

Source: SaciWATERs, Hyderabad, India.

maintaining laboratories to test and report the quality of water being supplied to communities. They also carry out various awareness building activities. Central Ground Water Board (CGWB) maps aquifers and identify the contaminated regions. The Board also had budget for awareness and dissemination of these results (Lok Sabha, 2014). It also provides regulation on borewell drilling in the affected regions (Government of India, 2015).

There had been no specific budgetary allocation for arsenic remediation until the setting of recent National Budget (2017). West Bengal, Jharkhand and Bihar now have specific allocation from the centre to address arsenic mitigation. Most of the budgets come from National Rural Drinking Water Programme (NRDWP) of which up to 67 per cent can be utilised for regions suffering from water quality. CGWB under the budgetary allocation for National Aquifer Management Programme has mapped arsenic affected regions;

Civil society organisations (CSO) including NGOs, academics and media have also encouraged technology development, awareness and implementation. The efforts have ranged from promoting filtration options, reverting to traditional water sources, health related interventions, behaviour change programmes and more. Private agencies are also involved through creating and driving filtration technologies through either private-public partnership for supply of safe water at a cost or utilising open market of water purifiers.

These efforts, despite being deliberate and rigorous have not achieved much success in mitigating the arsenic problem partly because of the sectoral conceptualisation, structural limitations, limited understanding of the issue, but largely also because of the circular nature of the 'wicked' problem of arsenic (Fanaian and Biswas, 2016), resulting in unresolved problems of arsenic mitigation.

Addressing arsenic contamination in water through 'network' mode

Arsenic Knowledge and Action Network (AKAN) was formulated in 2013 as an informal network of organisations and individuals across South Asia to develop a holistic ecosystem for accessing safe drinking water through enhancing drivers, filling gaps and curbing deterrents. The network has since expanded to include Assam, West Bengal, Bihar, Uttar Pradesh and Karnataka. The following section highlights a few of the key elements put forward in this direction.

AKAN has held multi-stakeholder consultation and joint workshops to further enhance the understanding and placing of the problem within local contexts and identifying entry points for interventions. This approach is also mandated under the National Rural Drinking Water Policy (NRDWP) guidelines. Below are the experiences from the states:

Assam: Here, the problem of arsenic contamination was conceptualised as an issue of lack of/ ineffective communication between the solvers and bearers of the problem, as various state and district level consultations and deliberations showed. Several new areas of concerns such as the exclusion of local communities from quality testing of water were identified leading to their integration by PHED and health department and local Panchayat in various processes.

Bihar: Identifying gaps in addressing arsenic contamination in Bihar were relatively easier. This enabled a diverse group to collaborate and initiate locally contextualised action in three districts, ranging from awareness and communication to the integrating women Self Help Groups (SHGs). An informal platform for engagement and dialogue with *Jal Choupal* has been endorsed by the Bihar government to address water quality.

In Assam, AKAN engaged the community members with the help of a local team in understanding preferences and alternative sources for access to safe water, leading communities in the villages of Titabar sub-division to clean the ponds and using pond water for drinking purposes in addition to having piped water connection to their villages. AKAN's constant endeavour has been to converge its efforts with existing programmes at different levels.

Endnote

Arsenic contamination is assuming grave proportion in states of Bihar, West Bengal, Assam, Punjab, Karnataka, Haryana, Jharkhand, Uttar Pradesh and parts of Manipur and Chhattisgarh. There has been multi-stake efforts of which AKAN has been an important partner to create enduring solutions for living with arsenic. The core approach allows for priorities to be laid out and followed depending on local and regional contexts. Dealing with arsenic contamination requires active participation of the community, government and civil society organisations without undue emphasis on technological interventions only. While this approach is not free from its share of challenges, it is suggestive of a holistic model to address arsenic contamination.

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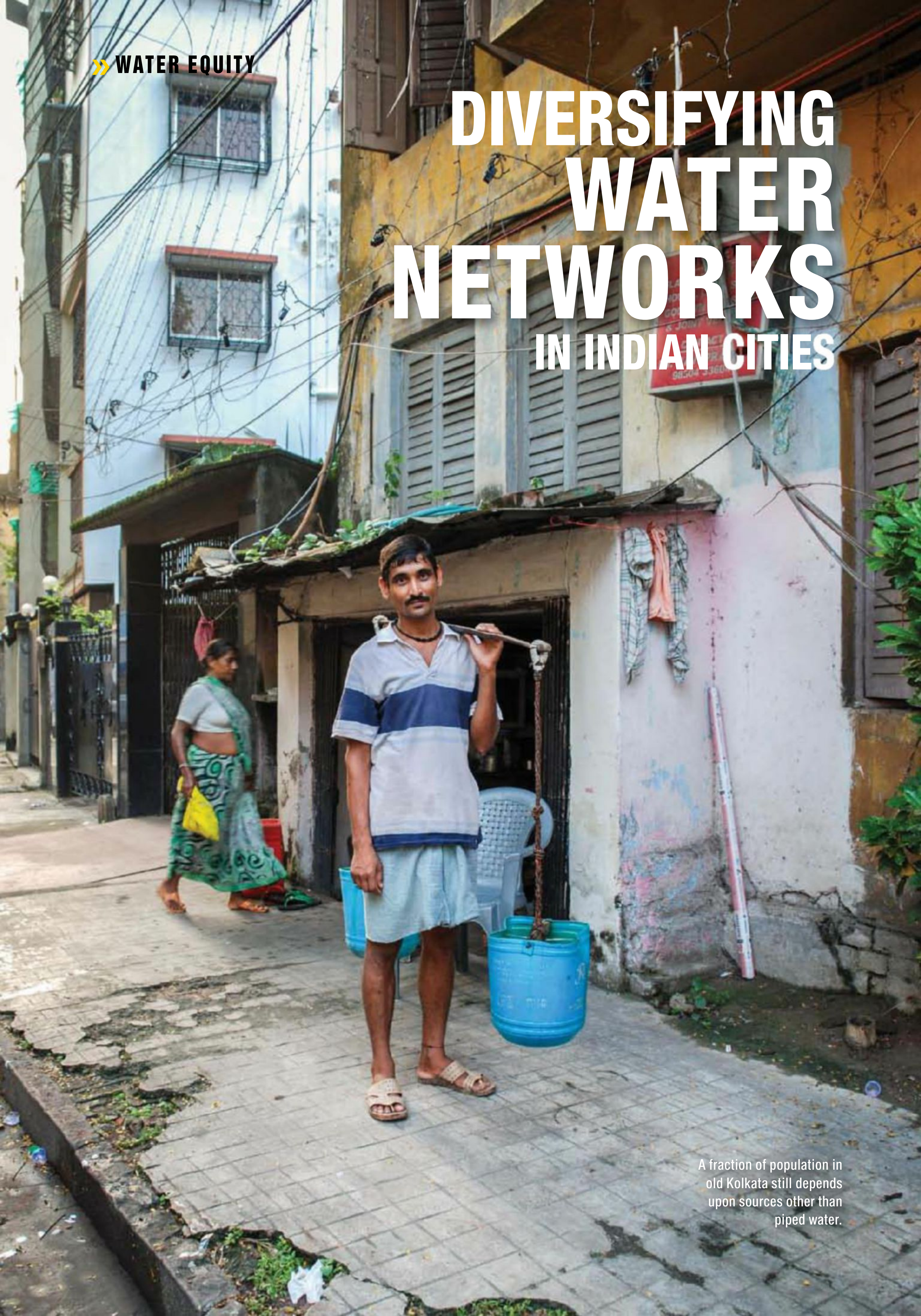
DIVERSIFYING WATER NETWORKS IN INDIAN CITIES



A fraction of population in old Kolkata still depends upon sources other than piped water.

By **GOPA SAMANTA**

Management of drinking water has become a debatable issue and India is no exception. The centralised piped network introduced in British India has continued post-independence as the only model of water supply in cities. There is thus a link between the current water crisis in cities and lack of diversification of water sources.

Starting from big metropolitan cities to the smaller cities of India, the historical trajectory of water is the same. The supply usually runs from diversified sources to a centrally organised piped network. The metropolitan cities of India such as Mumbai, Kolkata, Delhi and Chennai experienced these trajectories during the colonial period following the model of centrally managed water supply and sewer system of British cities, especially that of London. The same legacy is being carried forward in the post-independent India with overwhelming importance given to the centrally organised water network utilising mostly groundwater and ignoring the other sources which helped the citizens to survive over generations.

This high dependence on groundwater has been continued and enhanced for several reasons. It is considered to be 'pure' water and is therefore free from contamination. It is relatively cheaper than the tank or water treatment plants. At present, most of the cities in India are thus fully or partially dependent on groundwater (Kaur, 2015). In doing so, however, the cities' groundwater is overexploited and its levels have become alarmingly low in most cases. Moreover, in the cities of coastal locations such as Chennai, the over exploitation of groundwater has led to the intrusion of seawater in many places, affecting its potability (Janakarajan, Llorente and Zérah, 2006). Also, apart from the four water reservoirs located in the northern part of the city, which are filled by monsoon rainfalls, Chennai city is entirely dependent on its groundwater resources. Chennai's river basin mainly comprises three rivers, but these are not used as sources for drinking water; they are highly polluted with sewage and waste (Manny, 2015).

The city of Kolkata has been using five water treatment plants for a long time. There has been no addition to the list in the recent past to use the waters of Ganga. However, the city has 28 pumping stations with reservoirs to utilise the groundwater and 6 more are under construction. This data indicate that the story of water in the Indian city has become the story of groundwater, irrespective of the city's size (Kolkata Municipal Corporation, Undated).

In an in-depth empirical study on the city of Chandernagore in West Bengal, Ganguli (2014) has shown how the water culture of the people in the city has changed over time along with the provision of piped water as the other sources were gradually abandoned. Although the city is located on the bank of the River Hugli, the city government withdraws groundwater from 43 deep tube wells to supply water. His calculation shows that the dug well could have supplied 15 per cent of total annual water demand of the city. This could have reduced the pressure on groundwater to a considerable extent as dug well water is easily renewable from the surface water sources, ensuring in the process the net availability of water. He also observed that newly developed areas of the city were still dependent more on dug well water as they did not get sufficient municipal supply.

PHOTO: PRASAD

> The high dependence on groundwater is because it is considered to be 'pure' and therefore free from contamination.

Although the water table rises during the rainy season and falls during the dry season, the overall trend of groundwater level has declined in the area. The water is drawn from a depth of 100 to 135 m to ensure a good quantity and quality of water. There is a new water treatment plant to utilise the river water that has been constructed using central government funding, but it is not being utilised by the city government because of its high maintenance cost, which needs to be met by the municipality itself.

The physical set up of the town gives the area a real opportunity to utilise a good amount of surface water. Many ponds of different sizes are present in the area. Around 8.30 sq km area (37.7 per cent of the total) of the city is under surface water bodies. These ponds, besides supplying direct water to the community, also recharge dug wells round the year. In the past, people used these ponds for bathing and washing before they had access to piped water supply. The water culture has undergone tremendous changes in the city from diversified sources to mono source of municipal supply. Thus with the centralisation of ground water dependent sources, the use of diversified sources is sizeably reduced.

The city of Burdwan in West Bengal has four big ponds, locally called *sayar*, which were mainly dug by the family of Burdwan Raj in the seventeenth and eighteenth century (Chakraborty, 2010). Most of these ponds are now either in a bad condition or have ceased to exist due to the land sharks' demands supported by political power. '*pukurchuri*', a Bengali term meaning theft of pond, has become a reality in today's cities in West Bengal whether they are located in the metropolitan area of Kolkata or in other small towns.

The initial development of the city of Kolkata during the British period was intimately connected to the construction of ponds and lakes (Ray, 2013). It was a marshy lowland area frequently interspersed with wetlands. That is why the city building process itself needed extra soil to raise the land higher. In doing so, people usually dug ponds to get an additional supply of soil. It was the practice not only of individual households, but also of the local government such as Kolkata Improvement Trust. This Trust dug Dhakuria Lake (now known as Rabindra Sarobar) between 1920 and 1930 to enhance the city's construction process in the watery parts of the south (Ray, 2013).

During the British period, too many ponds in the city became a significant problem in terms of health and hygiene since most of these ponds were unclean and breeding grounds for mosquitoes and other insects. The British administrators started to build big tanks such as Lal Dighi to supply safe drinking water to the city and simultaneously destroyed small ponds. After independence, Kolkata received an enormous flow of refugees from Bangladesh. The city was expanded towards the south and east at the cost of ponds and wetlands to accommodate these people.

The ponds and wetlands were earlier used by the poor people not only for bathing and washing, but also for their livelihood. In each city of Bengal, the death of ponds has been accentuated since the time municipal governments started to supply piped water in sufficient quantities even to the poor. The poor could not afford to pay for private tube well and would earlier use the ponds to meet their different needs. The filling of ponds for real estate development also becomes easier when local communities lost interest in ponds as they were no longer directly dependent on them. When no protest was seen from the communities living near those ponds, land development became a cakewalk.

The dependence on groundwater increases with the decrease in the size of the cities; smaller the cities, poorer are their financial conditions (Sengupta, Goswami and Rudra, 2014). The utilisation of the surface water from rivers requires big projects and huge financial resources which are often not available to the city governments. If we try to trace the history of water supply of major cities in India (Dossal, 1991; Sharan, 2014; Lahiri-Dutt, 2015), we will see that the dependence on groundwater has increased over time in each city. In most cases, the available groundwater is exploited in an unregulated manner resulting in ecological degradation (Janakarajan, Llorente and Zérah, 2006).

Way forward

In most cases, surface water bodies in and around cities are highly polluted and contaminated. However, local government can take initiative not to let the people and companies within the city to pollute and contaminate the surface water so that they can use that for municipal supply. During our field research in West Bengal, it was noticed that some cities, even if they are located on river banks and have water purification plants constructed under Jawaharlal Nehru National Urban Renewal Mission (JNNURM), do not use the sources because of higher maintenance costs. Rather they prefer to tap groundwater which costs less. Dug wells, another common source of water at household level, have been discarded by the people when they have easy access to piped water from the municipal sources. The dug well accumulates subsurface water which is different from ground water. Such sources of water can be well utilised for all domestic purposes except drinking. Moreover, urban local bodies must practice demand management policies for water as it has already become a scarce resource in almost all cities in India.

Endnote

The sheer negligence of urban surface and subsurface water in places such as the Bengal delta where such resources are physically available and yet there is too much dependence on groundwater makes the future of water in cities unsustainable. Historically speaking, people depended on diverse sources, now the groundwater has become the major source, neglecting all other sources. Now the time has come when we need to turn the trend again to diverse sources for the sake of the future of the water vis-a-vis the future of the cities.

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By **KUNTALA LAHIRI-DUTT**

DIVERGENT STREAMS

FEMINISTS' ENGAGEMENTS IN GENDERING WATER

Water is a gendered subject with social and cultural constructs. The contemporary plea to place women at the centre of water management undermines feminist demands for women's role.

PHOTO: PRASAD

Women share a multi-dimensional relationship with water, Rishikesh, Uttarakhand.

Today, social scientists generally tend to accept water to be a gendered subject that inhabits the social and cultural domains. The positivist approach to water, seeing it simply as a physical resource which can be quantitatively measured and placed against absolute numbers of populations, controlled and modelled for scaling up has been seen as having inherent limitations (Fam et al., 2015). Researchers involved in studying the human dimensions of water have critiqued such discourse as devoid of history and context and commented upon how this discourse gives rise to a political economy that favours large scale management practices and leads to commodification of water (Bakker, 2004; Swyngedouw, 2009).

The pursuit of looking at water through a gendered lens has a powerful effect upon the uses of water—upon the relationships between those who use it and on those who supply it. Yet, the thematic field of gender and water is not defined exclusively by scholarly researchers; multiple actors who undertake policy advocacy at global and national scales as well as practice in the field, heavily influence the priorities and often tend to drive the agenda collectively.

Ecofeminisms

The first stream of thought that has influenced scholarly research on gender and water was ecofeminism. In simple terms, ecofeminism is based on the idea that women like nature reproduce and are therefore similar to nature. This similarity invokes an innate relationship between the two making women care for environment. The view that all women are 'carers' of the environment, naturally prone to conserving a natural element such as water, has been critiqued because such an approach tends to ignore social relations, gendered attitudes, perceptions and constructions to emphasise the nature-nurture model that oppresses women. It also puts the burden of care straightaway and informally on women as a whole overlooking their differences. We now know that the relationship between women and the environment varies considerably according to the socioeconomic categories of a population. Urban, middle or upper class women may demonstrate no particular consciousness about water and other elements of immediate ecology, at least no greater than urban men, albeit differently as produced by their work and space relations.

Gendered water management: feminists' tensions

The main debate within the contributions made by post-ecofeminism scholars and researchers include Francis Cleaver and Diane Elson on the one hand and Margreet Zwarteveen and Ruth Meinzen-Dick on the other. The first strand of researchers, such as Cleaver (1998), focuses on the structures and institutions, networks and practices. Cleaver argues that women's uses of water occur in the domestic or non-market sphere. This sphere is dominated by informal structures, networks and management through customs and practices and through 'rules of use' rather than market principles. For example, in rural Kenya, Uganda and Tanzania, the distance travelled for water collection can be up to 4 km. The return journey from water collection chore takes on an average 25 minutes. According to the study done by the Department for International Development (2011), each household spends about 1 hour 40 minutes collecting water in rural Africa. According to Cleaver and her colleagues, if both women and men are included in the management of domestic and commercial water resources, it would help develop new skills in implementation and management, women's representation in decision-making, awareness of health and hygiene and enlarge their income-generating capacity. This proposition has been questioned by some who argue that project efficiency comes at a high cost in terms of women's time, isolates and separates them and does little to empower women. Consequently, this area continues to remain fraught with debate.

The other stream of thought is led by Zwarteveen (1995; 1997) who puts the emphasis on women's productive uses of water. Nearly one-third of agricultural workers in India are women. In addition, most rural women produce some crops for the household, managing an enormous amount of water in this way. However, the crops produced by women or the water managed by them receive very low or zero priority from irrigation analysts. In fact, the single biggest impediment in making water as a resource to empower women lies in the lack of recognition of women as irrigators and water users. When irrigation planners think of water users, they think of individuals as men, reflecting the deeply rooted conception of the farm household as consisting of a male head who is the main farmer, decision maker and provider. In contrast, his wife is seen as a dependent. In this conception, it is assumed that women do not need water as individuals or farmers since they will indirectly benefit from their husbands' rights and access to water. This long standing assumption in economic theory and policy is based on considering the household as a unit of congruent interests. From irrigation specialists, these ideas percolate into NGOs. Take for example, gendered participation in water users' associations. The biggest barrier to women's participation stems from membership rules that directly or indirectly exclude women - only formal right holders to irrigated land that often are male heads of the households - can become members.

The pursuit of looking at water through a **gendered** lens has a **powerful** effect upon the uses of water.

The most critical area within which rural women interface with water resource planning in their productive roles is in irrigation, which is a government water resource department, led by irrigation professionals. They are simply not trained well enough to see the innumerable productive chores performed by women in spite of a body of evidence reflecting the negative impacts of irrigation policies and interventions on the gendered distribution of resources and incomes within households as well as between households. Zwarteveen (1997) attributes this neglect to the attitude of the irrigation professionals who tend to express water-related problems in technical terms making them become socially or politically neutral without distinguishing between different social categories of water users. It may not mean that most irrigation professionals do not recognise that irrigation interventions are socially or politically neutral, they probably do. However, given the typical objective of making more water available for agriculture by controlling the available flow of water through canals/reservoirs/dams and hydraulic structures as per the planned geographical patterns and chronological schedules,the issues around gender simply do not belong to their 'normal professionalism' to explicitly discuss social or political assumptions or implications of their designs and plans. Particular regions or communities are often consciously selected to benefit from state irrigation interventions. But, the question of which households—let alone which individuals within the households/communities/regions should be entitled to access and use water is rarely dealt with explicitly. Moreover, taking intra-household effects of irrigation interventions into account is rejected because of fear or unwillingness of policy makers and planners to openly interfere with the 'private' sphere of families and policies.

A closely related impediment to questioning gender differences in rights to water is that it appeared to extend the competition and possible conflict over access to and control of water that was known to exist between men and women. It looked as if accepting women's claims and needs for water would double the number of competitors for water. This is true of course for those who assume that women have never used water and have never competed for water.

The debate highlights the contested relationship between feminism and rural women. Feminist thought both in developed countries and in developing countries, have been characterised by a reluctance of rural women to engage with feminism and vice-versa, leading to a constrained relationship between the two. Shortall (1992) talks about patriarchal power structure and masculine dominance over women's lives in rural areas. Urban-based, post-modern, feminists talking on theory and methodology have alienated farm women, prompting Sachs (1996) to suggest that 'a feminist viewpoint does not immediately derive from [rural] women's experiences. Although women do the majority of work in agriculture at the global level, elder men, for the most part, still own the land, control women's labour, and make agricultural decisions in patriarchal social systems.' Yet, feminists continue to engage with water experts. Zwarteveen's (2006) book, 'Wedlock or deadlock? Feminists' attempts to engage with water engineers identify three 'worlds' of masculinities. The first world is characterised by masculinity primarily because rights to irrigation water, infrastructure and irrigated land, almost everywhere in the world, continue to be primarily vested with men. The second world of 'thinking about irrigation' is masculine in that irrigation narratives have long de-valorised women's contributions or rendered thinking and speaking about women irrelevant. In the third world of irrigation as profession, masculinity is evident in the large numbers of male irrigation professionals.

Rights-based approaches

Many development institutions brought gender issues at the foreground of water-resource management debates primarily through the philosophy of water rights. The United Nations, during its development decade on water (1981-1990) was focussed on providing 'clean drinking water and sanitation for all by 1990'. The 1992 Dublin Principles concisely stated the centrality of women as the main issue and thrust in water management, considering water as an economic good. Water has also been recognised as an essential factor in ensuring the universal human right. The Millennium Development Summit, which identified the eight Millennium Development Goals (MDGs) also put a great thrust on gender equality and women's empowerment-as many as five of the goals touched upon gender and water. The Sustainable Development Goals that has now replaced the MDGs put gender more firmly within the framework. Moreover, the resolution establishing the International Decade for Action, 'Water for Life' (2005-2015), calls for women's participation and involvement in water-related development efforts. One expects that the interventions related to water will be impossible without due attention to their gendered effects and yet the rights-based approach has been not without its share of debates. In some cases, women may have some usufruct rights, but they often depend on male mediation. The positive benefits from interventions usually go to richer classes and to men, probably a reflection of the techno-centric ideologies that dominated in the past and continue to form the backdrop of interventions.

Endnote

The United Nations had recognised that 'the predominant concern continues to be the sustainable achievement of efficient distribution of water rather than empowerment, equality or broader societal changes' as far back as in 2005 (United Nations 2005). One reason for the prioritising of efficiency over empowerment may lie in the very nature of the continued domination of techno-centric ideologies in managing water. Such ideologies subsume gender issues despite the earlier commitment made in the Dublin Principles. The rush to meet the millennium development goals had enhanced this: recent documents have highlighted the fact that 'putting women at the centre' as proposed by WatSan is necessary to achieve the targets of the millennium project rather than targeting women's empowerment (World Bank, 2003; Lenton, 2006). A positivist and market-driven approach to development such as this risks prioritising the attainment of tangible results to measure gender, at the cost of examining more invisible, but equally important aspects of gender relations.

When the women are placed 'at the centre', the researchers need to carefully think through the intentions to examine the implications of the agendas for feminist knowledge. It is possible that when women are placed at the centre, such lofty ideal hides a utilitarian view of women to extract value for invested concerns; the successes are then treated as equivalent to women's empowerment, thereby entrenching women's position as 'targets' of development, undermining feminist demands for women's autonomy and agency.

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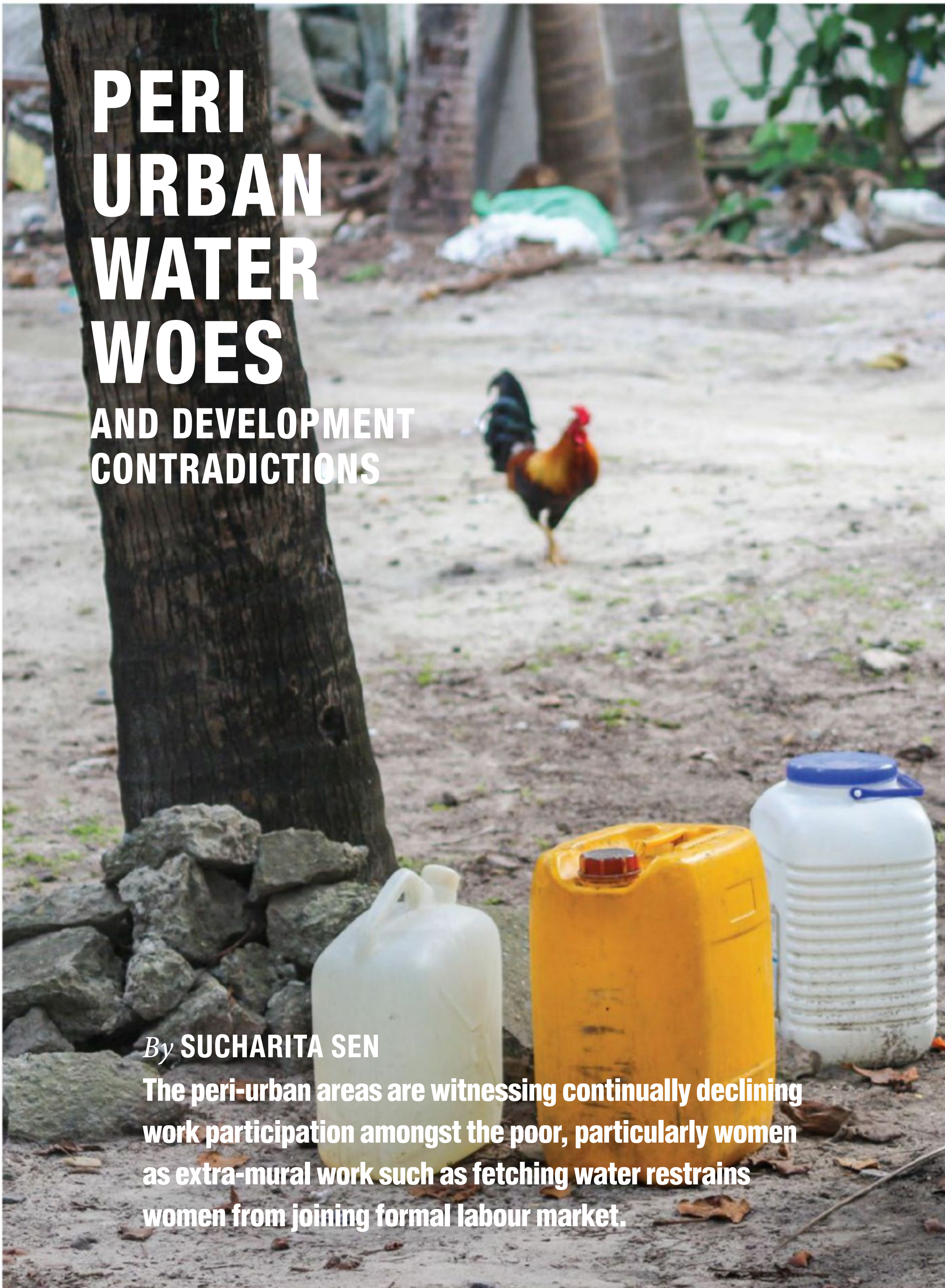


PERI URBAN WATER WOES

AND DEVELOPMENT CONTRADICTIONS

By SUCHARITA SEN

The peri-urban areas are witnessing continually declining work participation amongst the poor, particularly women as extra-mural work such as fetching water restrains women from joining formal labour market.

Lining canisters at 4 O'clock in the afternoon to access tap water in Minicoy Island, Lakshadweep.

PHOTO: PRASAD

The development paradigm in the Global South in the past three decades and a half has centred around cities, that too large cities and India is no exception. The World Development Report (2009) entitled *Reshaping Economic Geography* asserts that as investments are bound to be crowded around large cities in the years to come, increasing inequalities in the early stages are unavoidable, though it is expected that at a later stage the rural-urban gap will bridge through rural to urban migration, since these cities will not only be the centres of future growth, but will also provide jobs.

The private investments have been growing in India from the nineties—not particularly in the urban cores, but in the peripheries of the mega-cities of India (Chakraborty, 2000). This has manifested in a visibly higher increase in population in 2011 over 2001 in the urban areas of districts surrounding the six largest cities of the country, namely, Delhi, Mumbai, Kolkata, Bangalore, Chennai and Hyderabad (Fig. 1).

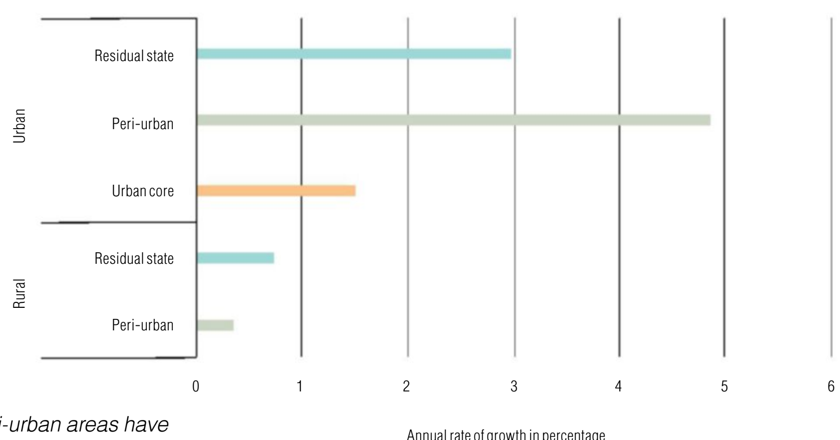
Urbanisation process and peri-urban work spaces: What do they offer for women?

Given the growth scenario, it may seem reasonable to expect that job opportunities will be created as a result of urbanisation which would actually favour the areas around large cities. This is true in some respects; the average wage rates are indeed higher in these spaces of urban expansion compared to the rural interiors. However, an emerging pattern which is counter-intuitive is that the gender disparities in workforce participation rates (WPR) in these spaces are higher than in both, the urban cores and residual states (Table 1).

This is not surprising as the women participate extensively in the family farms in the rural areas; a considerable chunk of it is on a part-time, unpaid basis. In urban India, however, the work opportunities for women are limited although the incidence of paid work is higher.

Notably, there was a continuum as one moved from the urban core to peri-urban spaces to the state interiors in terms of relative WPRs in 2005-2006. In 2010-2011, the peri-urban spaces represent a discontinuum in the sense that it has a higher gender disparity in WPR not only in relation to the state interiors, but also in comparison to the city cores. A question that is pertinent to ask is why this should be the case as these are the places where the effects of urbanisation are most visible, which in turn is expected to create jobs for all. Is the nature of urbanisation of a kind that is not producing inclusive opportunities to give women the same kind of job openings as it does for men? Possibly so, and some of the existing literature do point towards this (Neetha and Mazumdar, 2011). But more significantly, the evidence suggests that

Fig. 1: Population growth in and around 6 largest megacities in India



Peri-urban areas have shown the highest population growth rate during 2001-2011

Source: Adapted from Sen 2016, calculated from the Census of India 2001-2011

Table 1: Gender disparities in workforce participation (WPR) in and around six largest metropolitan cities of India

Spatial units	Ratio of female to male WPR (15-59)	
Rural	**2004-05**	**2011-12**
Districts around megacities	0.45	0.41
Residual State	0.7	0.54
Urban		
Urban Core	0.26	0.29
Districts around megacities	0.29	0.26
Residual State	0.38	0.31

Note: A figure of 1 would indicate an equal workforce participation of men and women; the lower the fraction, greater is the difference between the workforce participation by men and women.
The point to be noted here is the gender disparities have increased over the years in city fringe spaces), as it has in the 'residual states'.
Source: Adapted from Sen 2016.

Fig. 2: Share of women bringing water from outside household premises: 2011-2012.

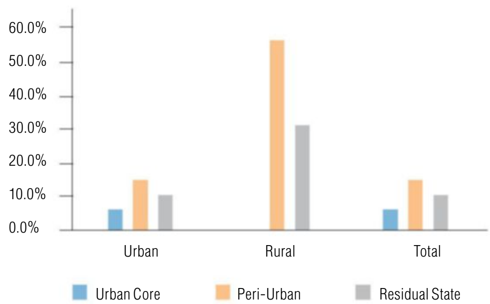
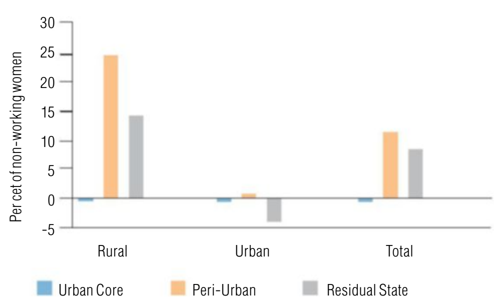


Fig. 3: Change in share of women bringing water from outside household premises: 2010-11 Over 2004-05.



Source: Calculated from Employment-unemployment rounds, National Sample Survey, 2004-2005 and 2010-2011.

Share of rural women bringing water from outside their premises is not only high but has increased over time from 2004-05 to 2010-11.

Women participate extensively in the family farms in rural areas; a large chunk of it is on a part-time, unpaid basis.

women from the poorer households have actually withdrawn from workforce more than those from the richer ones (Raveendran and Kannan, 2012).

Gender division of work and deepening water collection burdens

Why have more women from the poorer households dropped out of work as compared to women from the richer cohorts? After all, it would seem that the poor women are least likely to do so, given the need to financially support their families.

It is well known that there is a sharp gender division of work with respect to domestic and extra-domestic activities. Typically, women not only often solely carry out the care giving work in the home spaces, but are also responsible for extra domestic activities in rural areas that require them to go outside the domestic bounds to collect water, fuel and fodder; the last two duties are, however, more common in rural areas.

Data reveal that not only a larger share of women are bringing water from outside the household premises in the districts around the metros, compared to both the urban core and state interiors, the increase in this for the two periods under consideration is actually the highest in case of the former (Figs. 2 and 3). The share of non-working women going out for fodder and fuel collection also shows a similar trend. These comparative figures defy any sense of rational anticipations. After all, the rural areas are rapidly urbanising in these spatial platforms where the current processes are playing out most intensively. It would not be unreasonable to

Women gathering to collect in the peri-urban area of Anajpur, Rangareddi district, Andhra Pradesh. This adds to their burden.

expect that infrastructure as basic as water would be developed in these areas. On the surface at least, this does not seem to be the case. But be this as it may, this pattern at least partially explains the high and increasing gender disparities in work participation in the peri-urban spaces in recent years.

Water for drinking and domestic use as well fuel for cooking are indispensable resources without which a household cannot function. If these resources become scarce over time for some reason and larger number of women need to spend more time in collecting and managing these, it is reasonable to presume that they may actually be forced to withdraw out of paid work under these circumstances.

Why is there an increasing peri-urban water insecurity?

The process of urbanisation described by the World Development Report 2009, of rural-urban migration and expansions of large cities, in reality, creates a very vulnerable situation among the residents in the peri-urban population including migrants, particularly women, commonly, the most vulnerable of the migrants. The construction workers who build the city in a literal sense live in a state of flux without access to basic amenities (Tacoli, 2008).

South Asian Consortium of Interdisciplinary Water Resource Studies (SaciWATERs), based in Hyderabad is currently engaged in analysing periurban water insecurities with special reference to climate change and informal water market. The ongoing work reveals that the water insecurities emerge from two basic reasons: spatial water outflows from these areas and large scale water contamination due to industrial pollution. Both phenomena become more acute in times of water scarcity; Telangana, for example, was reeling under acute drought conditions from 2013 to 2015 and peri-urban residents of Hyderabad reported increased water insecurity both due to reducing water quantity and deteriorating quality. A higher incidence of privatisation of drinking and domestic water in these spaces feeds the urban expansions. This leads to a spatial water outflow from these areas which results in rapid groundwater depletion. Two observable impacts can be seen. First, the locals are forced to purchase water for both domestic and drinking purposes from the water vendors which becomes even more costly during lean seasons and drought years. Second, the groundwater depletion has resulted in large stretches of cultivable land turning fallow and ceasing to be a source of livelihood. Ground water pollution, both from city sewage and industrial affluent has also contaminated a number of the surveyed villages near peri-urban Hyderabad that has rendered the groundwater unfit for drinking.

Our survey reveals that some of the poor scheduled caste households were forced to depend on these sources when the prices became unaffordable to them in the drought year of 2015. This entire situation, and waning surface water supply by the government is observed to have a particularly distressful effect in terms of water collection burdens. These processes, to a large extent, provide an explanation for the phenomenon of reducing women work participation in the peri-urban areas. In addition, there is rapidly declining agriculture which has been a primary provider of employment for women. This decline is not only due to shifting land use, but also because of water scarcity in the wake of rapidly reducing base of safe drinking water that is available free of cost.

Policy Contradictions

The National Water Policy 2012, acknowledges that 'water is fundamental to life, livelihood, food security and sustainable development'. The latest Draft National Water Framework Bill, 2016, is however, somewhat baffling that avers 'the state's responsibility for ensuring every person's right to safe water for life shall remain even when water service provision is delegated to a private agency (emphasis added) and in case of such delegation, the right of citizens to safe water for life and the duty of the state to provide the same shall remain in force'. The fundamental contradiction between 'delegating' water service provision to a private agency and fulfilling state's duty towards maintaining 'the right of the citizens to safe drinking water for life' appears to have bypassed the policy makers. The threat, as observed, is not restricted to only privatisation of water, but also to the polluting industries concentrated around large urban centres that they find favourable for obvious reasons. Ironically, looked from a perspective of growth, which has become central to policy directions in recent times, these urban-centric investments would be in tune with the very path to development described by World Development Report, 2009. The connection that is not made often is how the path of commodification of water, that is de jure a common resource, leads to not only an economically unequal and unsustainable end, but how this route throws women into far more disadvantageous positions compared to men.

It is well-known that there is a sharp gender division of work with respect to domestic and extra-domestic activities.

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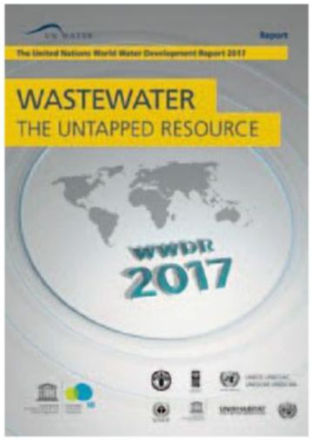
Website

UN Water
www.unwater.org
UN-Water is an inter-agency coordination mechanism of United Nations pertaining to all matters related to freshwater, including sanitation. The main purpose of it is to provide a platform for addressing the cross cutting nature of water and hence maximise world wide action and coherence. Further scope of UN water includes freshwater (surface, groundwater) and the linkage between freshwater and seawater.

World Research Institute
www.wri.org/
WRI is a research organisation spanning over 50 countries, with offices all around the globe, including India. Its team of 450+ experts and staff works in close coordination with leaders to turn ideas into action for sustainability and economic opportunity for human well-being. They plan to combine people to sustain environment for all people.

Water Data Portal
waterdata.iwmi.org/
It is the water data portal for International Water Management Institute. It is a non-profit organisation which has been doing water related research for thirty years and provides data to researchers around the world as global public goods (GPGs). It gives access to data relating to water and agriculture. The water data portal has meteorological, hydrological, socioeconomic, spatial data layers, satellite images as well as hydrological model setups.



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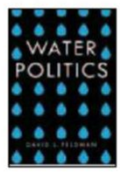

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