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Chief Editor : Deepika Kachhal
Senior Editor : Shyamala M. Iyer
Sub Editor : Vatica Chandra

Joint Director (Production) : V.K. Meena
Cover Design : Gajanan P. Dhope
E-mail (Editorial) : yojanace@gmail.com
E-mail (Circulation) : pdjucir@gmail.com
Website : www.yojana.gov.in
Facebook : https://www.facebook.com/pages/Yojana-Journal

Let noble thoughts come to us from all sides

Rig Veda

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Chief Editor's Office : Room No. 660, Soochna Bhawan, CGO Complex, Lodi Road New Delhi 110 003 Ph: 24362971. Yojana (English): Room No. 647, Soochna Bhavan, C.G.O. Complex, Lodi Road, New Delhi - 110 003. **Business Manager (Hqs.) :** Ph :24367260, 24365609, 24365610

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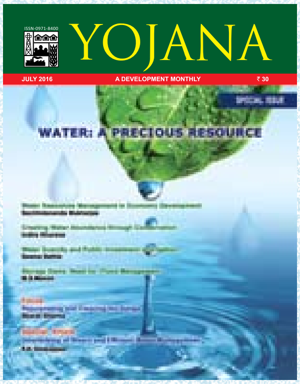
Water: Driving Force of Nature



Ancient Indians knew the indispensability of water for life on earth. According to ancient beliefs, the universe comprised of five basic elements: kshiti (earth), apah (water), teja (light/heat), marut (air) and vyoma (ether/space). As per the Rig Veda, all life evolved from water (apah). Pure water was called divyajal due to its properties of sheetam (cold to touch), suchihi (clean), shivam (replete with useful minerals and elements), Istham (transperant) and vimalam lahu shadgunam (acidic balance should not exceed normal limits). Besides, there are copious references to medicinal properties of water.

With two thirds of the earth's surface covered by water and the human body consisting of 75 percent of it, it is evidently clear that water is one of the prime elements responsible for life on earth. Civilisations owe their evolution to water ever since the beginning of humankind. Water influenced where people lived as our ancestors formed small cities around water for agricultural reasons.

This precious resource has now become a very crucial factor for our economy. It is a vital component not only for agriculture, industry, transportation but also for forestry, recreation, and environment. However contrary to the past, modern society has become apathetic towards this miracle of life. Rivers, seas and oceans are being exploited, mistreated and contaminated leading to water becoming a scarce commodity in almost every part of the world. Precious man-days or rather woman-days are lost in searching for water for household purposes in villages. In urban areas too there are frequent fights over water. Severe scarcity of water during droughts affects agriculture and farmers' welfare leading to loss in agricultural output and quite often suicides by desparate farmers. At the same time excess of water during floods also results in immense loss of life and property year after year. This dichotomy has become a regular feature of our economy.

Realising the gravity of the situation, experts world over are busy finding newer ways to conserve water. Governments are busy formulating policies to deal with water related issues. Indian government has been taking a number of steps to mitigate the problems caused by floods and droughts to both the farmer and the common man. Improved irrigation practices have been introduced to farmers through awareness campaigns, Pradhan Mantri Sinchai Yojana being one such programme. Water conservation methods like rainwater harvesting and flood water management are being introduced in a big way all over the country to address the looming crisis.

On a larger scale, while inter linking of rivers is expected to help by channelizing excess water in some rivers to the dry river beds in other regions without disturbing the ecology, storage dams across major rivers can absorb excess water during floods which can be used for irrigation, electricity generation and various other purposes. Projects like Namami Gange and Yamuna action plan are being looked upon as potential solutions to save drying and dying rivers. Commitment on part of centre and state governments is the need of the hour.

There is a true proverb in Hindi "Jal hai to Kal hai" which means if there is water then only our future is safe. However man has been mercilessly misusing this precious resource given by nature. It is time that the bugle call is sounded to make everyone realize that water cycle and the life cycle are one. Therefore, from today let all of us start saving each and every drop of water and conserve this priceless resource. ❑

Role of Water Resources Management in Economic Development

Sacchidananda Mukherjee

...countries should invest in water infrastructure, institutions and policy reforms to achieve human development and sustain economic growth. Further analysis shows that in hot and arid tropical countries, the investment in large water storages had helped support economic growth. Moreover, it seems to reduce malnutrition and incidence of child mortality

India is experiencing a high average annual economic growth of 7.28 per cent since 2002-03.[1] The growth is not only supported by consumption of fixed capital (man-made capital), but also by natural resources.[2] Apart from goods and services, production and consumption processes also generate pollution and wastes which are deposited into the environment (air, water and land). In addition to direct use as inputs, environment acts as a sink of wastes and assimilates the pollution load. If pollution load exceeds the assimilation capacity of the environment (air, water and land), it causes environmental degradation (air and water pollution, soil (land) degradation). The unpaid ecosystem services of the environment (e.g., pollution assimilation) as a factor of production and the depletion and degradation of some natural resources (like air, water and soil pollution) are not accounted into the present System of National Accounts (SNA); as a result it is difficult to understand the actual *environmental debt* of Indian economy.[3] In other words, the contribution of natural resources like water (both depletion and degradation) in GDP is not accounted and hence, it could limit the potential to achieve high economic growth in the long run (by posing constraints on availability of water and/or various ecosystem services) and/or economic development (by imposing costs (public health) on society in terms of water pollution). If pollution abatement is not matched with equivalent level of production and/or consumption activities, it could result in large scale water pollution. The costs associated with water pollution are borne by the society,[4] in terms of public health costs (costs associated with mortality and morbidity due to water pollution)[5]and loss of livelihoods due to environmental degradation (water pollution and land degradation). Apart from public health concerns, the loss of livelihoods due to environmental degradation is a serious concern for developing countries like India where a large section of the population still depends on primary activities (agriculture, animal husbandry and fisheries) for livelihoods (Mukherjee and Chakraborty, 2012). In India, growing population and rising demands will further enhance the dependence on environment both as a source of natural resources and as a sink for wastes. Apart from local environmental impacts, climate change induced vulnerability of 300 million coastal population of India, temporal and spatial variability of monsoons, retreat of glaciers and so

The author is an Associate Professor at the National Institute of Public Finance and Policy (NIPFP), New Delhi. He was earlier with International Water Management Institute (IWMI), Hyderabad and World Wide Fund for Nature (WWF)-India, New Delhi. He has worked on public finance, environmental economics and water resources management issues in India for more than a decade. He has published papers in national and international journals and co-edited many books.

on could be detrimental to our socio-economic development.

It is not only water security which influences the achievement in economic growth and human development, but also the level of use of water in different sectors; condition of the water environment; and technological and institutional capacities in water sector (Kumar et al., 2008). Kumar et al. (2008) show that improving the water situation, vis-à-vis improved access to and use of water, institutional capabilities in water sector and improved water environment, through investments in water infrastructure, creating institutions and making policy reforms, can support economic growth of a nation. However, the study also shows that economic growth is not a pre-requisite for solving water related problems. Instead, countries should invest in water infrastructure, institutions and policy reforms to achieve human development and sustain economic growth. Further analysis shows that in hot and arid tropical countries, the investment in large water storages had helped support economic growth. Moreover, it seems to reduce malnutrition and incidence of child mortality.

In the *Global Risks Report 2016*, World Economic Forum (2016) lists water crisis as the largest global risk in terms of potential impact. There are several dimensions of water scarcity – physical, economic and environmental (related to water quality). Increasing population pressure, large scale urbanisation, rising economic activities, changing consumption patterns, improving living standards, climate variability, expansion of irrigated agriculture and changing cropping pattern towards water intensive crops are among the major drivers for rising demand for water. Ever-increasing demand for freshwater in the last few decades and large scale temporal and spatial variations in availability and demand are among the major causes for water scarcity. The origin of water scarcity is the geographic (spatial) and temporal mismatch between freshwater demand and availability. The impact of water scarcity can be measured in terms of social, environmental and economic impacts. Annual assessment of water availability cannot capture variability within the year and therefore underestimates water scarcity and corresponding social and economic impacts (Mekonnen et al., 2016). High water scarcity prevails in areas with high population density or the presence of much irrigated agriculture or both. In the Ganges basin of India, water consumption and water availability are countercyclical, with water consumption being the highest when water availability is the lowest (Mekonnen et al., 2016). According to a recent estimate, based on monthly water availability during 1996 to 2005, globally four billion people face severe water scarcity at least for one month of the year. Of these 4 billion people, one fourth (1 billion people) live in India, whereas half a billion people in the world face severe water scarcity throughout the year. Of this half a billion people, 180 million people live in India. This underlines the severity of the problem in the Indian context.

Crop choice plays an important role to mitigate water scarcity in arid and semi-arid regions. Farmers' access to information on water availability and any probability of drought prior to sowing the crops could help them to choose the right crops to mitigate the impacts of water scarcity. The diversification of the livelihood basket could be the best option for adaptation.

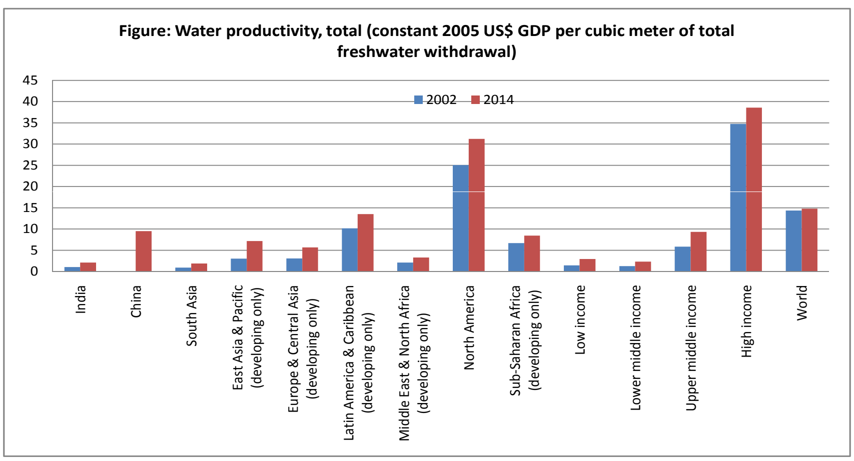
Being the largest user of water, water scarcity impacts the irrigated agriculture substantially. Depending on severity of the scarcity, impact on agriculture varies. Any fall in agricultural productivity or crop failure in the extreme situation leads to loss of livelihoods for the farmers. However, water scarcity induced impacts on livelihood is not uniform across all farmers. It depends on mitigation and adaptation capacity/strategy of the farmers to absorb any volatility in water availability as well as socio-economic situation of the farmers. Crop choice plays an important role to mitigate water scarcity in arid and semi-arid regions. Farmers' access to information on water availability and any probability of drought prior to sowing the crops could help them to choose the right crops to mitigate the impact of water scarcity. The diversification of the livelihood basket could be the best option for adaptation. Famers who do not depend on agriculture alone for their livelihoods could adapt to water scarcity. Fall in income in agriculture spreads across all sectors of the economy through backward and forward linkages. If the impact of drought is severe, then it would lead to inflation driven by rise in food prices. Water scarcity results in rising income disparity which leads to reduced demands for manufactured goods and services. In the long run, it may lead to general economic recession.

Impact of water scarcity on manufacturing and service sectors will differ depending on their water intensities. It is expected that in the manufacturing sector, water intensive industrial activities like textile bleaching and dyeing, leather processing, food processing and beverages, pulp and paper industries will bear the maximum impact of water scarcity. In the service sector, maximum impacts will be on hospitality (hotels and restaurants), medical services (hospitals) and construction/ real estate sector. In textile bleaching and dyeing clusters in South India, water is purchased in tankers from surrounding villages. Though the industrial use of water is very low when compared to agricultural use, the disposal of industrial effluents on land and/or on surface water bodies make water resources unsuitable for other uses. By avoiding cost of pollution abatement, which is a private cost, manufacturing units could transfer the cost to the society at large by not following prescribed standards for industrial effluent disposal. It results in pollution of ground and/ or surface water (Mukherjee and Nelliyat, 2007).

Access to safe drinking water is vital for human well-being (UNDP 2006). Achieving universal access to improved water supply and sanitation (WSS) facilities by 2030 is one of the Sustainable Development Goals (SDGs) (Goal 6), which aspires to, 'Ensure availability and sustainable management of water and sanitation for all' (UN, undated). Pollution from both point and non-point sources make water resources unsuitable for drinking. Thus, environmental sustainability of safe sources of drinking water for future generations is at stake. People exposed to polluted drinking water are vulnerable to various water borne diseases. Costs associated with mortality and morbidity of water-borne diseases is high. To avoid the potential health hazards (morbidity and mortality) associated with consumption of polluted water, government and/or households invest in various pollution avoidance activities – by investing in water treatment, source substitution, or by purchasing bottled water. It is mostly the poor and marginal section of the population who suffer the most, as they cannot afford to protect themselves from the impacts of pollution, as neither have they had access to supplied water nor, can they afford to invest in water purification.

Large scale diversions and withdrawals of water in the upstream of rivers leave little fresh water available for the downstream uses. Not many perennial rivers have adequate fresh water flow during summer to maintain the desired environmental flow (or ecological flow) for sustaining basic ecosystem functions (services) – e.g., groundwater recharge. Interdependence of surface water and groundwater is vulnerable to disturbance of river ecosystem and it leads to large scale depletion and degradation of water. In many parts of India, groundwater level is falling at an alarming rate. Adoption of water intensive crops (e.g., sugarcane, paddy) throughout the year, low investment in surface water based irrigation system, unreliability of canal water supply, political interference in distribution of canal water, and elite capturing lead to increasing dependence on groundwater for irrigation. Reckless pumping of groundwater over the year, encouraging rainwater harvesting and watershed structures at the upstream which leave little water available for downstream lead to fall in groundwater level (Srinivasan and Lele, 2016; Patel et al., 2008). Myopic approach in water resources management by withdrawing public investment from surface water based irrigation system; encouraging irrigated agriculture and groundwater based irrigation system by providing free electricity are among the primary causes of the present scarcity of water. Adoption of irrigated agriculture and shifting cropping pattern in favour of water intensive crops reduces adaptive capacity of agriculture to water scarcity.

Now the key questions that emerge are – a) do we need production of so many water-intensive crops (e.g., paddy, wheat, sugarcane), and allow them to rot in open fields or exports at throughway prices? and b) since many parts of India are grappling under severe water scarcity, shall we continue with our present pricing of water? Water use efficiency is very low in India and our overall water productivity, as measured by constant 2005 US$ GDP per cubic meter of total freshwater withdrawal, is much lower than the world average and it is also lower than the corresponding



Data Source: The World Bank's World Development Indicator Database.

figures for developing countries in Latin America and Caribbean and Sub-Saharan African countries. In the absence of full cost pricing of water (e.g., production and distribution cost, resource cost, environmental cost, scarcity value), it cannot promote water use efficiency and therefore, water productivity will remain low in India.

Like scarcity, floods also have substantial economic impacts. Apart from large scale loss of crops and property, livestock and human lives, it results in morbidity due to water borne diseases. There is hardly any systematic study to forecast floods across river basins in India. Furthermore, there is hardly any study to estimate economy-wide impacts of floods. The economic, social and environmental costs of floods may not be lower than the cost of constructing flood mitigation infrastructure. Limited storage capacity of our reservoirs and dams, climate variability and high inflow of water during monsoons lead to floods. Urban floods has become a recurrent phenomenon in Indian cities. In many cities, there is no storm water management infrastructure separate from domestic wastewater (sewage and sanitation) infrastructure. Moreover, our existing wastewater infrastructure is under stress and not adequate to handle (collection, transportation, treatment and disposal) all the waste water generated in the city. Negligence in management of natural drainage channels and traditional water storage structures like rainwater tanks and wetlands further aggravate the problem (Sharma et al., 2015). Storm water is a valuable freshwater resource and if managed properly, it could reduce dependence of cities on water supply from far away sources. Water footprint of our cities is expanding very fast and in most of the cases, it is far away from the cities (Mukherjee et al., 2010). Recent blocking of water supply from the Munak canal (in Haryana) and large scale water scarcity in Delhi shows how cities are dependent on far away sources to meet day-to-day water needs.

The concerted attempts to secure and maintain water sustainability, however, needs to take note of not only the existing challenges, but also the emerging concerns. Some of the concern areas, the effects of which will increasingly be faced in India, includes, emerging challenges of inter-sectoral allocation of water, rising conflicts due to diversions of water (from distant sources) to cities and industries, restoration of ecological flows of the rivers for reviving basic ecosystem services, conservation and protection of water resources (e.g., river basin management), protection of local sources of drinking water both for rural and urban areas to meet the demand for water supply,growing urbanization and water pollution, minimization of environmental impacts of development projects (e.g., industry, mining, infrastructure and urban development), controlling pollution from non-point sources and emerging pollutants (e.g., residues of pharmaceuticals and personal care products, perfluorinated compounds) and climate change induced impacts on environment and natural resources, etc.

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End Notes

1 Growth rate of GDP (at factor cost) (at 2004-05 prices) (RBI, 2014)

2 The present System of National Accounts reports the consumption (depreciation) of fixed capital (man-made) and it has gone up from 10.63 per cent to 13.13 per cent of GDP (factor cost) during 2002-03 to 2013-14 (RBI, 2014).

3 "Environmental debt refers to the accumulation of past environmental impacts of natural resource depletion and environmental degradation, owed to future generations." – OECD (undated)

4 By avoiding costs of pollution abatement, polluters transfer a huge cost to the society in terms of polluted air, water and degraded forest and soil.

5 For example in India water-borne diseases annually put a burden of USD 3.1 to 8.3 billion in 1992 prices (Brandon and Hommann 1995). A recent study conducted by the Water and Sanitation Programme (WSP) of the World Bank estimates that the total economic impacts of inadequate sanitation in India amounts to Rs. 2.44 trillion (USD 53.8 billion) a year - this is equivalent to 6.4 per cent of India's GDP in 2006 (WSP undated). ❑

(E-mail: sachs.mse@gmail.com)

FROM OUR READERS ...

I am an avid reader of Yojana I must say that this is a magazine worth praising, with excellent content. The magazine not only keeps us aware of the current government schemes and programmes,but also supplements our knowledge on pertinent issues.I wish to thank the team for the sincere efforts they put in. The articles on manifold burning topics are thought provoking and enlightening. I request you to include some topics such as social evils-dowry system, female infanticide, corruption prevalent in India, the eradication of which is the need of the hour. Some issues related to national sanctuaries, biosphere reserves, natural calamities can also be added. *Saundarya Sinha*

Response from Yojana Team

We are really grateful to our readers who take time out to send in encouraging words and valuable suggestions. It makes our work seem worthwhile. We do try to incorporate your suggestions in our journal whenever possible. We will definitely consider them while planning our issues.

Please do write in with your feedback on our issues. It will help us in planning our issues.

Thanks once again

YOJANA WEB- EXCLUSIVES

Yojana publishes articles on various topics in its 'Web-Exclusives' column for the benefit of its readers on the website of Yojana : www.yojana.gov.in. Announcements about the articles under the Web-Exclusives section are carried in the Yojana magazine of the month.

We are carrying the following articles under the Web-Exclusives section of Yojana for July 2016.

Addressing the Challenges of Water by M. Ojit Kumar Singh

Water Availability Crisis and Ways to Check the Depletion by Dr. Harender Raj Gautam

Please send in your comments and suggestions to us on ***yojanace@gmail.com***

Creating Water Abundance Through Conservation and Judicious Use

Indira Khurana

The movement towards water abundance will require action on many fronts as short and long term measures. These range from creating assets such as water banks, reducing demand, stretching the water drop by its multiple use and the use of innovation and technology

The world today faces imminent threats due to water scarcity with implications for world peace, justice and security. Water scarcity affects socio-economic growth. The World Economic Forum's Global Risk Report 2016 recognised water crises as the third risk in a list of top ten risks in terms of impact. A recent World Bank report confirms that climate change will increase water-related shocks on top of already demanding trends in water use.

Estimates indicate that around 4 billion people or two-thirds of the world's population face severe water shortage for at least one month every year. Water scarcity can result in low productivity and crop failure, leading to food shortages, increasing prices and subsequent hunger.

According to the UN, food output must grow by 60 per cent to feed a population of nine billion or more in 2050. Production of food requires considerable inputs of energy and water, raising challenges of conflicting demands. But by 2030, the world will have to confront a water supply shortage of 40 per cent. Agriculture already accounts for approximately 70 per cent of global freshwater withdrawals and is perceived as one of the main factors behind the increasing global scarcity of freshwater. Globally, irrigation water withdrawals are expected to grow by about 6 per cent in 2050.

In September 2015, the UN adopted the 2030 Agenda for Sustainable Development with 17 Sustainable Development Goals (SDGs). Goal 6 is dedicated for ensuring access to water and sanitation for all.

In the context of India, challenges for achieving this Goal are immense but possible, provided some steps are taken at the earliest .

India's Current Water Crisis

A snapshot of the 2016 water crisis in India is given below:

- **One third** of India's districts are affected by severe drought, affecting some **33 crore** people in **256 districts** in **10 States**.
- In March 2016, only **24 per cent water was left in 91 key reservoirs**.
- Since January 2015, around 1,000 farmers have killed themselves due to acute drought and debt in **Karnataka**.
- Some **1,000 villages in eight districts of Gujarat** are suffering from acute drinking water crisis.
- Water wagons from Miraj in Western Maharashtra are serving the dry regions of **Latur**. As a preventive measure against riots, people gathering near water sources are banned. No more than

The author is Lead – WASH (Water, Sanitation & Hygiene), in IPE Global Limited, an international social development consulting organisation, working on natural resources management, drinking water and sanitation, food security and rural livelihoods for more than a decade.She has written several papers and reports, co-authored and co-edited books and written several articles for the print and electronic media.

five people are allowed at wells and public storage tanks till the monsoons arrive.

- The **Bundelkhand districts across Madhya Pradesh and Uttar Pradesh** continue to reel under the third drought in a row. Almost 50 per cent of its water sources have dried up. Women travel long distances to collect drinking water. Agriculture has failed, leading to mass migration, poverty and hunger. Four major reservoirs that supply water to Hyderabad city have dried up.
- **Shimla, Himachal Pradesh** is an example of a hill town facing acute water shortages and Jaundice outbreak due to contaminated water supply. Officials estimate a daily shortfall of 14 million litres of water, affecting around 80-85 per cent of the towns' local population**.**
- **In Pune, Maharashtra,** the Government is relying on water tankers to meet the increasing demand for water.
- There are reports on **industrial shutdowns** due to shortage of water.
- Tajola, an industrial township is cutting production for two consecutive days in a week. Here, 60-70 per cent units are from water intensive sectors such as fertilisers, chemicals, pharma, food and beverages and metals.
- Around 13 sugar mills in Sholapur and Marathwada in Maharashtra have shut down. Textile industries and dyeing factories are shutting down production during water cuts.
- Power production was disrupted in Farakka, West Bengal due to water shortage.

This shortfall of water across the States has led to crop failure, mass forced migration, suicide, death, closing down of health care facilities and industry. It has also seriously affected the health of women and children. For a country blessed with (a) 14 major, 55 minor and 700 small rivers; (b) an annual average rainfall of 1,170 mm; and, (c) a tradition of rainwater conservation across the country, these crises could be avoided. The problem here has been more due to water mismanagement than its actual scarcity.

Reversing the Trend: Creating Water Abundance

Concerted, consistent and sustained efforts can lead to drought proofing and creating water abundance. It can also help alleviate the challenges posed by climate change. But for this to happen, cooperation from all stakeholders is required.

The first step in water management would involve undertaking comprehensive, consistent and constant campaigns to re-establish the relationship between people and water.

This shortfall of water across the States has led to crop failure, mass forced migration, suicide, death, closing down of health care facilities and industry. It has also seriously affected the health of women and children. For a country blessed with (a) 14 major, 55 minor and 700 small rivers; (b) an annual average rainfall of 1,170 mm; and, (c) a tradition of rainwater conservation across the country, these crises could be avoided.

This would help stakeholders across all sectors internalise that water is a scarce resource. Awareness generation among communities is the prerequisite for water conservation activities. It will also mean people taking charge of water management and making and adhering to commitments.

The movement towards water abundance will require action on many fronts as short and long term measures. These range from creating assets such as water banks, reducing demand, stretching the water drop by its multiple use and the use of innovation and technology. Some of these are outlined below.

Immediate Steps:

These steps are important to handle the immediate crisis and include the following:

1. ***Form drought mitigation committees in the villages:*** These village committees should comprise of panchayat members and representatives of all interest groups in the village. These committees can take care of, and monitor, drought requirements and management.
2. ***Elicit commitment to prevent suicide:*** The distressed villagers should have confidence that they are not alone and collectively take an oath that they will not commit suicide.
3. ***Arrange for tanker water supply where there is drinking water scarcity:*** Involve villagers to ensure that the water is safe and provided to all in the village. The Ministry of Drinking Water Supply and Sanitation has provisions for emergency situations such as drought and these should be availed of.
4. ***Arrange for water and fodder for livestock in livestock camps*:** People are forced to sell/ abandon their livestock (for example in Bundelkhand region, Rajasthan), since they are not able to provide for them. These camps will provide essential requirements for livestock and prevent distress sale.
5. ***Implementation of the Right to Food (RTF):*** Assess the functioning of the public distribution system (PDS) and other programmes under the RTF and ensure availability of food grains to the affected. This again, is a Supreme Court direction.
6. ***Restore/rehabilitate/ create water conservation structures:*** Send a message to the villagers that every drop of rain that falls on a field, habitation, village or Gram Panchayat should not go waste. This monsoon must be harvested. There are several things that can be done. For instance,

i) Farmers can make *medbandhis* (boundaries around their field) on their field so that the rainwater can be conserved. A small recharge pit should also be dug to capture the rain. Dugwells should be cleaned and ready to welcome the rains.

ii) Almost all the villages will have a tank, *talab*, dug well, or any other structure. The village committee can assess the status of these and undertake repairs, desilting, etc. All *nallahs*, streams or rivers should be protected and used for recharge.

iii) New rainwater conservation structures such as ponds, etc should be constructed. After the monsoon arrives, it is important that villagers map the areas where water flows or collects so that these can be used in the future for creating rainwater conservation structures.

Funds allotted for MGNREGA must be directed towards reviving and creating water conservation structures. There is a need to facilitate smooth and swift transfer of funds to the villagers which is now a Supreme Court order as well. MPLAD and other government funding can be used.

Long Term Measures

Long term measures are required for the development of water assets. These will require detailed planning and funds, but the task is doable.

India is blessed with an annual average rainfall of 1,100 mm, most of which falls in around 100 hours. This primary source of water must be captured either for direct use, or for recharge of groundwater aquifers and surface waterbodies. If rain is not managed well, it leads to flooding during the monsoon and water scarcity in the following months. The option is to capture the rain and create a 'water bank' for current and future use.

To put rainwater back into the natural water cycle means to collect, clean, hold and release it, in accordance with the natural surroundings. Every region of India has had traditional water harvesting systems suited to the region, which must be revived at scale. These models can be tested, replicated and modified if required to suit contemporary needs. Across the country, there are examples where communities have rallied together and conserved water. Coupled with appropriate agricultural practices, it is this effort that has helped them withstand the onslaught of drought, some of them even in consecutive years (*see Box: Cross country community efforts of water conservation*).

Artificial Groundwater Recharge: Subsurface Water Banks

The percentage of recharging of groundwater needs to be at least doubled. This is easily possible by natural processes and artificially directing rainwater into underground aquifers. Rainwater harvesting and artificial groundwater recharge serves dual purposes: absorbing excess water and releasing it when required. Since the open land mass is declining, especially in urban areas, artificial recharge at scale can greatly help in alleviating water scarcity, reduce flooding and improving water quality.

Artificial groundwater recharge is the infiltration of surface water into shallow aquifers to (a) increase the quantity of water in the subsurface, and (b) improve its quality by natural attenuation processes. It can be practiced in river valleys and sedimentary plains by infiltrating river or lake water into shallow sand and gravel layers. Water can be infiltrated into aquifers through basins, pipes, ditches and wells.

Artificial infiltration of surface water into aquifers offers qualitative and quantitative advantages.

Natural processes reduce the contamination of infiltrated river water.

Infiltration also allows for better water management as the level of water between the river and groundwater aquifer can be manipulated during periods of low and high river water discharge. Over time, a balance is struck between the river and the aquifer, allowing for water availability throughout the year. This enables a continuous water supply over the entire year. Generally, artificially recharged groundwater is better protected against pollution than surface water, and the delimitation of water protection zones makes it safer.

River beds offer a great opportunity for recharge. Over time, there will be

Water Conservation : Cross Country Community Efforts

In drought hit areas, communities have contributed towards creating solutions to save, manage and restore water. A few examples are given below:

- In drought hit Bundlekhand, Parmarth, a civil society organisation is supporting resilience amongst the drought affected families through development of more than 100 drought risk reduction plans, rainwater conservation and establishing community and institutional linkages. Jal Sahelis (Friends of Water) are managing in-village water supply and water conservation efforts.
- Under Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) project implemented in 7 drought prone districts of AP, farmers are managing their groundwater systems and have adopted suitable agricultural options.
- In 2002, drought hit Raj Samadhiyala village in Gujarat, managed to take up three crops a year using the rainwater harvested through the construction of farm ponds, percolation tanks, check dams and sub-surface structures.
- Hiware Bazaar village, Ahmednagar district of Maharashtra, adopted an integrated model of water management wherein, the villagers contributed by providing labour. Annual water budgeting exercise was introduced in 2004.
- Drought prone Laporiya village in Rajasthan has a unique dyke system called the 'chauka' to capture rainwater, improving water availability for drinking and harvest.

a balance between the surface and groundwater leading to rivers that will flow throughout the year and recharge groundwater aquifers. The Palla floodwater recharge that has been initiated by the Delhi Jal Board is one such example.

If done at larger scale, the volume of water that can be saved is enormous. While there are environmental, financial and social issues in constructing artificial storage spaces such as dams, recharging groundwater aquifers is a 'natural' choice. Artificial recharge, thus, offers a tremendous potential.

If rainwater conservation is undertaken in rural and urban areas from the smallest unit up to the state (Fig. 1), then there is cause for optimism.

Water Conservation : Sectoral Approaches

Some of the steps that can be taken by the agricultural sector – the largest consumer of water and the industry are outlined below.

Agriculture

The agricultural sector has to tackle multiple water related issues- low efficiency in water use – 38-40 per cent for canal irrigation and 60 per cent for groundwater irrigation schemes; declining water availability; increasing food demand due to population increase; changing food habits; commitments under RTF; and, competitive demands over water. It is also predicted that water demand for irrigation will rise over time.

Some options for increasing water use efficiency in agriculture include:

a) *Promote agricultural crops which can grow in available water:*

Crops like sugarcane and rice require huge amounts of water. These should be grown only in areas where there is sufficient water. Local varieties should be encouraged and a minimum price/ market and marketing systems developed for these.

b) *Adopting Micro Irrigation (MI):*

Drip and sprinkler irrigation helps reduce water consumption and can result in savings between 40-80 per cent of water. Irrigation methods such as irrigation scheduling, tillage, mulching and fertilisation can increase the transpiration component of evapo-transpiration which results in higher utilisation of water by crops, enhancing their productivity.

c) *Land and Water Management Practices:*

These include integrated practices such as soil-water conservation, adequate land preparation for crop establishment, rainwater harvesting, efficient recycling of agricultural wastewater, conservation tillage to increase water infiltration, reduce run off and improve soil moisture storage.

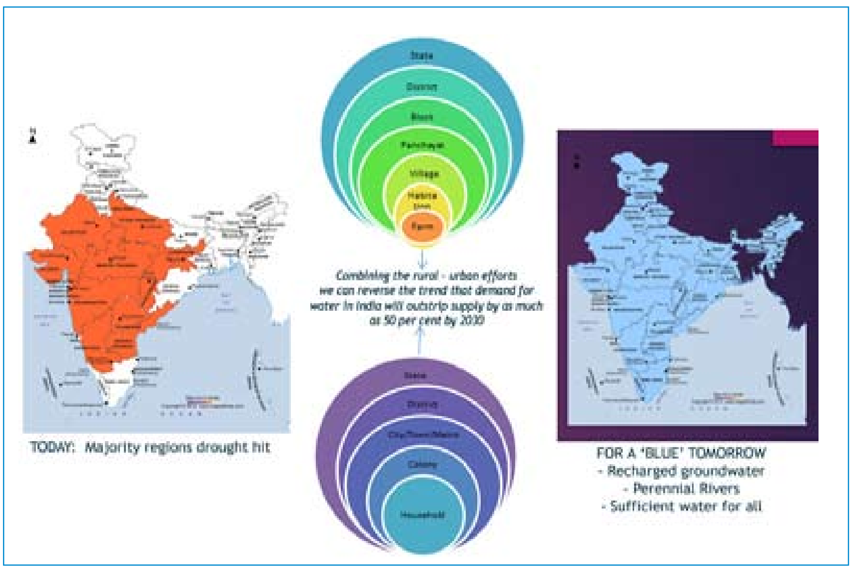
d) *Laser Levelling:*

This technique removes unevenness of the soil surface, having significant impact on the germination, stand and yield of crops. It can save around 20-30 per cent of water and enhance outputs by at minimum 10 per cent.

e) *System of Rice Intensification (SRI):*

SRI is well known for reducing water requirement by around 29 per cent and the growth duration by 8-12 days, resulting in increased water productivity of rice. This technology is also useful for sugarcane cultivation.

Figure-1



Source: Indira Khurana

Industry

Industries contribute substantially to the Indian GDP and their demand for water will increase with the expansion of the industrial sector. Water use by industries has led to misuse and pollution creating a situation of water scarcity and poor water quality.

To begin with, there has to be a change in the way industries perceive water: from the traditional view of water as a cheap resource available in plenty, to one that has competitive users and affects basic human rights. Water dependent industries are competing for water with local farmers, households and other users. Fortunately, the risk of water being a scarce resource often motivates companies to reduce their water usage in the production process. Companies are eager to reduce their water footprint[1], get certified for their water responsive behavior and products. Some of the options before the industry are given below.

a) Increasing Water Efficiency

Increasing water efficiency is pivotal in reducing water demand. If a systematic approach is followed, the water consumption can be reduced by 25-50 per cent in industrial units. Some of the methods that can reduce water footprint include, change in technology from water cooling to air cooling, replacing of water intensive equipment and fixtures, waste water recycling and reuse into industrial process, and rainwater harvesting and its use.

b) Life Cycle Analysis

Life cycle analysis can help to assess the environmental impact associated with the various stages of a product's life right from the cradle to the grave (from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance and disposal).

For obtaining Cradle to Cradle (C2C) certification, there is a need to meet a special criteria for water. Water Stewardship as a part of the Cradle to Cradle certification requires actions that not only improve the water footprint in industrial processes and supply chain, but also in the ecosystem where the industry is operating. There are five levels – Basic, Bronze, Silver, Gold and Platinum, with industries meeting better water standards at each level.

c) Supply Chain Water Management

Companies are designing effective water management strategies for their supply chain. For instance, H&M in partnership with WWF has established pillars of water management which include: developing training materials that would inform the design and sourcing team about water related impacts of producing fashion and raw materials; identifying possibilities of saving water at company owned facilities; working with stakeholders such as local and regional Governments; NGOs and other companies for better water management of river basins in China and Bangladesh; and, educating customers on the significance of water management.

d) Water Offset

For situations where water consumption cannot be reduced through efficiency improvements, water reuse or recycling, 'water offsets' investments to watersheds are adopted. Adoption of water offset would typically involve planting trees or investing in efficiency measures in far off lands.

Conclusion

It is possible to reverse the trend and make India a water rich country. A basket of measures such as those suggested above indicates some of the steps that can be undertaken. It does not really matter how much rain India gets unless all our efforts are made to harness it for immediate and future use.

Disclaimer: This paper reflects the ideas of the author and IPE Global is not responsible for the contents.

Endnotes

1 The water footprint of a product is the volume of fresh water appropriated to produce the product, taking into account volumes of water consumed and polluted in the different steps of the supply chain.

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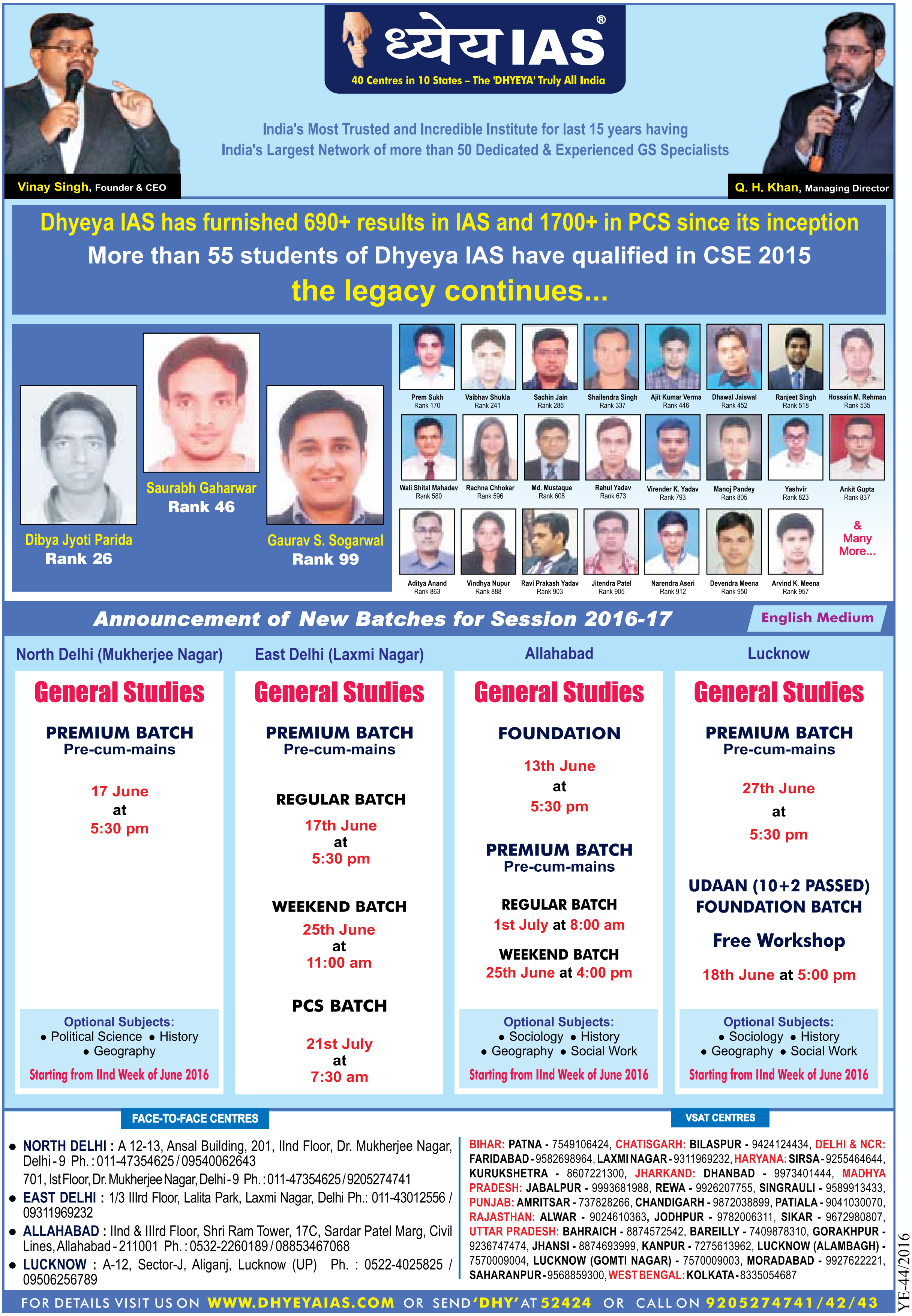
(E-mail: dr.indira.khurana@gmail.com)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REGULAR BATCH
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DO YOU KNOW?

Water and Constitution

Water is one of the most important resources for any country and the majority of this water is obtained from rivers to meet the needs of irrigation, cattle rearing and various other sanitation purposes by our states.These rivers, flowing in all directions passing through different states in India are either intra-state (flowing within a single state from the point of its source to its mouth) or inter-state river (which flows through the boundary of two or more states), which, in some cases have even led to disputes among the states. And this is where the role and the power of Union government comes into play, i.e. to manage these inter-state rivers and tackle any related disputes. It is also enshrined in our constitution that it is our fundamental duty 'to protect and improve the natural environment including forests, lakes, rivers, and wild-life and to have compassion for living creatures.

As per Indian constitution, a state government has the power to make laws for the water resources of that state. Under Entry 17 of the state list, the legislative power of a state has to be exercised without adversely affecting the interests of other states and avoiding any dispute. But since the power to legislate the regulation and development of interstate rivers lies with the Parliament, the authority of the state Government over water can be exercised, but it will be subjected to limitations that can be imposed by the Parliament.Thus, it won't be right if we say that water is entirely a state-subject.Rather, it is as much a Union subject as it is a state subject as the supremacy in all its matters lies with the Parliament. In view of this, our Indian Constitution has many provisions with regard to water, interstate water sharing and related disputes.

The legislative framework of the constitution related to water is based on Entry 17 of the State List, Entry 56 in the Union List, and Article 262 of the Constitution. These are:

a) **Entry 17 in List II (State List) in Schedule VII :** Although water is a state subject and therefore is in the State List, but it is subject to the provisions of Entry 56 in the Union List, which reads as:

b) **Entry 56 of List I (Union List):** Regulation and development of inter-state rivers and river valleys to the extent to which such regulation and development under the control of the Union is declared by Parliament by law to be expedient in the public interest.

Article 248 (Residuary Powers of Legislation): Parliament has exclusive power to make any law with respect to any matter not enumerated in the Concurrent List or State List.

Article 254: Inconsistency between laws made by Parliament and laws made by the Legislatures of States: If any provision of a law made by the Legislature of a State is repugnant to any provision of a law-made by Parliament which Parliament is competent to enact, or to any provision of any existing law with respect to one of the matters enumerated in the Concurrent List, then, subject to the provisions of clause (2), the law made by Parliament, whether passed before or after the law made by the Legislature of such State, or, as the case may be, the existing law, shall prevail and the law made by the Legislature of the state shall, to the extent of the repugnancy, be void.

c) **Article 262:** (1) Parliament may, by law, provide for the adjudication of any dispute or complaint with respect to the use, distribution or control of the waters of, or in, any Inter-State river or river valley. (2) Not withstanding anything in this Constitution, Parliament may by law provide that neither the Supreme Court nor any other court shall exercise jurisdiction in respect of any such dispute or complaint as is referred to in clause (1).Some other articles and entries may also have a bearing on the matter.

The River Boards Act 1956: The River Boards Act, 1956, provides for the establishment of River Boards, for the regulation and development of inter-State rivers and river valleys. On a request received from a State Government or otherwise, the Central Government may establish a Board for "advising the Government interested" in relation to such matters concerning the regulation or development of an inter-State river or river valley (or any specified part) as may be notified by the Central Government. Different Boards may be established for different inter-State rivers or river valleys. The Board will have persons having special knowledge and experience in irrigation, electrical engineering, flood control, navigation, water conservation, soil conservation, administration or finance. Functions of the Board are advisory and cover conservation of the inter-State river, schemes for irrigation and drainage, development of hydro-electric power, schemes for flood control, promotion of navigation, and control of soil erosion and prevention of pollution.

Inter-State Water Disputes Act, 1956: This Act extends to the whole of India. Under this Act, a State Government which has a water dispute with another State Government may request the Central Government to refer the dispute to a tribunal for adjudication. If the Central Government thinks that the dispute cannot be settled by negotiation, it refers the dispute to a Tribunal. The Tribunal then investigates the matter and gives its decision, which is considered final and binding on the parties, and even the Supreme Court and other courts shall not interfere with its decision. The Central Government may frame a scheme, providing for all matters necessary to give effect to the decision of the Tribunal.

The scheme may establish an authority for implementation. (Section 6A).

Water Tribunal: In case the states fail to implement the terms of any agreement relating to the use, distribution or control of such waters, the state can request the Central Government to refer the water dispute to a Tribunal for adjudication under section 3. If the Central Government feels that the water dispute cannot be settled by negotiations, the Central Government shall, within a period not exceeding one year from the date of receipt of such request, by notification in the Official Gazette, constitute a Water Disputes Tribunal for the adjudication of the water dispute, provided that any dispute settled by a Tribunal before the commencement of Inter-State Water Disputes (Amendment) Act, 2002 shall not be re-opened"

When a Tribunal has been constituted under section 4, the Central Government will (subject to the prohibition contained in section 8) refer the matter of water dispute to the Tribunal to investigate the matter, which then would forward its report to the Central government giving its decision on the concerned matter within a period of three years. So far, we have had many cases where the tribunals were constituted, such as Cauvery Water Disputes Tribunal (CWDT); The Krishna Water Disputes Tribunal (KWDT)filed by the party States of Maharashtra, Karnataka and Andhra Pradesh; Mahadayi/Mandovi and Vansadhara water disputes, the requests were received from States of Goa and Odisha ,where the establishment of a Tribunal is in advanced stage of implementation; Ravi & Beas Waters Tribunal (RBWT) involving Punjab and Haryana; Sutlej Yamuna Link (SYL) Canal involving Haryana's share of Ravi-Beas waters and non-completion of SYL Canal in Punjab.

Panchayati Raj Laws:

Under Section 92 of Panchayati Raj Law, it is a fundamental right of the village Panchayat to form a Water Committeee to ensure proper water management, equal distribution, tax collection and protection of water resources.

Under its Section 99, it is the duty of the Gram Panchayat to provide adequate water for domestic usage and animals, construct and clean drains, wells, lakes used for irrigation; Remove or fill the wells lakes, puddles, hollows etc.

Under its Section 110, Panchayat has the authority to approve the construction of drainage pits.

Under Section 200, Panchayat can collect water related taxes, Panchayat providing piped water can collect the tax for it in any form, in case of various class, according to the special water tax collected from Panchayat owned wells and ponds for the purposes other than household use and for animals. ❑

(Compiled by Vatica Chandra, Sub Editor)
(E-mail: vchandra.iis2014@gmail.com)

YE-46/2016

SPECIAL ARTICLE

Interlinking of Rivers and Efficient Water Management

R K Sivanappan

...it is very essential that the government must take action seriously for the inter linking of rivers in the country to use all the available water in the rivers (195 MHM) without postponing further. As discussed earlier, the water availability in the country is plenty, but it is unevenly distributed and hence, the water scarcity problem exists in many parts of the country particularly in south and in the west

India is endowed with plenty of water and land resources. India's land area is about 2.5 per cent of the world, water resources is 4 per cent of global availability and the population is about 17 per cent of the World. The available area is about 165 M.Ha., which is the second highest in the world. In the 1990's, about 65 per cent of the population of India comprised of cultivators (farmers) and agricultural labour indicating the country's dependence on agriculture i.e. land and water. Therefore, the need for water resources development for over all social and economic development was duly recognized from the very beginning.

India has abundant water resources, but the water problem is very serious in many states. This year (2016) water problem /scarcity was noticed in about 10 States i.e Maharashtra, Rajasthan, Karnataka, Telangana, Andhra Pradesh, Madhya Pradesh, etc. About 32 crores of the population does not have access to drinking water. As a scientist working in this field for more than 60 years, I have been indicating for the last 30-40 years that the water problem in India is a man made problem and not the fault of nature. India gets an annual rainfall of 1150 mm as compared to the world average of 840 mm and about 400 mm in Israel. Israel is managing the water successfully whereas in Cherrapunji in India where the rainfall is about 11,000 mm, availability is a problem for 2-3 months before the commencement of monsoon every year.

Water is the most crucial natural resource and its availability greatly influences the health of people and development of that area. According to the standard definition; for water availability from 1000m^3 /per capita / year to 1700 m^3/ capita / year, shortage will be local. Below 1000m^3/per capita/year, water supply begins to hamper health, economic development and human well being. At less than 500m^3 / per capita/ year, water supply becomes a primary constraint to life and countries experience absolute scarcity. The 1000m^3 /per capita/year, has been accepted as a general indicator of water scarcity by World Bank and other agencies.

Water Resources

World wide also, water resources are abundant. The available water is sufficient even if the population of the world is increased to 25 billion (i.e 3 to 4 times of the present population). In India, the total available water is sufficient for a population of 1650 million (1500m^3 / per capita/ year)

River basins are the basic hydrological unit for assessment of water resources of the country. The

The author is an international water consultant and Founder Director, Water Technology Centre, Tamil Nadu Agriculture University and former member, State Planning Commission, Govt. of Tamil Nadu.

entire country has been divided into 20 basins; comprising of 12 major basins having a catchment area of 20,000 km^2 and the remaining 8 basins are medium and small.

The National Commission for Integrated Water Resources Development Plan had assessed the country's water resources as 195.29 MHM in 1999. According to Central Water Commission, the utilizable water resources in all the 20 basins is 69 MHM which is about 35 per cent of the total surface water. This water will meet irrigation needs for a cropped area of 76 MHa. The inter basin transfer proposed by the National Water Development Agency (NWDA) envisages additional utilization of about 20 – 25 MHM water. Also, according to a very preliminary study, about 16 MHM of water resources can be additionally utilized through artificial recharge of ground water totalling about 40MHM.

The latest assessment of replenishable ground water resource had been made at 43.20 MHM in the year 1994 – 95 by the Central Ground Board. The utilizable ground water had been assessed as 39.56 MHM (7 MHM for domestic and industrial uses and 32.56 MHM for irrigation) which can irrigate about 64 MHa. The total irrigation is about 140 M.Ha (SW=76 M.Ha, & G.W = 64 MHa). The basin wise details of various water resources and their utilization components are given in Table1.

The assessed gross available water and utilizable water are as follows:

River flow (surface water) + ground water	=195.29 + 43.20 = 238.49 MHM
The assessed utilizable water	= 69.00 + 39.56=108.60 MHm

Based on population of India from 1991-2050 (expected), the gross availability of water and utilization water resources per capita / year are given in Table 2.

The utilizable water resources per capita per year varies from 3020 m^3 in Narmada basin and about 180 m3 in Sabarmathi basin. Out of 20 basins, 4 basins had more than 1700 m^3 / p/y utilizable water resources, while 9 basins had between 1000-1700 m^3, 5 basins between 500-1000 m^3 and 2 basins had less than 500 m^3 in the year 1991 when the population of India was 851 million. The population in 2050 is expected to reach about 1650 million and the food grain requirements of the country may be around 550-600 metric tones, including losses in storage and transportation, seed requirements and carry over for years of monsoon failures (allowances of 15 per cent), etc.

The total storage build up in various basins through major and medium projects upto 1995 is about 17.37 MHM. The major and medium projects under construction and identified account for 7.54 MHM and 13.23 MHM respectively. The total being 38.15 MHM. After taking into account the minor storage structures including tanks/ponds (about 4 mhm), the total storage capacity would be about 42 MHM. This accounts for the population of 1210 million as per storage capacity created in the country per person which comes to about 350 m^3 compared to

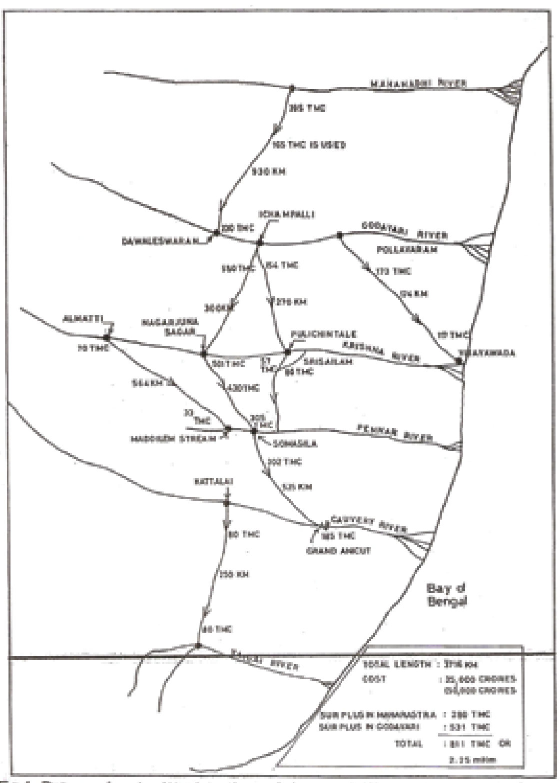


Fig.1 .Proposal submitted to the ministry of Water Resources GOI for approval and for central legislation

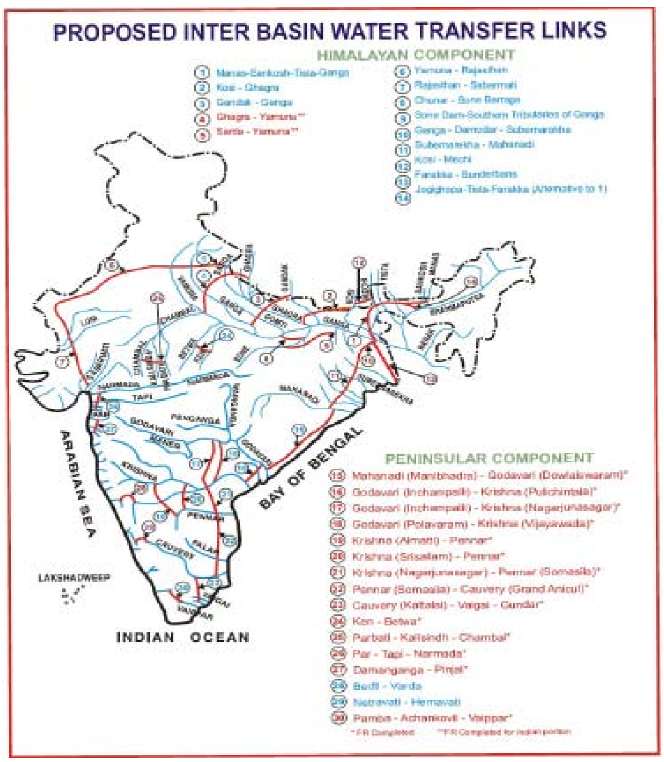


Fig. 2 Proposed inter basin water transfer links

(Source: Hydrology & Water Resources Information System for India, National Institute of Hydrology

USA 5961 m^3 and China 2486 m^3. In this connection, it is not out of place to mention that there are about 45000 large dams in the world, of which, 46 per cent are in China, 14 per cent are in USA and only 9 per cent in India. Japan and Spain are having 6 per cent and 3 per cent respectively. The above facts indicate that India's water storage capacity and dams constructed are very meager compared to various countries of the world taking into consideration their population.

From the data /details in Table 1 and 2, it is seen that even if the entire surface water and ground water available in the country is taken into account i.e. 238.50 MHM for the physical population of 1650 million in 2050, the per capita availability of water per year comes to 1450 M^3 which is less than 1700 and this indicates water shortage-the country will face water stress condition according to World Bank / U.N norms. If the utilizable water alone is taken into consideration (108.60 MHM) for the projected population of 1650 million in 2050, per capita water is 680 M^3 which is less than 1000m^3/P/Y which indicates that the country will face severe water scarcity and severe constraint on food production and economic development.

Inter Linking of Rivers:

Under these circumstances, it is very essential that the government must take action seriously for the inter linking of rivers in the country to use all the available water in the rivers (195 MHM) without postponing further. As discussed earlier, the water availability in the country is plenty, but it is unevenly distributed and hence, the water scarcity problem exists in many parts of the country particularly in south and in the west. The unused water is 65 per cent which is flowing into the sea and which should be utilized profitably by diverting from surplus areas to deficient parts in the country. To solve the water problem, the Govt of India had created the National Water Development Agency (N.W.D.A.) in 1982. It is an autonomous society to

work under the over all control of the Ministry of Water Resources, G.O.I.

The main objectives of the NWDA are to study the following 3 inter linking of river projects to find out the possibilities of the project:

1. Ganga- Brahmaputra-Cauvery linking or Himalayan River Development.
2. Inter linking of Peninsular Rivers ie Mahanadi, Godavari, Krishna, Pennar, Cauvery and Vaigai or Peninsular Rivers Development.
3. Divert the west flowing rivers in Kerala, Karnataka, Goa and Maharastra to East ie to Tamil Nadu, Karnataka, Andhra Pradesh, and Maharastra.

We can, easily and economically without disturbing the environment and ecology of the forests and without displacement of people, divert the West flowing water to the East Tamil Nadu across the Ghats through pump storage schemes, utilizing the wasted existing thermal power in the night time, during monsoons for removing shortage of supplies for irrigation, industry and drinking water.

Though, all the 3 proposals are feasible and workable, immediate action can be taken for items 2 and 3 simultaneously as the detailed study has been undertaken and the cost is within the reasonable limit.

a) Inter Linking of Peninsular Rivers

The NWDA has done an excellent job. It has identified 17 links under Peninsular River Development Plan. It has also prepared the pre-feasibility reports of all the 17 links along with completing feasibility reports of most of the links.

Among the various Peninsular rivers, Mahanadi and Godavari do have enough surplus supplies, even after meeting the ultimate projected demands of the basin states. It is proposed to provide Mahanadi – Godavari link running along east coast, to transfer excess supplies of Mahanadi and Godavari by gravity flow. This proposal is likely to irrigate drought prone areas of Maharastra, Andhra Pradesh and Tamil Nadu. The Krishna - Pennar link is to meet the enroute irrigation requirements in Krishna and Pennar basins.

The Pennar – Kaveri link shall fall into Cauvery at Grand Anicut. After utilizing the enroute, about 180TMC will be reaching Grand Anicut. Of this, about 100 TMC is proposed to be utilized in the Cauvery basin and balance of about 80 TMC will be used in Vaigai and Vaippar basins. The area which can be irrigated from this water is about 2 M acres. The NWDA has estimated the cost 10 years back at Rs. 30,000 crores for connecting Mahanadhi – Godavari – Kaveri and Vaigai having a length of 3716 Km to divert the surplus quantity of about 1000 TMC. (see Fig.1)

The author has collected data and worked out the water requirements (demand) of Kerala state according to which surplus available is about 500 TMC though the NWDA has estimated about 1000 TMC. If this quantity (i.e.500 TMC) is diverted to East (Tamil Nadu), it is possible to bring 5 million acres under irrigation in the southern districts of Tamil Nadu.

As part of diversion, the NWDA has prepared blue prints to divert the west flowing rivers in Kerala State to East in Tamil Nadu state, according to which, the Pamba and Achankoil rivers which carry about 250 TMC in Kerala can be diverted to Vaippar river in Tamil Nadu to an extent of 22 TMC that can be used in the drought prone area of Tirunelveli, Toothukudi, Virudhunagar districts to irrigate about 2.26 lakhs acres at an estimated cost of Rs.1400 crores.

Yet another project in the minds of farmers in Tamil Nadu is Pandiar and Punnampuza Scheme. This scheme

Table 1- Mean flow, Utilisable Surface and Ground Water Resource-Basin Wise

S. No.	River Basin	Mean Flow Surface water BCM	Utilizable Flow Surface water BCM	Replenishable Ground Water BCM	Utilisable Ground Water BCM
1	Indus	73.31	46.0	26.50	24.3
2a	Ganga	525.02	250.0	171.00	156.8
2b	Brahmaputra	*629.05	24.0	26.55	24.4
2c	Barak	48.36	-	8.52	7.8
3	Godavari	110.54	76.3	40.64	37.2
4	Krishna	**69.81	58.0	26.40	24.2
5	Cauvery	21.36	19.0	12.30	11.30
6	Subernarckha	12.37	6.8	1.82	1.7
7	Brahmani-Bartarni	28.48	18.3	4.05	3.7
8	Mahanadi	66.88	50.0	16.50	15.1
9	Pennar	6.32	6.9	4.93	4.5
10	Mani	11.02	3.1	7.20	6.6
11	Sabarmati	3.81	1.9	-	-
12	Narmada	45.64	34.5	10.80	9.9
13	West Flowing Rivers Between Tapti to Tadri	87.41	11.9	17.70	16.20
14	West Flowing Rivers Between Tadri to Kanyakumari	113.53	24.3	-	-
15	East Flowing Rivers between Mahanadi & Pennar	22.52	13.1	11.22	10.3
16	East Flowing Rivers of Kutch & Saurashtra & Luni	16.46	16.7	18.80	17.20
17	West Flowing Rivers of Kutch and Saurashtra & Luni	15.10	15.0	0	0
18	Area of Inland drainage in Rajasthan	0.00	-	-	-
19	Minor Rivers draining into Bangladesh & Myanmar	31.0	-	18.12	16.8
	Total	1937.99	675.8	423.05	388.0

Source: CWC, Publication 6/93-Reassessment of Water Resources Potential of India. Ground Water Resources of India CGWB-1995

* Includes Additional Contribution of 91.81 BCM being flow of 9 Tributries Joining Braharmaputra

** Assessment is based on mean flow of the yield series accepted by KWDT award. The figure of the CWC assessed from run-off data at Vijaywada is 78.12 BCM

*** Computed on proportionate basis from annual replenishment 10 BCM=1 MHM

Table 2- The Available and Utilizable Water Per Capita Per Year In M^3 in India (From 1991)

Year	Population Million	Available Water 283.5 MHM per capita/ year M^3	Utilizable water 108.60 MHM per capita/year M^3	Remarks
1991	850	2830	1290	500 M^3-Absolute Scarcity
2001	1030	2316	1055	100-Scarcity and stress
2011	1210	1970	910	1700-Shortage will be local
2025	1350-1400 (estimated)	1700	780	>1700M^3-Water-No Problem M^3=Cubic mlter
2050	1650 (estimated)	1445	680	M.H.M-Million Hectarl Meter

Table 3- Annual yield of west flowing rivers in Karnataka state

Sl. No.	Sub-basin	Catchment area (in sqkm)	Average yield (MCM)
1	Kalinadi	412	934
2	Shravathi	3592	8816
3	Chakra River	336	991
4	Netravathy	3222	9939
5	Varahi	759	2263
6	Mahadavi	412	934
7	Bedthi	3574	5040
8	Independent catchment between Sharavathi and Chakra River	401	906
9	Aghanashini	1330	3028
10	Independent Catchment between Sharavathi and Chakra River	1042	3066
11	Independent Catchment between Varahi and Netravathy	3067	9457
12	Independent Catchment between Netravathy and Barapole	1320	4474
13	Barapole	560	1274
	Total		57489MCM or 2000 TMC

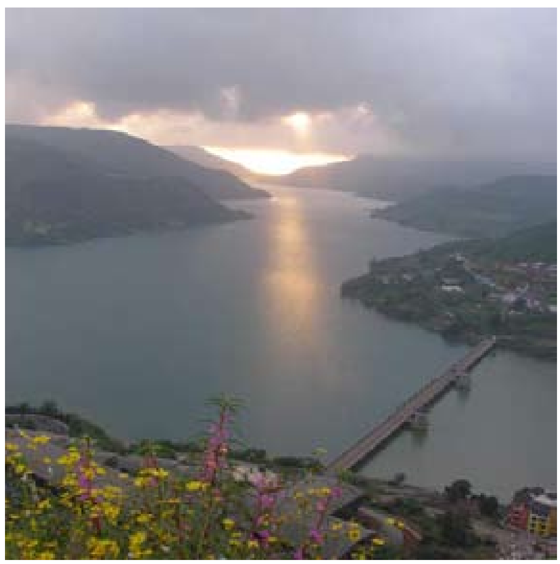
Source : Water Resources Development Organisation, Government of Karnataka, Bangalore

was visualized long back as a hydro electric project, but when farmers of Tamil Nadu wanted it as an irrigation cum hydro electric project, the Kerala Government did not give permission. If this project is implemented (only Tamil Nadu water since the catchment area is in Tamil Nadu), about 10-12 TMC of water which is flowing to the Arabian sea can be diverted to Bhavani/ Moyar basin in Tamil Nadu and this water can irrigate about 1.2 to 1.5 lakhs acres in dry districts of Coimbatore, Tiruppur and Erode districts. This project can be implementd immediately as the NWDA has done the detailed survey and it is economical, feasible and viable.

b) Diversion of West Flowing Rivers to East

In Karnataka, the Western Ghats which is about 13 per cent of the geographical area of the state has 60 per cent of the state's water resources in terms of quantity due to high intensity of rainfall and every drop of it is running as waste into the sea. The balance 87 per cent of the area of the state, mostly comprising Krishna and Cauvery basins have only 40 per cent of the waters for which Karnataka has water disputes with Tamil Nadu and Andhra Pradesh fighting in courts. The West flowing rivers in Uttara Kannada and Dakshin Kannada Districts of Karnataka state like Nethravathi, Kumardhara, Varahi etc have in all about 2000 TMC annually(Table 3) as against Krishna and Cauvery put together of 1300 TMC.

We can, easily and economically without disturbing the environment and ecology of the forests and without displacement of people, divert the West flowing water to the East Tamil Nadu across the Ghats through pump storage schemes, utilizing the wasted existing thermal power in the night time, during monsoons for removing shortage of supplies for irrigation, industry and drinking water. By this, it is possible to use the water in Karnataka and share the excess water with Tamil Nadu and Andhra Pradesh.



The five projects suggested above, if implemented, can solve the water and energy problem of southern states, namely Andhra Pradesh, Karnataka, Tamil Nadu, Kerala and Puducherry.

c) Himalayan River Development

Meanwhile, a detailed study can be taken up to find out the feasibility for all links to connect Brahmaputra - Ganga to other West and Southern rivers of the country to solve the water crisis of the entire country (see Fig.2). The cost of the project may be about Rs.8 to 10 lakh crores, which is also not much, compared to the benefits. For implementing this project, cooperation of Nepal, Bangladesh, Bhutan may be necessary, therefore we can implement the peninsular river development and divert west flowing rivers to East to start with and linking of Ganga – Brahmaputra can be taken up later.

Efficient Water Management:

The following are the new irrigation strategies – water management practices which can be followed /introduced to overcome the scarcity of water in the country.

- Systems of rice intensification (SRI method) should be followed in paddy cultivation to save water of about 40-50 per cent and to increase the yield by about 3/4 tons/Ha.
- Provide drainage especially in canal / tank irrigation and reuse the drained water, if it is suitable, for irrigation.
- Conjunctive use of surface and ground water.
- Using sprinkler irrigation in canals and tank command areas for all closely spaced crops except rice.
- Introducing drip irrigation in well irrigated areas for all row crops – cotton, sugarcane, banana, coconut and vegetables, etc.
- Irrigation based on water / fertilizer production function curves.
- Training farmers and extension officers in water management.
- Conducting seminars/workshops in villages to bring awareness among all farmers for safe water and to increase yield.
- Demonstrations and workshops may be organised in villages and in the farmer's field to use water judiciously.
- Extension offices in water management should be created in the block level as in the case of agronomy, plant protections, etc.

If the rain water is harvested, conserved and managed properly as detailed above, there should not be any water scarcity problem in the country. ❑

(E-mail: sivanappanrk@hotmail.com)

Water Scarcity and Public Investment in Irrigation

Seema Bathla

...the time is ripe to change gears and make investments focusing on minor and micro irrigation systems, adopt technological and other interventions that yield higher returns and also improve water use efficiency. This would necessitate a change in the fiscal policy instruments related to water viz. investments and subsidies on the use of canal water and groundwater, among others

India has been reeling under a major water crisis. The impact of drought has been identified in more than 50 per cent of districts, the worst in Maharashtra, Karnataka, Jharkhand and Telangana. Though the extent and magnitude of water scarcity varies across regions, and so its impact on crops, livestock and natural resources, it has tied the nation together to explore possible ways to handle the grappling situation that has affected nearly 330 million people. The Central government has initiated drought relief programmes to compensate crop losses, sent water trains to the highly water scarce areas and planned judicious use of groundwater. The states have also received financial help from the Centre to cope up with the emerging crisis.

However, the problem of drought is recurrent now and has become a major cause for worry, given the fact that almost 75 per cent of water is utilized for irrigation purposes. Rainfall deficit, together with high temperature would not only have adverse effect on agricultural productivity and food security, but may also impinge upon livelihood of a sizeable population dependent on agriculture in the country. A proposal has already been placed to push investments in macro as well as micro irrigations under the Pradhan Mantri Krishi Sinchai Yojana. It would, therefore, be important to know whether the public expenditure incurred largely on major-medium irrigation has contributed to upscale irrigation intensity and accelerate agricultural productivity. If not, then the time is ripe to change gears and make investments focusing on minor and micro irrigation systems, adopt technological and other interventions that yield higher returns and also improve water use efficiency. This would necessitate a change in the fiscal policy instruments related to water viz. investments and subsidies on the use of canal water and groundwater, among others.

This paper quantifies the public resource allocation towards major-medium and minor irrigation schemes and estimates marginal efficiency of these investments with an aim to shed light on possible policy interventions to address water scarcity. The investigations were carried out from 1981-82 to 2013-14 across major Indian states as both water and agriculture are state subjects and one may find large inter-state variations in spending towards these sectors and their development over time. The sources of data are Finance Accounts, and Agricultural Statistics at a Glance, Government of India. Time series data

The author is Professor, Centre for the Study of Regional Development, Jawaharlal Nehru University, New Delhi. She has published two books (one co-authored) and more than 40 research articles in national and international journals. She was conferred Jawaharlal Nehru Award for Outstanding Post-Graduate Agricultural Research by the Indian Council of Agriculture Research, New Delhi in 2008.

and education during the 1990s, which also made a strong case for diverting expenditure from subsidies to investments (Fan, Gulati and Thorat 2000).

However, a big push in investment in irrigation was given during the 2000s to trigger agricultural growth that had been at its minimal for long. The investment shot up from almost Rs.94.4 billion during the eighties and the nineties to Rs.240.4 billion during the 2000s at real prices. It grew at a faster rate in Andhra Pradesh, Gujarat, Karnataka, Maharashtra, and undivided Bihar and Madhya Pradesh. Carrying forward the past practice, a major portion of expenditure (81 per cent) went towards investment in medium schemes and nearly 13 per cent towards minor irrigation[1] works, 1 per cent in command area development and 5 per cent in flood control and some into subsidies on account of canal irrigation. From 2005-06, northern states along with Madhya Pradesh, Kerala, Odisha also initiated investments in major irrigation schemes with the result

on public expenditure is converted into real price at base 2004-05 using SDP deflators. Irrigation subsidy is calculated as the difference between total operation and maintenance costs and total revenue in the irrigation sector based on a detailed data from Finance Accounts. Interest payments are included in revenue receipts.

...though investment in minor irrigation is relatively small compared to that in medium irrigation, huge expenditure is incurred by the government to provide subsidized power to farmers to pump water from beneath the earth. Furthermore, states hardly make direct investment in micro irrigation systems except for providing capital subsidy to farmers on their purchase.

Inter-state Differentials in Investments in Irrigation

In almost all the developing countries, public expenditure is considered to be a key policy mechanism that contributes in accelerating agricultural productivity in a significant way. An increase in farm productivity is also taken to be a major route to poverty reduction (Mosley 2015). The empirical evidence on productivity enhancing, as well as poverty reducing effects of public expenditure on investments and farm input subsidies are well documented for each country (Fan 2008). Broad that findings in the Indian context show that investments on agriculture R&D, major-medium irrigation systems, and various input subsidies contributed the maximum during the seventies and the eighties. These investments, in conjunction with adoption of HYVs during the green revolution period, significantly helped accelerate private investment, attain higher crop yields and change the country from chronic food deficit to food secure. The powerful productivity and poverty effects of irrigation investment and subsidy were taken over by roads

that the average share of capital expenditure on medium projects in total expenditure on irrigation declined to 62 per cent and that of major ones went up to 19 per cent. The investment in the major-medium projects together increased by 3 times, and the same in minor irrigation grew by 2.5 times. The annual rate of growth is certainly higher in investment in major-medium irrigation schemes compared to that in the minor irrigation schemes.

It is worthwhile to mention that, though investment in minor irrigation is relatively small compared to that in medium irrigation, huge expenditure is incurred by the government to provide subsidized power to farmers to pump water from beneath the earth. Furthermore, states hardly make direct investment in micro irrigation systems except for providing capital subsidy to farmers on their purchase.

Though the rate of investment in irrigation has been impressive, the most disquieting feature has been a decline in its share in both total investment and expenditure (capital plus revenue) invariably in each state. Considering the major 17 states, the average share of public investment in irrigation and flood control in total investment was 50 per cent during the eighties, decreased to 41 per cent during the nineties and further reduced to 32 per cent during the 2000s. In terms of total expenditure, the share fell from 6.9 per cent to 4.2 per cent over this period. A relatively lesser preference of the states towards the development of irrigation and for that matter agriculture, may explain stagnation in areas irrigated by canals and continuous deceleration in agricultural productivity.

Large inter-state disparities in public investment in irrigation are also discernible. Richer states viz. Andhra Pradesh, Gujarat, Karnataka and Maharashtra tend to spend more than Rs.2000 per ha on irrigation compared to low income and agriculturally dominant states such as Bihar, Madhya Pradesh, Uttar Pradesh, Rajasthan and Odisha (Fig.1).Importantly, per ha spending on irrigation subsidy is less

Fig-1

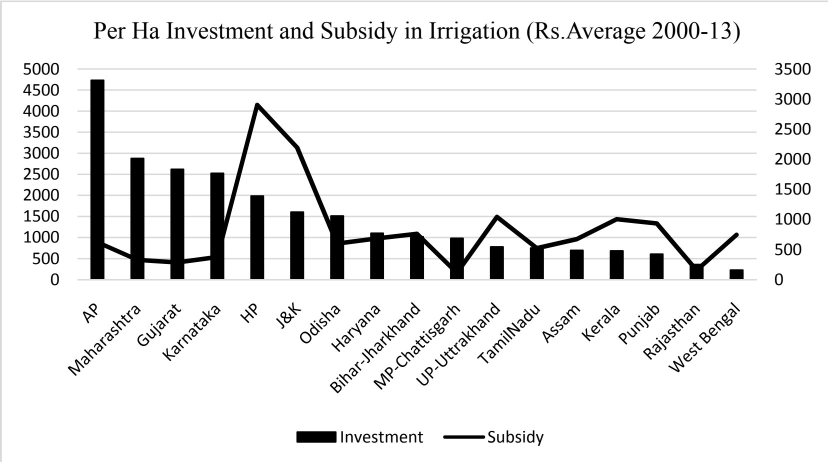
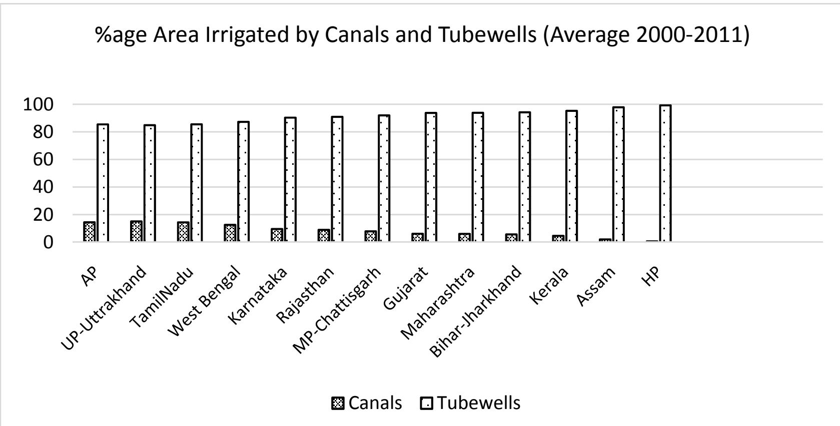


Fig-2



than Rs.1000 in several states except in HP, J&K, Kerala and Punjab. In fact, public spending in these states along with that in Assam, West Bengal and UP has been more on subsidy, which is somewhat disturbing.

Consequent upon increase in investment, the area irrigated by canals has gone up in Odisha, Rajasthan, Andhra Pradesh, Gujarat, and Karnataka in recent years. But it appears trivial in view of a sizeable spending on irrigation from Rs.104 billion to Rs.340 billion in 2000-01 to 2013-14 in the country. Also, irrigation intensity of public canals is much lower than that of tubewells, which are primarily owned by farmers.

As per official estimates, irrigation potential in the country is 139.9 million hectares. It is expected that 54 per cent of it would be realized from surface irrigation and remaining 46 per cent from groundwater sources. The prospects seem grim as only 63.25 million hectares of area has been irrigated so far, which is 45.5 per cent of the net area sown in the country. The maximum contribution to irrigated area is of tubewells at 61.7 per cent, followed by canals at 26.3 per cent; other sources at 9.3 per cent and tanks at 2.59 per cent respectively. Surprisingly, an increase in net irrigated area achieved from 55 million hectares to 63.25 million hectares during 2000s is attributed mainly to 'other sources'. The situation is alarming as area irrigated by canals is virtually at a standstill. The picture at the sub national level reveals states to rely majorly on groundwater as a major source of irrigation (Fig.2).Certainly, the states, especially the poorer ones depend on canal irrigation and need to step up investment.

Besides the low levels of investment, marked inefficiency in completion of major projects could be holding back states to realize the irrigation potential. Table 1 furnishes decade wise estimates on marginal efficiency of investment (MEI), separately in the major-medium and minor irrigation works. A high and positive MEI during the eighties went down substantially during the nineties[2] in every state, barring Gujarat and Kerala. An impressive performance is visible during 2000s, mainly in Andhra Pradesh, Karnataka, Kerala, Madhya Pradesh and Uttar Pradesh. As regards minor irrigation, MEI is relatively better and has improved in almost all the states except in Maharashtra, Haryana and Punjab.

These findings also validate results obtained in Bathla et al. (2015) on a sharp drop in the marginal effect of public expenditure in irrigation on agricultural productivity. The marginal returns from additional investments during the nineties at 1.41 considerably fell to 0.12 per cent when expenditure incurred during the 2000s is also considered. In contrast, returns from investment in tubewells, which are privately owned, are four times higher. Evidence further shows that the ratio of irrigation potential created from minor irrigation is much higher than that from medium and large irrigation projects. Essentially, minor irrigation projects should be given priority by the policy makers, more so as these structures play a significant role in recharging of wells, drought mitigation and flood control. This would necessitate scaling up investment in rural energy and also some policy controls and checks to avoid excessive withdrawal of ground water.

Way Forward:

Judging from the meteorological department's reports, agriculture in the current year would withstand the ongoing drought due to predicted normal monsoons, but the situation calls for long term solutions. First and foremost, the fact that public

Table 1: Marginal Efficiency of Public Investment in Major-Medium and Minor Irrigations

	Major-Medium			Minor		
States	1981-89	1990-99	2000-13	1981-89	1990-99	2000-13
AP	0.71	0.15	2.38	0.10	0.03	0.29
Assam	0.05	-0.002	0.01	0.08	0.01	0.08
Gujarat	0.43	0.73	0.99	0.003	0.07	0.29
Haryana	0.10	0.03	0.07	0.02	0.01	-0.02
HP	0.004	0.002	0.01	0.02	0.003	0.02
J&K	0.03	-0.03	0.01	--	0.01	0.05
Karnataka	0.41	0.54	0.99	0.08	0.01	0.21
Kerala	0.33	0.58	1.03	0.06	0.03	0.22
Maharashtra	1.62	0.77	0.46	0.28	0.29	0.12
Odisha	0.37	0.11	0.05	0.07	-0.01	0.21
Punjab	0.09	0.11	-0.07	-0.01	0.004	0.001
Rajasthan	0.31	0.16	-0.03	0.06	0.02	0.05
Tamil Nadu	0.18	0.07	0.17	0.01	0.02	0.06
West Bengal	0.11	0.04	-0.03	--	0.04	0.02
Bihar-Jharkhand	1.22	-0.46	0.49	0.02	-0.04	0.19
MP_Chattisgarh	0.98	-0.09	0.93	0.35	-0.06	0.50
UP-Uttarakhand	0.94	-0.22	0.62	0.35	-0.23	0.22

Note: MEI = 1/ICOR and ICOR was estimated using capital stock in major-medium and minor irrigation and SDPA; The SDPA, taken at 2004-05 prices is three years moving averages. Capital expenditure is taken as stock by taking base year value in stock and making allowance for depreciation in expenditure each year.

investment in major-medium irrigation works are not yielding the expected returns implies that the respective state governments must strive towards faster completion of ongoing projects and increase investment efficiency. They should also strategize fiscal policy by reallocating resources from major-medium irrigation to minor and micro irrigation, wherever feasible. Accelerating investments in micro irrigation systems, comprising drip and sprinkler irrigation has greater potential to improve water use efficiency, especially in sugarcane and banana. Undoubtedly, states have undertaken various promotional efforts and provision of subsidies on these, but their level of adoption and spatial spread remains low, at less than 5 per cent of cropped area. Studies show that micro irrigation helps to save water, reduces the cost of cultivation and improves crop yield. Net return per inch of water supplied through drip irrigation was in the range of 60-80 per cent as compared to conventional irrigation systems. However, among others, high initial capital cost, suitability of designs to different soil conditions, problems in receiving subsidy and small holdings are reportedly affecting the wide spread adoption of this technology. Subsidy, being an important factor influencing adoption decision of farmers, if not disbursed on time and appropriated by better off farmers, may affect the vast majority of resource poor small and marginal farmers in accessing this technology (Viswanathan et al. 2016). The National Mission on Micro Irrigation should be given high priority.

Additional spending on subsidies on irrigation as well as power, yield less than 100 per cent returns in terms of increase in agricultural productivity (Bathla et al. 2015). But reallocation of public expenditure from subsidies towards investment seems impossible given India's political scenario. Also, some agriculturally dominant poorer states may need to push up productivity and hence, find subsidies an easy route to entice farmers. One way to avert over exploitation of water resources could be rationalisation in the distribution of subsidy to those states and farmers that actually need it. Some other measures, as suggested by Gulati (2016) are to install meters to measure power consumption, and also canal waters, and then incentivise farmers to save their consumption by rewarding them with monetary value of, say 75 per cent of the savings at a price equivalent to what it would cost to supply from fresh investments. Another option could be that government replaces inefficient pump sets by more energy efficient ones which would save power by almost 30 per cent. Last but not the least, increased water conservation and technologies along with promotion of cultivation of less water intensive crops and drought resistant varieties would contribute to handle the crisis.

The newly formed state - Telangana has embarked upon a major project "Kakatiya" under which, water harvesting and management is taking place through revival of traditional tanks and lakes. India's partnership with Israel to learn and adopt innovative strategies to harness rain water during the recently organised 'India Water Week, 2016' is another useful step in this direction. These initiatives, if implemented can go a long way in increasing irrigated area, sustaining agricultural productivity and doubling farm income, as is looked-for by our Prime Minister. The need of the hour is a strong commitment of the state governments to strategize timely investments and be in the mission-mode.

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Endnotes

1. Public expenditure under minor irrigation includes both surface and groundwater schemes viz. lift irrigation, tubewells, wells, tanks etc.
2 A decline in capital-use efficiency during the nineties could also be explained by a low growth in agricultural income (Bathla 2014). ❑

(E-mail: seemab@mail.jnu.ac.in
seema.bathla@gmail.com)

NORTH EAST DIARY

HANDLOOM AND HANDICRAFTS FROM NORTH EASTERN STATES

In order to promote the rich cultural heritage of the North Eastern States of India, Ministry of Development of North Eastern Region(DoNER) and Ministry of Textiles have undertaken a joint initiative to promote the handicrafts and handloom products of the North Eastern States of India by organizing an exhibition of high quality products from North Eastern Region at CCIC (Central Cottage Industries Corporation) showroom in Delhi. The products are being sourced from artisans and weavers including master craft persons and National awardees from all over India. ❑

"PURBASHREE STALL" AT DILLI HAAT

The North Eastern Handicrafts and Handlooms Development Corporation Ltd (NEHHDC) has set up the Purbashree stall at Dilli Haat, Delhi. This stall will further boost the development and promotion of North East handicrafts and handlooms products. It is for the first time that the stall has been set up on a permanent basis which is devoted exclusively to North east. The stalls showcasing North-east were earlier put up on temporary basis. These stalls will showcase the North Eastern culture and ethnicity, help in generating the revenue and will also help in the promotion of start-ups. ❑

PLATINUM JUBILEE CELEBRATION OF FIRST ASSAM REGIMENT

The First Battalion The Assam Regiment celebrated its 75th Raising Day (Platinum Jubilee) with ceremonial fervor at Shimla, Himanchal Pradesh, on 15th July, 2016. The highlight of the whole occasion was release of 'First Day Cover' by Colonel of the Assam Regiment & Arunachal Scout, Lt Gen Subrata Saha and flagging in of a Motorcycle Rally, led by Brig Charandeep Singh, by Lt Gen PM Hariz, General Officer Commanding -in - Chief of the Army Training Command.

The Battalion was raised on this very day in 1941 and has had an illustrious military history. It is one of the only units in the history of warfare to have been awarded six Battle Honours, namely, Jessami (Nagaland), Kohima (Nagaland), Aradura (Nagaland), Mawlaik (Burma), Kyaukmyaung (Burma) and Toungoo (Burma) and one Theatre Award BURMA within a short span of three years of its raising. The Battalion is also the proud recipient of Chief of the Army Staff Unit Citation for its role in combating terrorism on Line of Control in Jammu & Kashmir. ❑

Water Harvesting: The Traditional Way

Rain water harvesting systems and water management systems have been in existence in India since time immemorial. Preservation and management of water was taken up in a very serious way.

Evidence of water harvesting and management have been found even in the Indus Valley civilization.- Archaeological evidence of irrigation and drinking water supply systems through a large number of wells with brick lining have been found at several Indus Valley sites. Dholavira, an important site of Indus Valley had several reservoirs to collect rain water. In Lothal (Gujarat) and Inamgaon (Maharashtra) and other places in north and western India, small bunds were built by the local people to store rain water for irrigation and drinking.

Kautilya's Arthashastra mentions dams and bunds that were built for irrigation during the period of the Mauryan Empire.The Satvahanas (1st Century B.C.-2nd Century A.D.) introduced the brick and ring wells. Lake and well irrigation was developed on a large scale during the time of Pandya, Chera and Chola dynasties in South India (1st-3rd Century A.D.) and large structures were built across the Cauvery and Vaigai rivers. Water resources development on a large scale took place during the Gupta era (300-500 A.D.). In the South, the Pallavas expanded the irrigation system in the 7th Century A.D. The famous Cauvery Anicut was built during this period. Large-scale construction of tanks (Tataka) for tapping rain water was also done in Tamil Nadu. The Chola period (985-1205 A.D.) witnessed the introduction of quite advanced irrigation systems, which brought prosperity in the Deccan region.

Baori

Dams, tanks and irrigations canals were built by kings from different dynasties all over the country. In eastern India, Pala and Sena Kings (760-1100 A.D.) built a number of large tanks and lakes in their kingdoms. Rajtarangini of Kalhana gives a detailed account of irrigation systems developed in the 12th Century in Kashmir.Feroze Shah Tughlaq (1351-1388 A.D.) built the Western Yamuna Canal in 1355 to extend irrigation facilities in the dry land tracts of the present-day Haryana and Rajasthan. Emperor Shahjahan built many canals, prominent among these being the Bari Doab or the Hasli Canal. Under the rule of Rangila Muhammad Shah, the Eastern Yamuna Canal was built to irrigate large tracts in Uttar Pradesh. The Vijaynagar Kingdom (1336-1546 A.D.) in the south took keen interest in building large and small storage tanks like the Anantraj Sagar tank across the Maldevi river and the Korangal dam. The Bahamani rulers (1388-1422 A.D.) introduced canal irrigation for the first time in the eastern provinces of the Deccan.

Jhalara

All forts, built in different terrains and climatic conditions, had elaborate arrangements for drinking water. Those built on hilltops or in rocky terrain depended mainly on rain water harvested from surrounding hills. The Amber Fort near Jaipur built about three centuries ago is a classic example of such a system. It has an automatic arrangement for desilting and aeration of harvested rain water before its entry into the large storage tank. The Jodhpur fort in western Rajasthan had water harvesting arrangements to tap both rain water and groundwater. The Panhala Fort of Maharaj Shivaji built on a hillock near Kolhapur in Maharashtra had Baolis and wells to tap underground springs originating in nearby higher hill slopes. The fort at Chittor on top of a hill has a large reservoir formed from the harvested waters of springs.At the Buddhist site of Sanchi (Madhya Pradesh) dating back to the 3rd Century B.C., there are three ancient tanks to store rain water from the hill slopes.Most of the old temples in South India built centuries ago have large tanks in their premises. These tanks are either fed by harvested rain water or by tapping underground springs. In Tamil Nadu alone, there are 39 temple tanks with areas varying from 0.25 to 3 hectares. These are all fed by rain water. Though these were used mainly for bathing and religious purposes, these also recharged the drinking water wells.

While the state only built infrastructure for storage of water on a large scale and for irrigation purposes, individual communities had their own water management and rainwater harvesting techniques - each being suitable to the geography and climate of the locality.

Both Gujarat and Rajasthan had well developed and efficient water management systems, mainly due to their arid and desert geography. Notable among these are the Paar system, talabs/bandhis, sazakuva, Johads, naada/bandhas, rapat, chandela and bundela tanks, kund/kundis, Kuis and Beris, jhalaras, nadis, tobas, tankas, khadins, vav/vavdi/bavadi/baoli, virdas and Ahar Pynes.

Water harvesting practices were also prevelant in other parts of the country. South Bihar had a traditional floodwater harvesting system called aharpynes. Katas/Mundas/Bandhas are the main irrigation sources of the ancient kingdom of the Gonds(now in Orrisa and Madhya Pradesh).

Water management in Bengal was one of managing plenty – since most parts of Bengal faced frequent flooding. Accordingly, inundation channels were built to facilitate entry of flood water to the fields carrying not only rich silt, but also fish swam into the lakes and tanks to feed on the larva of mosquitoes. This helped check malaria in the region. Small irrigation channels linking rice fields to streams were also found in Jalpaiguri district of West Bengal.

Bamboo-Drip-Irrigation

Water harvesting methods in the hilly and high regions were different from those in the plains, since these systems had to manage run offs down the slopes of hills and mountains. The zings in Ladakh, kuls in the Spiti Valley in Himachal Pradesh, Naula in Uttaranchal, Khatri in Hamirpur, Kangra and Mandi districts of Himachal Pradesh and the Kuhl in Himachal Pradesh are some of the water management systems practiced in the higher reaches of the country.

Just as in other things like agriculture, cuisine, dress and culture, the water management systems of the North East were peculiar to the region. The zabo is a system practiced in Nagaland which combines water conservation with forestry, agriculture and animal care. The cheo-ozihi is a system which brings the waters of the river Mezil in Nagaland through a long channel, diverted into branch channels and to terraces with the help of bamboo pipes. Dongs are ponds constructed by the Bodo tribes of Assam to harvest water for irrigation. Meghalaya has an ingenious system of tapping of stream and spring water by using bamboo pipes to irrigate plantations. This system is known as bamboo drip irrigation and has been practiced by tribal farmers of Khasi and Jaintia hills to drip irrigate their black pepper cultivation.Apatani is a wet rice cultivation cum fish farming system in elevated regions practiced by the Apatani tribes of Ziro in the lower Subansiri district of Arunachal Pradesh.

Temple-Tanks

Water management in the four southern states of Tamil Nadu, Kerala, Karnataka and Andhra Pradesh consisted of Eris(tanks) in Tamil Nadu which have traditionally played the role of flood management, maintaining ecological harmony, preventing soil erosion and wastage of run off during periods of heavy rainfall and recharging ground water; the Ooranis of South Travancore, which are tanks to irrigate small acres of land; Surangams(tunnels), a system practiced in Kasargod district in Kerala where the terrain is such that there is high discharge in rivers in the monsoon and low discharge in the dry months; and the Korumbus, a temporary dam stretching across the mouth of channels made of brushwood, mud and grass. These are built twice a year especially before the onset of the monsoon season in order to supply water during the winter and summer months. Kare are tanks found predominantly in the central Karnataka plateau. These were fed by channels branching off from anicuts(check dams) built across streams. The Cheruvu, found in Chitoor and Cuddapah districts of Andhra Pradesh are reservoirs to store run offs. Cheruru embankments are fitted with thoomu(sluices), aluguormarva or katju(flood weir) and kalava(canal).

The Kohli tanks were built by the Kohlis of Bhandara district, Maharashtra to irrigate their fields. These tanks, built even 250 years ago, were the backbone of irrigation and are still crucial for sugar and rice irrigation. The Bhandaras are check dams or diversion wiers found in Maharashtra. The Phad is a community irrigation system prevelant in north-western Maharashtra, which probably existed some 300-400 years ago. This system is operated on three rivers in the Tapi basin – Panjhra, Mosam and Aram in Dhule and Nasik districts.

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Rejuvenating and Cleaning the Ganga: Past Efforts and Future Plans

Bharat R Sharma

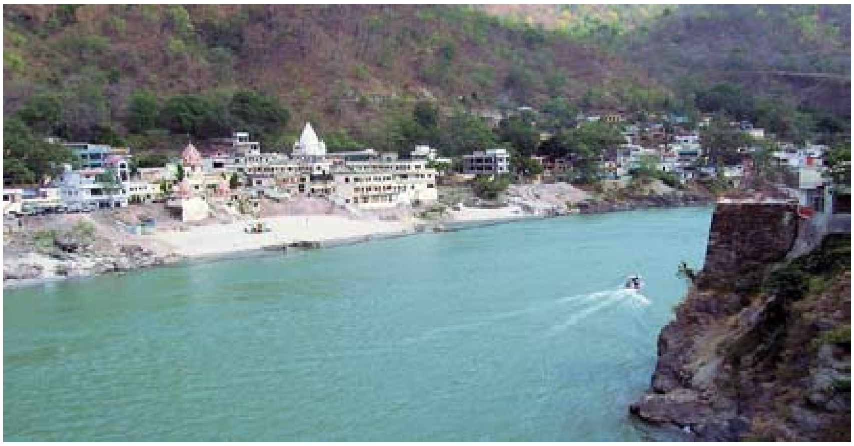
Global experience with large, but once equally or even more polluted than the Ganges today, rivers such as the Danube, the Thames, the Rhine, the Nile, and the Elbe show that strong river basin management organisations capable of generating basin-scale knowledge and scenarios, identifying hotspots of pollution and potential solutions incorporating urban and rural waste for closing the nutrient gaps in agriculture, prioritising interventions and investments and advising on awareness and policy are central to river cleaning and rejuvenation

Occupying a special place in every Indian's heart, Ganga is the most sacred river in the country with a unique cultural and spiritual significance. Traversing over 2,500 km, the colossal Ganga River is celebrated and used by millions of people from its origin in the Gangotri glacier in the Himalayas to the Sunderbans delta in Bangladesh. The Ganga basin generates approximately 40 per cent of the country's GDP and is a valuable environmental and economic resource for India. Along its long journey, the river enriches the vast lands of Gangetic plains and sustains 50 major Indian cities and hundreds of smaller towns. Several tributaries in the higher reaches have the potential to generate sufficient hydropower to boost India's energy supplies and in the downstream, the river has the potential to become a vibrant waterway to carry goods and people across long distances.This is the only river basin in India which is resource rich with lots of surplus water still available.

But unfortunately, this massive river is currently reeling from decades of negligence and ill-treatment meted out to it by an ever growing population. The mere mention of Ganga brings up conflicting images in mind. On one hand, it is the epitome of holiness symbolizing purity but on the other hand, it is a large, polluted, stagnant body of water filled with dirt and plastic. Heavy pollution loads, over-abstraction in the lean season for extensive irrigation, competing water demands and diversions and obstructions in the main stream and tributaries have wrecked havoc on the health of the river and its ability to nourish the millions of people who live and work in the basin (Ruhl, 2015). It is at this point when one wonders as to how one of the world's mightiest rivers ended up as a garbage dump!

Issues affecting the river are myriad and seldom simple. They range from untreated sewage and industrial waste dumping to restricted flows and rampant underground water withdrawal. All forms of pollutants including discarded offerings and heavily dyed clay idols used in various religious acts and ceremonies are blatantly released into the river. The degraded water quality affects millions of people who depend on the river's water across boundaries and countries. To top it, floods and droughts are a common phenomenon in the basin which kills people and seriously damages crops, livestock

The author is Scientist Emeritus (WR) International Water Management Institute- New Delhi. He was earlier Asst. Director General (Integrated Water Management), Indian Council of Agricultural Research (ICAR), New Delhi. He has more than 170 research and policy publications/ books and several awards to his credit. His key contributions include improving large irrigation commands, assessment and management of groundwater in the Indo-Gangetic and Yellow river basins, impact of large inter-basin water transfers on regional resources, assessment and improvement of water productivity and ICT applications in water resources management. He has published and worked extensively in South Asian and East African countries.



and infrastructure. The combination of glacial retreat, decreasing ice mass, early snowmelt and increased winter stream flow add on to the pressure and suggest that climate change is already affecting the Himalayan ice cover impacting the river in the long term.

The water quality challenges vary across the course of the river: (i) from Gangotri to Rishikesh, the river is enjoined by several small and fast flowing tributaries and is much less polluted due to human activities but is threatened by ill-planned dams for hydropower generation affecting highly sensitive and fragile ecosystem and bio-diversity, (ii) the middle stretch from Rishikesh to Kanpur, Allahabad, Patna and Farakka is heavily abstracted and the most polluted (pollution levels decrease as one traverses downstream) due to domestic, municipal, agricultural and industrial effluents. It also causes heavy flooding in the eastern Uttar Pradesh and northern Bihar plains. (iii) the last stretch forms part of the *Sunderbans*-world's largest active delta and has experienced considerable changes in the channel path, salinity ingress and tidal storms and is subjected to water sharing conflicts among the riparian countries (IITC, 2010).

Gangetic Pollution: Main Causes

Ganges basin is considered the world's most populous river basin and is home to more than 600 million urban and rural Indian population, or about half of the country's total population. The incidence of deep and multi-faceted poverty is high in the basin and the water and sanitation infrastructure is either absent or unsatisfactory. The basin is largely agrarian with urban centres having several small scale, unregulated and polluting industries and a number of pilgrimage or religious centres. So the root cause of pollution is from unmanaged sewage, septage and solid waste generated by a large population, industrial effluents, agricultural chemicals and waste and remains of religious offerings which are exacerbated by reduced flows during lean months and the climatic variability.

i. Sewage, Septage and Municipal Solid Waste:

The main stream of the Ganges passes through 36 Class I cities (with population over 100,000); 14 Class II cities (population between 50,000 and 100,000) and about 50 smaller towns with population above 20,000. According to Central Pollution Control Board of India (CPCB, 2013), these Class I and Class II cities generate more than 2.7 billion litres of sewage every day, although this figure may be underestimated (CSE, 2014) as it is calculated as a portion of the municipal water supplied to towns and cities, neglects urban run-off and does not include the wastewater generated in smaller towns. With the installed capacity of 1.2 billion litres per day (functional or actual, operational capacity is even much smaller), only a fraction of this wastewater is treated before it reaches the river. According to an inspection and estimation of the CPCB, only about 26 per cent of the wastewater generated along the Ganga is treated and the vast amount of wastewater is directly dumped into the river. The tributaries of the

Table 1. Freshwater consumed and wastewater generated by major industrial units in the Ganges basin

Industrial units	Total Units	Water Consumption (MLD)	Wastewater Generation (MLD)
Chemical	27	210.9	97.8(46.4 per cent)*
Distillery	23	78.8	37.0 (46.9 per cent)
Food, Diary & Beverages	22	11.2	6.5(58.0 per cent)
Pulp & Paper	67	306.3	201.4(65.8 per cent)
Sugar	67	304.8	96.0(31.5 per cent)
Textile, Bleaching & Dyeing	63	14.1	11.4(80.9 per cent)
Tannery	444	28.7	22.1(77.0 per cent)
Others	41	168.3	28.6(17.0 per cent)
Total	**764**	**1123**	**501 (44.6 per cent)**

Source: Central Pollution Control Board (of India), 2013

*Figures in parenthesis are percent of wastewater generated to the total water consumption

Ganga like Ramganga, Gomati, Kali, Yamuna, Hindon and several others are even more polluted and aggravate the problem as they merge into the main river. CPCB has identified 138 large wastewater drains which disgorge a massive 6 billion litres of highly polluted water directly into the Ganga. Storage, leakage and disposal of solid wastes through septic tanks is another serious problem. The Ganges basin states of Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal have a very poor sanitation infrastructure. As per the latest Census (2011), about 45 to 53 per cent of the urban households use septic tanks and there are no plans and mechanisms for septic management and these are emptied into open fields, landfills and drains which eventually pollute the river flows. Open defecation is practised by more than 25 per cent of the population and is a serious and direct threat to human health and water pollution. The collection capacity and proper disposal of solid waste is utterly lacking in the Ganga basin states. Most villages, towns and cities dump the solid waste of organics, plastics, glass, dead animals and other disposables around the banks of the river which not only choke and pollute the stream, it is an eyesore and repelling aesthetics for the population.

ii. *Unused or Abandoned Religious Offerings:*

The Ganga is India's most sacred river and surrounded by traditions and mythologies. Offerings of various kinds of materials are offered daily to the river by millions of devotees. On special occasions and festive seasons millions of pilgrims gather at its banks, take bath and remove all the dirt of body and clothes into the river. Highly coloured clay idols of deities are immersed into the river. Taken together this may amount to several tons of toxic materials contaminating and choking the river. The river also finds the ultimate disposal place for unclaimed dead bodies and other half or fully burnt dead bodies which decay and pollute the freshwater,

iii. *Industrial Wastewater:*

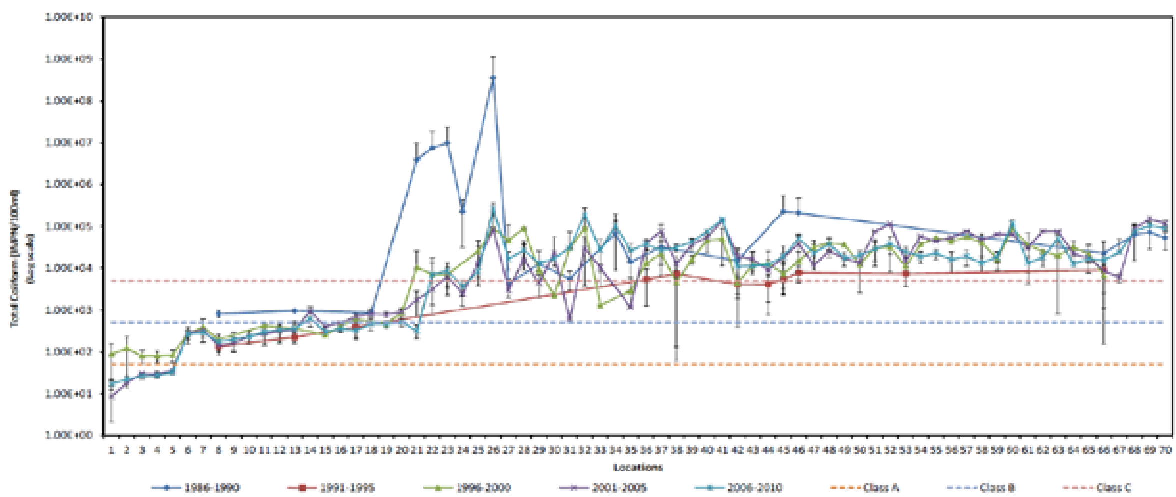
The large urban centres are also the industrial hubs for the highly polluting large and small chemical, distillery, food and dairy, pulp and paper, sugar, textile and dyeing, and tannery industry. All these industries consume, pollute and discharge large amounts of wastewater into the river (Table 1). The regulations for treatment of these wastewater are weak and often flouted by the unscrupulous industries. These effluents are generally toxic, poisonous and non-degradable and thus pose a major threat to the riverine aquatic life.

As is evident from the data, the textile, tannery and pulp and paper industries, the most prevalent in the basin, are also the most polluting industries. Several of these are in small scale and household sector and thus devoid of any self or imposed regulation.

iv. *Pollution from Agricultural Fields:*

Though pollution from agricultural fields is not as intense and severe as the municipal and industrial pollution, yet in certain stretches of intensive agriculture close to the river banks and in the basin can be hazardous especially the residues from insecticides and pesticides (Trivedi, 2010). Agro-chemicals have the potential to damage the riverine ecosystem to the extent that the river loses its self-treatment capacity. Pollution due to livestock and aquaculture is not properly understood. The continued increase in the use of fertilisers and agro-chemicals and intensification and diversification of agriculture pose a potential threat to the deterioration of freshwater quality.

Figure 1: *Variation in 5-year average total coliform at 70 locations along the Ganga River (source: IIT Consortium, 2013)*



Class A: water for use as drinking water source without conventional treatment but after disinfection.
Class B: waters for use for organized outdoor bathing.
Class C: Class C waters for use as drinking water source with conventional treatment followed by disinfection

v. *Insufficient Environmental Flows:*

A healthy river requires that after meeting all the requirements of the diverse stakeholders, adequate quantities of high quality water must continue to flow in the river throughout the year. At no point of time and in no particular stretch of the river, the flow may become insufficient and discontinuous. As all the human users and uses are very vocal and demanding, it is generally the silent but most important 'environmental flow' which generally gets sacrificed. Large scale abstractions of surface water directly through diversion canals and distributed groundwater pumpage throughout the basin seriously impact the river flow regime. The middle stretch of around 1,080 km from Haridwar to Varanasi is the most degraded due to significant irrigation diversions through extensive canal network and groundwater pumpage and high degree of pollution loads from different sources. Flow estimates after the canal diversions at Haridwar, Bijnor and Narora indicate that original Ganga River is almost completely lost, with little or no capacity to perform its ecosystem services and assimilate the large pollution loads (Mateo-Sagasta, 2015).

Past Efforts to Clean the Ganga

The poor river health, besides the large negative environmental, cultural and health impacts also constrains the livelihood options for many of those dependent on the river as more than 200 million people in the basin are among the India's poorest. The pervasive poverty in the states of Uttar Pradesh, Bihar and West Bengal has a strong correlation with 'water poverty' (Sharma et al., 2010). Faecal contamination caused by increasing amounts of untreated sewage and septage directly discharged into the streams is a major concern for the Ganges. Coliform levels are high all along the river and make the water generally unsuitable for traditional bathing, not to speak of drinking, barring a few upstream locations. What is even more alarming is that the situation has not improved in the last decades; on the contrary, coliform levels are on the rise and have substantially increased from 1996 through 2010 at all locations throughout the entire course of the Ganga River (IITC, 2013, Fig. 1). The Ganges Basin has an installed capacity to treat up to 44 per cent of the sewage produced in its Class I cities, but only 8 per cent of the Class II towns (Table 1) (CPCB, 2009) and virtually 0 per cent in smaller towns. Vast parts of the cities and most towns are, however, not covered by sewage networks or these networks are not operational or not ending in treatment plants, and so large quantities of wastewater remain untreated. But even where there are constructed sewers and treatment plants, these often do not operate properly or are not maintained, which means that the actual treatment is much lower than the installed capacity (CSE, 2014).

The poor river health, besides the large negative environmental, cultural and health impacts also constrains the livelihood options for many of those dependent on the river as more than 200 million people in the basin are among the India's poorest. The pervasive poverty in the states of Uttar Pradesh, Bihar and West Bengal has a strong correlation with 'water poverty' (Sharma et al., 2010).

Waste and wastewater from cities, industries and agriculture contain pathogens and chemicals that concentrate in the Ganga waters and sediments and accumulate along the trophic chain posing serious risks for human health, the environment and productive activities (Hernande-Sancho et al., 2015). This also impacts the riverine species. In the middle segment, most of the aquatic species are under severe threat because of the impacts of industrial effluents disposed into the river (Sarkar e al., 2012). Accumulation of heavy metals has been observed in fish in this stretch of the river. In Allahabad, a heavily polluted stretch, a steady decline of all economic fish species has been observed during the last six decades. According to Sarkar et al., 2012, the fish catch/km declined from 1344 to 300 kg between 1950 and 2010.

Two serious and revealing assessments by the Central Pollution Control Board conducted during 1982 and 1984 found that most pollution from point sources was coming from 25 Class I cities in Uttar Pradesh, Bihar and West Bengal and these formed the basis for the first-ever multi-state, national level substantial effort for controlling the pollution of the river which was launched in the form of Ganga Action Plan (GAP) in 1985. Main focus of the plan was on interception, diversion and treatment of sewage generated from these 25 cities. The plan continued for several years without achieving any improvement in river water quality. Subsequently, GAP II was started in 1993 and is still under progress in five states of Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal. Through the provisions of GAP-I and GAP-II, interception, diversion and treatment of sewage of more than 37 cities was established. The plan also identified grossly polluting industries and made it obligatory to install the effluent treatment plants. As per Ministry of Environment and Forestry, an estimated amount of Rs. 1612.38 crore was spent upto 2011. Though these efforts made some beginning and were able to highlight the magnitude of the problem of pollution in the Ganges, it had several limitations and constraints. As per the findings of IIT Consortium (IITC, 2011), only limited pollution issues were considered, the ownership among the local urban bodies was lacking, there were large implementation delays, no business model or provisions for operation and maintenance of the created assets was established and as such, these remained shut or non-functional; and underutilisation of the installed STPs due to either non-conveyance of the sewer or non-availability of power to run the plants.

Present and Future Plans and Innovations

Faced with the directives from Tribunals and Courts and a very persistent civil society; and also the resolve of the new Government itself, a number of serious and meaningful measures are underway for cleaning and rejuvenating the river Ganga. Some important measures include:

i. Establishment of National Mission for Clean Ganga (NMCG):

The NMCG is established by (initially under Ministry of Environment and Forests) the Ministry of Water Resources, River Development and Ganga Rejuvenation Society under the Societies Registration Act 1860 for the implementation of the World Bank assisted National Ganga River Basin Project (NGRBP) of the National Ganga River Basin Authority (NGRBA). The NMCG is the planning, financing, monitoring and coordinating body at the Union Government and being supported by suitable State-level Program Management Groups (SPMGs) for the purpose of achieving the twin objectives of the NGRBA: effective abatement of pollution and conservation of the river Ganga by adopting a comprehensive river basin approach. For this purpose, the NMCG is empowered to take all necessary actions that may be necessary or incidental for the achievement of the objectives.

ii. Reallocation of the Business and Rechristening the Role of the Ministry:

Cleaning of the river Ganga is a flagship program of the new Government and is being regularly monitored by the Cabinet Secretariat and the Prime Minster's Office. Most of the business pertaining to the cleaning of the Ganga has been moved from MoEF&CC to the Ministry of Water Resources (MoWR). To reflect the new mood, name of the Ministry itself has been changed to *Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD&GR)*. Several foreign governments (Japan, France, Israel, UK, Singapore, Australia etc.) and institutions (IWMI, Thames Authority, Murray-Darling Basin Authority) have been requested to provide the support besides India's own Consortium of Indian Institutes of Technology.

iii. Namami Gange:

The Government of India recently (2015) approved the "*Namami Gange*" program, which integrates the efforts to clean and protect the Ganga River in a comprehensive manner. For the next Plan period, an outlay of INR 200 billion has been allocated and has subsumed the GAP programs into its ambit. This program is much more comprehensive and includes the treatment of wastewater flowing through the open drains through bio-remediation, use of innovative technologies , additional STPs, installation of new industrial effluent treatment plants and retrofitting of all the existing plants to make these functional and operate at full capacity.

Global experience with large, but once equally or even more polluted than the Ganges today, rivers such as the Danube, the Thames, the Rhine, the Nile, and the Elbe show that strong river basin management organisations capable of generating basin-scale knowledge and scenarios, identifying hotspots of pollution and potential solutions incorporating urban and rural waste for closing the nutrient gaps in agriculture, prioritising interventions and investments and advising on awareness and policy are central to river cleaning and rejuvenation.

iv. Ganga River Basin Management Plan:

Based on the exhaustive studies and consultations, a Consortium of seven IITs have developed a comprehensive Ganga River Basin Management Plan (GRBMP) and submitted to the Ganga River Basin Authority for its consideration and implementation (Tare et al., 2015). The proposed plan makes suggestions and recommendations in the form of eight missions: *Aviral Dhara* (Continuous uninterrupted flow), *Nirmal Dhara* (Un-polluted clean flow), Ecological Restoration, Sustainable Agriculture, Geological Safeguarding, Basin Protection against Disasters, River Hazards Management, and Environmental Knowledge-Building and Sensitisation. One of main recommendations is to ensure 'zero discharge' policy for all the polluting industries. A total of USD 100 billion has been estimated as an expenditure for the next 25 years for implementation of the recommendations.

Conclusion

Global experience with large, but once equally or even more polluted than the Ganges today, rivers such as the Danube, the Thames, the Rhine, the Nile, and the Elbe show that strong river basin management organisations capable of generating basin-scale knowledge and scenarios, identifying hotspots of pollution and potential solutions incorporating urban and rural waste for closing the nutrient gaps in agriculture, prioritising interventions and investments and advising on awareness and policy are central to river cleaning and rejuvenation. In India, the past and large parts of the current efforts and investments on pollution abatement are on construction of sewers and conventional sewage treatment plants. Current and planned investments are yet to address the problems of large but uncontrolled septage disposal and wastewater flows from non-networked sewer areas and non-point source pollution from agriculture and livestock. It is proposed that the new initiatives may be multi-pronged and address the problem holistically through (i) reduced pollution loads from unsewered urban areas and their safe use in agriculture, (ii) development of a viable environmental flow-water quality management system, (iii) support establishment of an innovative Ganga Demonstration centre, or a Ganga University, and (iv) improve governance, communication and implementation capacity of the major stakeholders. These components have good synergy with the cherished objective of securing clean and continuous flow in the Ganges.

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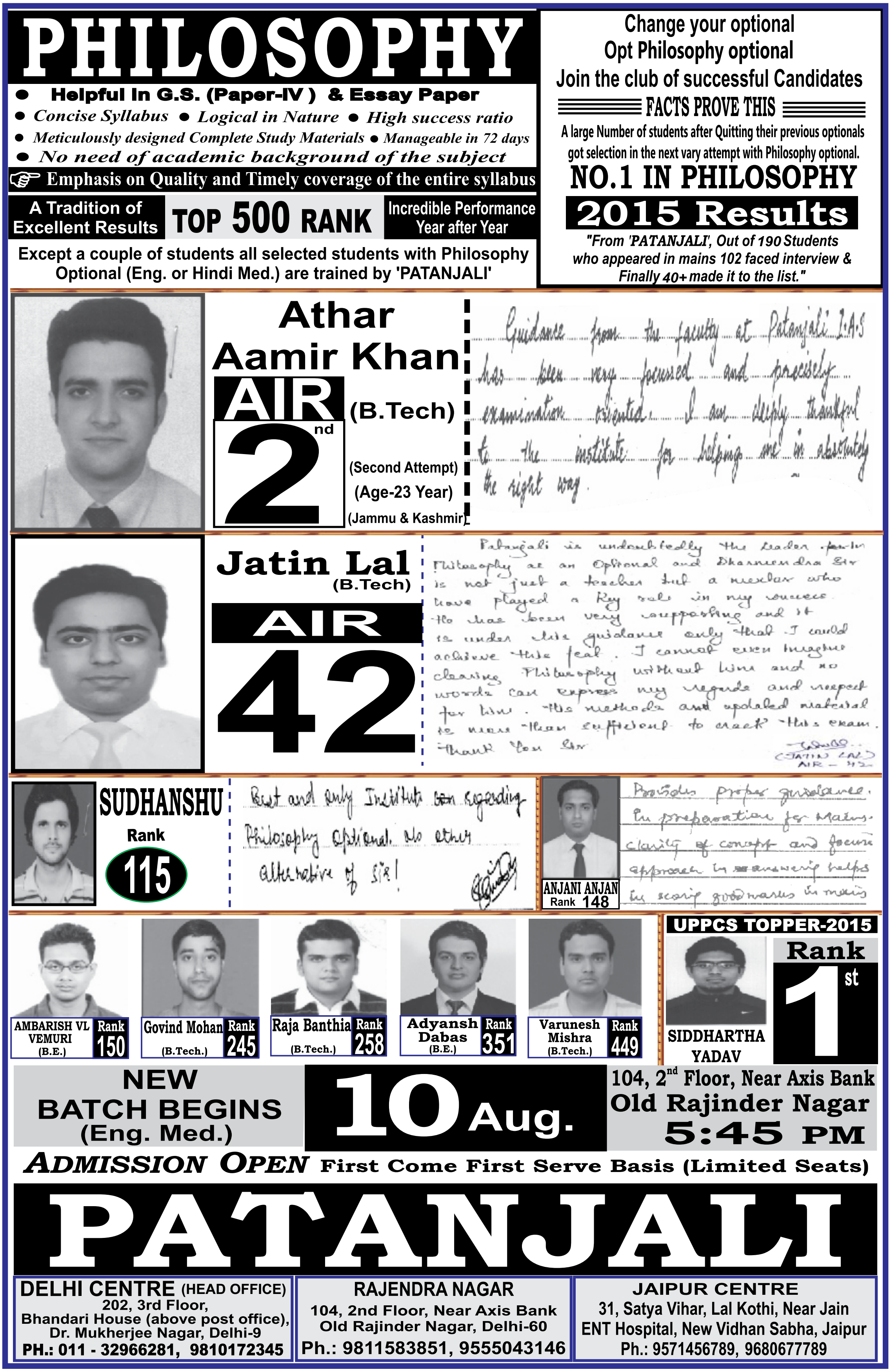
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YE-63/2016

Flood Management: Need for Storage Dams

M S Menon

...there are no universal solutions which can provide complete protection against floods. Hence apart from storage dams, the country also has to focus its strategy to have efficient management of flood plains, flood proofing including disaster preparedness and response planning including flood forecasting and warning and other non structural measures such as disaster relief, flood insurance etc. to mitigate the miseries caused by floods

India, which has 16 per cent of the world's population, has roughly 4 per cent of the world's water resources and 2.45 per cent of the world's land area. Even in the distribution of the available fresh water resources in the country, there are great variations in space and time i.e., between different parts of the country and in different periods in a year. The challenges faced by the water sector in the country are many, such as – the challenge to feed a growing population; challenge to meet their growing aspirations for a better life; challenge to control the floods and droughts occurring every year devastating lives and habitats; and the challenge to ensure sustainable growth process balancing a delicate environmental and ecological system.

Problems of Floods and Droughts

The Indian land mass receives on an average of about 4000 billion cubic metres (BCM) of precipitation and the average annual flow in the rivers is estimated as 1953 BCM, the balance being lost to immediate evaporation and soil moisture. Two-thirds of the water resources is contributed by the Ganga-Brahmaputhra-Meghna (GBM) river basin covering one-third of the geographical area of the country. Consequently, the remaining parts have to be satisfied with the balance resource. Also, over 80 to 90 per cent of the run-off in the Indian rivers occurs in the four monsoon months of June to September resulting in creating regions of harmful abundance of water during the monsoons and acute scarcity in summer. With such a wayward and changing nature, we have to adapt or compensate for these changes to survive. Since a few months account for most of the year's rainfall and consequent water availability, the ability to hold water in reservoirs and spread out its release over the year can mean the difference between devastating floods and droughts.

Due to its vastness, diverse relief features and geographical locations, different regions of the country have varied climates and rainfall patterns. It is not therefore, uncommon to find one part of the country under the grip of severe floods, while another part is suffering under the effects of drought. Many a times, it so happens that even in the same year in a state, some areas have excessive rains and consequent floods while some other areas suffer due to poor rainfall and consequent drought. Thus, the main characteristic of India's water resources is its uneven distribution in space and time leading to endemic and sporadic problems of water shortages and excesses.

The author has worked with the National Commission on Water Resources of MOWR, as a Consultant in Water Resources with the Planning Commission. He was Member Secretary of the Indian National Committee on Irrigation and Drainage, under MOWR. He has been involved with multipurpose water resources development projects in India, Nepal and Bhutan and as a Consultant deputed from Govt. of India with the Iraq Government. He was also involved with their projects on Tigris river and has been regularly writing in the national news papers on the various issues facing the water sector.

Further, the problems during floods get compounded due to human interventions in the river basins. Consequently, the upper catchments get degraded bringing more sediments down causing greater severity of floods and the activities of those encroached and settled in the flood plains downstream result in the loss of lives and property of inhabitants there.

Frequent occurrence of floods and droughts is a reflection of our failure to develop and manage our water resources. Needless to say that water, a key element in our ecosystem, is not getting enough attention except when droughts stalk the country side and floods devastate large tracts of land and habitats. Even then , instead of learning from the failures and taking recourse to obvious and available solutions, the issues are forgotten after providing some relief to the affected people till the next year when the problems again arise.

Flood Control and Management: Past Attempts

The need for flood management was felt in the early fifties and a National Flood Management Programme was launched in 1954[1].The area provided with flood protection then was about 3 million hectares (Mha), with a total length of embankments of around 6000 kms. As per the policy statement made in 1954, the objective set before the nation was to rid the country from the menace of floods by containing and managing the floods. However, it was realised later that absolute immunity from flood damage was not physically possible because of the unpredictability of several events which occur along with worsening situations rendered by manmade activities. Hence, it was decided then to provide reasonable protection measures which were found technically feasible and economically justifiable and to lay greater stress on flood forecasting, flood warning, etc. along with flood management.

A number of National and State level committees were set up subsequently to study the issues and ultimately in 1976, *a Rashtreeya Barh Ayog* (RBA) was set up [2] by the Government of India to review and evaluate the flood protection measures undertaken since 1954 and to evolve a comprehensive approach to the problem of floods as a part of optimum and multipurpose utilisation of water resources and suggest improvements wherever necessary. Area liable to floods was assessed at 34Mha at the time of RBA, when reasonable protection was already provided to an area of 10 Mha. The major concentration of the flood prone areas was found to be in the Ganga-Brahmaputhra-Meghna rivers basin and in the coastal deltas of the Peninsular rivers. Major recommendations made by RBA include flood plain zoning and management to regulate man made activities since periodic displacement and rehabilitation of people from the flood plains during floods had become a common feature.

Subsequently, the Centre had set up Regional Task Forces in 1996 to review the impact of the recommendations of the RBA and to suggest short term and long term measures. Their recommendations included [3], among other administrative measures, construction of large flood moderation projects, particularly in the North-East and following up the enactment of Flood Plain Zoning Act so as to tackle encroachment by people in the flood plains.

The National Commission for Water Resources, in 1999 [4], had also observed that storage dams and embankments provided effective protection to large flood prone areas. The Commission had also suggested the urgent need to enact Flood Plain Zoning Act to prevent human interventions in the flood plains.

In 2004,unprecedented floods in the Ganga and Brahmaputhra rivers necessitated the Centre to constitute a Task Force(TF) to suggest remedial measures. The Task Force had recommended more involvement by the Centre to make flood management efforts effective. The Working Group of the Planning Commission then had also emphasised the need for Central involvement and for setting up a Central Flood Management Organisation.

The National Water Policy, 2012, [5] had suggested that reservoir operation procedures should be evolved and implemented in such a manner so as to have flood cushion and to reduce trapping of sediments during flood season. It has also suggested to incorporate coping strategies for possible climate changes, such as increasing water storage capacity in dams.

Flood Damage Mitigation Works

Damage due to floods is mainly caused by the spilling of the river over its banks and inundating the marginal areas along the rivers. For reducing the damage, protective measures to be taken include structural measures such as storage dams to absorb and regulate the flood flows; and construction of embankments to confine the flows, thereby preventing spilling. Works of channel improvement and improving the drainage conditions in the area are also required to be carried out to address flood conditions caused by such situations. Wherever construction of embankment is not desirable due to acute drainage problems that would arise, schemes for raising such villages and connecting them to the nearby roads are also being implemented.

Flood control measures were taken up in a big way after the National Flood Control Programme was launched in 1954. Since then, more than 35000 kms. of embankments have been constructed and more than 39000 kms. of drainage channels improved. Also, over 7000 villages have been raised and protected and likewise protection works extended to more than 2700 towns/villages. A number of storage reservoirs have also been constructed during this period which have a total live capacity of about 250 BCM [6].

Flood Control and Moderation by Storage Dams

In the case of storage dams planned for flood control, the planning would be to maintain a low reservoir level during high flow months and use the storage capacity to absorb the incoming flood peaks. Soon after a peak passes down, the reservoir is brought down at a controlled rate to the low level to be ready to face the next flood. However, such projects only meant for serving flood moderation would not be usually economically justifiable. On the other hand, multipurpose projects for irrigation and power benefits could be planned to also include flood moderation benefits as well. If irrigation and power alone were the primary objectives, the endeavour would be to ensure a full reservoir level by the end of the filling period (September). In the case of projects planned for multiple benefits which include flood moderation, the attempt would be to seek the optimum combination of possible benefits through the planned operation of the reservoir, keeping in mind the declared purposes and intended benefits. Hence, a rational economic solution to the problem of floods during monsoons is to link it with the water demands for irrigation, power and other uses during the non -monsoon months. Thus, an irrigation and hydropower scheme could be made to provide flood moderation during the high flow period and meet various needs by drawing upon the stored water till the onset of the next monsoon.

When a multipurpose project reservoir is called upon to serve the flood moderation aspect, planned or unplanned, the operating authority is often faced with a difficult choice, particularly when the incoming flood peak occurs towards the end of the filling season. If the high reservoir level is brought down based on inflow forecasts and best judgment, the authority could be still criticised if the reservoir did not fill up later, leading to short falls in meeting the needs. The authority risks equal criticism if the reservoir level is not sufficiently lowered to absorb the incoming peak which would result in flood damages lower down .Self appointed activists against large dams could then quote such instances as man made floods to attack the water professionals. There have been many such cases where the authorities were called upon to explain such situations in the dam projects.

Major Projects Providing Flood Control Benefits

Flood control measures were taken up in a big way after the National Flood Control Programme was launched in 1954. Since then, apart from construction of embankments, improvement of river channels etc., many storage reservoirs were also constructed which could absorb and regulate peak floods when necessary. However, as of now, we have been able to hold back only a little more than 10 per cent of the annually available monsoon flows. Due to many issues, environmental, socio-economic and others coming in the way of executing water resources development projects, the progress in constructing storage projects have been slow in the country since the last few decades with the result that we are still facing the water woes resulting from floods and droughts.

Some such major projects completed after the National Programme was launched in 1954 which provided flood control benefits are the dams of the Damodar Valley Corporation (DVC), the Hirakud Dam on the Mahanadi, Ukai Dam on the Tapi, and the Bhakra Dam across the Sutlej. Some salient features of these projects are discussed as under. Major flood flows could be absorbed and discharges from the dams regulated by these projects to provide safety for the downstream villages and towns. However, when major floods arrive infrequently, such as in a period of one in 25 years etc., flood damages do occur in human settlements in encroached flood zones largely on the river banks and sometimes even in the main river channel , due to release of regulated discharges from the dam into the river channel below, necessitated by dam safety considerations. Enactment of the Flood Plain Zoning Act is the only way to control such situations.

Hirakud Dam

This is a major earth cum masonry dam constructed in 1957 across the Mahanadi river and has a live storage capacity of 5222 million cubic metre(mcm). The full storage is used for moderating floods during the monsoon and thereafter, the stored waters are utilised for irrigation and generating power. Prior to the construction of the dam, the Mahanadi delta used to be ravaged by floods almost every year.

Dams under the Damodar Valley Corporation

A series of four dams have been constructed on the Damodar and Barakar rivers for the moderation of floods and also for irrigation and power benefits. The four dams, namely, Konar, Maithon, Panchet and Tilaiya have a flood storage of 1603 mcm and have been in operation since 1958. These could considerably moderate floods in the lower Damodar region, even though the Maithon and Panchet dams are operating at less than the designed cushion for flood control.

Ukai Dam

The Ukai dam on the Tapi, completed in 1977 has a live storage of 6615 mcm. It has, to a great extent, reduced the flood havoc in the lower reaches and has saved Surat town from flood ravages. The project confers other benefits also, such as irrigation and power generation.

Bhakra Dam

When Bhakra was planned on the Sutlej river, great emphasis was laid on drought management in the region and thus, irrigation benefit was the main consideration while flood issues were not important. However, the fairly large storage of 7190 mcm. was always utilised in such a manner as to render flood moderation benefit for downstream reaches. After the commissioning of the dam in 1963, floods in the first few years of its operation were absorbed in the reservoir. As 65 per cent of the catchment of the river lies in Tibet (China), often the information about flash floods originating upstream does not reach areas downstream till the flood itself arrives. The worst such flood occurred in the year 2000 when the water level of the Sutlej river rose by 15 metres due to flash flood resulting from a cloud burst and temporary blockage of the river in Tibet. Though areas upstream of Bhakra dam were affected by the flood, it was fully absorbed and evened out when it impinged on the reservoir, thereby preventing downstream devastation in Punjab plains.

In the recent past, major projects like the Tehri hydro –project in the Bhagirathi (Ganga), could reduce the flood damages in Rishikesh and Haridwar caused by flash floods in the Uttarakhand region. The dam absorbed and regulated the unprecedented flood flows of 2.5 lakh cusecs which hit the reservoir and released only less than 7 per cent of the flood flows into the downstream river channel. Likewise, Sardar Sarovar Project on the Narmada river has also been able to reduce the flood ravages downstream by regulating the flood flows.

In this connection, the Indian River Linking (IRL) project which envisages construction of storage dams and a network of canal systems across the country to divert the flood waters of the Brahmaputhra and other major rivers to water deficit areas for equitable distribution and optimum utilisation of water, is an important available option to reduce the miseries of floods and droughts visiting the country frequently.

Conclusion

To conclude, it is feasible in most cases to provide a certain degree of protection against floods in terms of reduced frequency and flood damages by having storage dams across major rivers which would be able to absorb the peak floods and regulate the flows downstream into river channels. The proposed IRL project would be an available option to address the problems caused by devastating floods. However, there are no universal solutions which can provide complete protection against floods. Hence, apart from storage dams, the country also has to focus its strategy to have efficient management of flood plains, flood proofing including disaster preparedness and response planning including flood forecasting and warning and other non structural measures such as disaster relief, flood insurance etc. to mitigate the miseries caused by floods.

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(E-mail: msmenon30@gmail.com)

Climate Change and Water Resources

Sharad K Jain

Flood and drought management schemes have to be planned keeping in view the increase in severity of floods and droughts. It would be prudent to incorporate possible effects of climate changes in the design and management of water resources systems. The high magnitude floods are also likely to bring more sediment which may fill reservoir space. The design and management of both structural and non-structural water-resource systems should allow for the possible effects of climate change

Climate of a region represents the long-term (more than thirty years) average of weather. It is a resultant of an extremely complex system consisting of different meteorological variables which vary with time. Climate may be defined as "average weather" or more as the statistical description in terms of mean and variability of relevant weather variables over a period of time.

Climate change (CC) refers to a statistically significant change in either the mean state of the climate or its statistical properties (such as standard deviations, the occurrence of extremes, etc.), persisting for an extended period particularly decades or longer. Climate change is not only a major global environmental problem, but also an issue of great worry to a country like India.

Causes of Climate Change

CC can take place due to forcings that may be external to Earth or internal. Two external forcings are important. Earth's orbit and tilt of its rotational axis are changing slowly, caused by gravitational forces of other planets and orbit of solar system about the centre of Galaxy. 'Milankovitch Cycles' is the collective name for cycles in Earth's movement. Changes in these cycles cause very slow and long-term climate change. Three types of orbital variations are identified. Tilt of Earth's axis with respect to plane of orbit varies between 22.1° to 24.5° in about 41,000 years. The tilt does not impact total solar radiation received, but the space and time distribution changes. Next, axial precession is the gradual shift in orientation of Earth's axis of rotation relative to fixed stars, in a cycle of ≈26,000 years. When this axis is aligned to point towards Sun during perihelion, one polar hemisphere will have a greater difference between seasons while the other will have milder seasons. Finally, eccentricity of Earth's orbit around the Sun controls shape of Earth's orbit around Sun and the radiation received.

Internal forcing mechanisms of CC operate within the climate system. Great volcanic eruptions release huge amounts of gases, ash and aerosols and impact climate by reducing solar radiation reaching Earth. GHG emissions due to combustion of fossil fuels to generate electricity, heating, and transport account for ≈ 70 per cent of total emissions and are the main cause of global warming. Movement of tectonic plates has a direct connection between uplift, atmospheric circulation, and hydrologic cycle.

Greenhouse Effect: Short-wave radiation from the Sun passes through the Earth's atmosphere which contains different gases. A part of this radiation

The author is NEEPCO Chair Professor at IIT Roorkee. He has co-authored four books, edited 5 books and written number of technical papers. He is a member of many national and international committees.

is reflected back into space, a part is absorbed by the atmosphere and the remainder reaches the earth's surface where it is either reflected or absorbed. In particular, the earth's surface emits long-wave radiation towards space. Some of the gases in the atmosphere absorb a part of the long-wave radiation emitted by the Earth's surface and re-radiate it back to the Earth, forcing it to warm. These gases help modify the heat balance of the Earth by retaining long-wave radiation that would otherwise be dispersed through the Earth's atmosphere to space (Fig.1). This effect is known as the greenhouse effect and the gases causing this are called greenhouse gases (GHGs). The principle greenhouse gases present in the atmosphere include carbon dioxide (CO_2), nitrous oxide (NO_2), methane (CH_4), water vapour, chlorofluorocarbons (CFCs) and ozone (O_3).

Obviously, GHGs have an important role in controlling the temperature of the Earth and keeping it sufficiently warm for life to survive but excess of these gases is having harmful

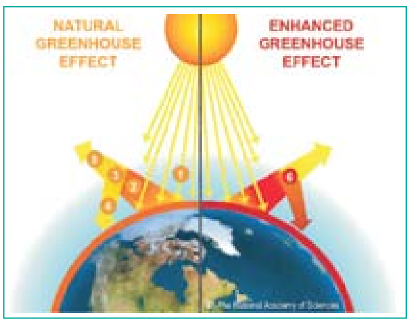

Figure 1: Illustration of the greenhouse effect (Source: National Academy of Sciences). Visible sunlight passes through the atmosphere without being absorbed. Some of the sunlight hitting the earth is (1) absorbed and converted to infrared radiation (heat). The surface (2) emits infrared radiation to the atmosphere, where some of it (3) is absorbed by GHGs and (4) re-emitted toward the surface; some of the infrared radiation is not trapped by GHGs and (5) escapes into space. Human activities that emit additional GHGs to the atmosphere (6) increase the amount of infrared radiation that gets absorbed before escaping to space, thus enhancing the greenhouse effect and amplifying the warming of the earth.

consequences. An increase in the levels of GHGs would lead to greater warming which could have major impact on the world's climate, leading to CC. Fig. 2 shows the gradual rise in concentration of CO_2 in the atmosphere in recent times. Global atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased from 280 parts per million to 399 ppm, 722 (part for billion) to 1834 ppb and 270 ppb to 328 ppb respectively, between pre-industrial period (1750) and 2015. In addition, presence of excess quantities of CFCs adversely affects the protective ozone layer which deflects the harmful short-wave rays.

Evidence of Climate Change

The Fifth Assessment Report of IPCC (2015) has produced many evidences which clearly show that global warming is indeed happening. Observed thermometer data at many places on Earth are available back to 1850. Record-high average global surface temperatures have been observed in recent decades. Earth's surface in each of the last three decades has been successively warmer compared to any preceding decade since 1850. IPCC (2014) notes that the period from 1983 to 2012 was likely the warmest 30-year period of the last 1400 years in the Northern Hemisphere. The globally averaged combined land and ocean surface temperature data as calculated by a linear trend shows a warming of 0.85 [0.65 to 1.06] °c over the period 1880 to 2012, when multiple independently produced datasets were used (Fig. 3).

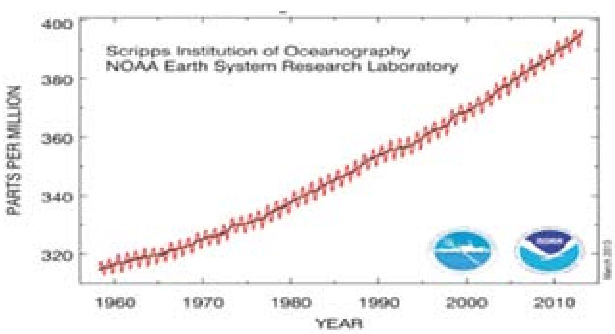

Fig. 2: Changes in concentration of CO_2 in the atmosphere in recent times (Source: NOAA).

Climate Change Impacts On Water Resources

To identify the initiatives that the professionals and decision makers need to take to overcome the adverse impacts of climate change on water resources, first, it is necessary to determine the likely impacts.

General circulation models or global climate models (GCMs) that represent physical and chemical processes in the atmosphere, Cryosphere, land surface, and ocean are the most advanced tools to simulate the response of the global climate system to rising concentrations of GHGs. Although, GCMs are very complex, only these models can provide physically consistent estimates of regional climate change that are required in impact analysis (http://www.ipcc-data.org/guidelines/pages/gcm_guide.html).

GCMs represent the climate using a 3-dimensional grid over the Earth, which typically has horizontal resolution between 250 and 600 km, 10 to 20 vertical layers in the atmosphere and about 30 layers in the oceans. Their resolution is thus, quite coarse relative to the scale at which data are required in most impact assessments. Moreover, many physical processes, such as thunderstorms, occur at smaller scales and cannot be properly modelled by many GCMs. Instead, their properties are averaged over the larger scale by way of parameterization. Different GCMs may simulate quite different responses to the same input forcing depending on the way certain processes and feedbacks are modelled. For example, some models are able to closely simulate the Indian summer monsoon rainfall but many models cannot. Results of GCM simulations are available as time series of climatic variables. For example, hydrologists may be interested in the time series of

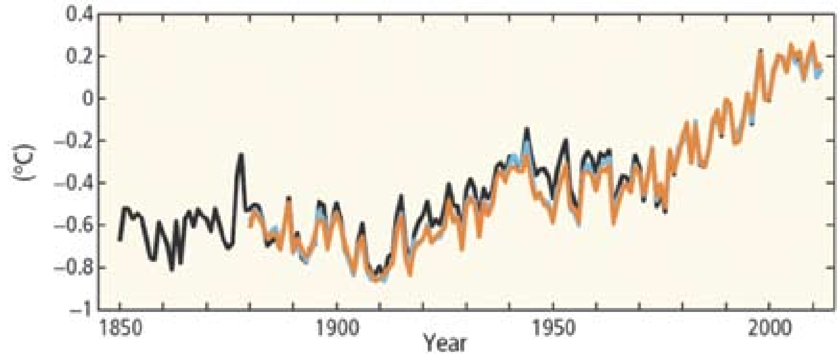

Fig. 3: Globally averaged combined land and ocean surface temperature anomaly (Source: IPCC).

temperature at a location for the period 2025-2075.

To identify the likely impacts of Climate Change on water resources, the following methodology can be followed:

- Select the GCM that closely simulates the climatic variables for the region of interest.
- Downscale (see below) the relevant GCM variables as per the requirement of the chosen hydrologic model.
- Use the hydrologic model to simulate the response of the catchment under future climatic conditions.
- Outputs from the hydrological models serve as inputs to water management models that can be employed for river planning, updating reservoir operation policy, etc.

Downscaling

In climate change studies, the time scales could vary from a short time interval of 5 minutes (for urban water cycle) to a year. Likewise, the spatial resolutions could vary from a few square kilometers (for urban watersheds) to several thousand square kilometers (for large river basins). Global Climate Models (GCMs) which simulate the global climate are among the best available tools to compute the global climatic variables. But these models, so far, are unable to reproduce well the details of regional climate conditions at temporal and spatial scales of relevance to hydrological studies. As noted earlier, outputs from GCMs are usually at a resolution that is too coarse for many climate change impact studies.

Many impact models require information at scales of 10 km or less. So an appropriate method is needed to estimate the smaller-scale information by using the large scale data. Downscaling tries to obtain small-scale (often station level) variables by using larger (GCM) scale variables. In other words, downscaling techniques are commonly used to address the scale mismatch between coarse resolution GCM output and the regional or local catchment scales required for climate change impact assessment and hydrological modeling.

Currently, two broad categories of downscaling procedures are used: a) dynamical downscaling (DD) techniques, involving the extraction of regional scale information from large-scale GCM data based on the modeling of regional climate processes, and b) statistical (or empirical) downscaling (SD) procedures that make use of the empirical relationships between observed (or analyzed) large-scale atmospheric variables and observed (or analyzed) small scale (or stations) data. Fig. 5 depicts the general approach and need for downscaling.

Climate Change: Adaptation and Mitigation

According to IPCC, adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation can be of different types. Anticipatory or proactive adaptation takes place before impacts of climate change are observed. Adaptation that is not in response to climatic inputs but is triggered by changes in natural systems and by market or welfare changes in human systems is called as autonomous or spontaneous adaptation.

IPCC defines mitigation as: “An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (GHG).” Related to CC, mitigation is any action taken to permanently eliminate or reduce the long-term risk and hazards of climate change to human life and property. Mitigation of climate change is a global responsibility. Agriculture and forestry have significant potential for GHG mitigation. While mitigation

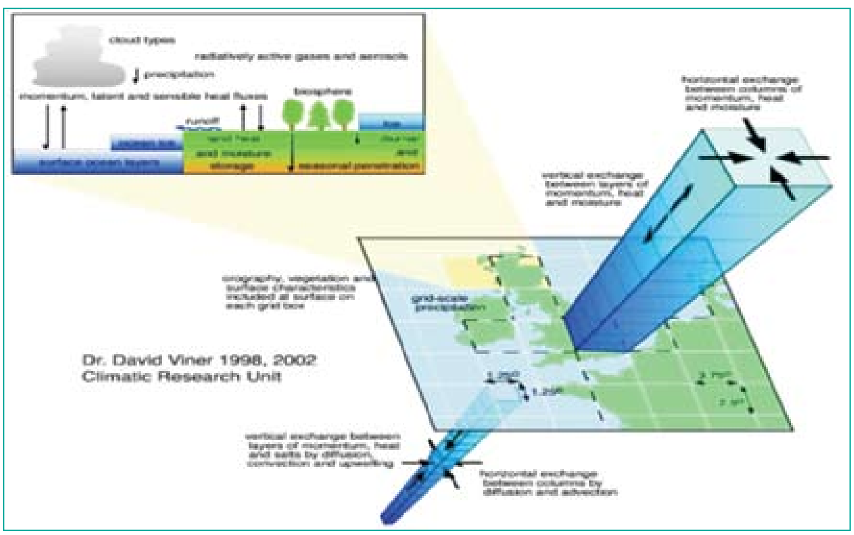

Fig. 4: Discretization scheme used in a GCM (Source: IPCC).

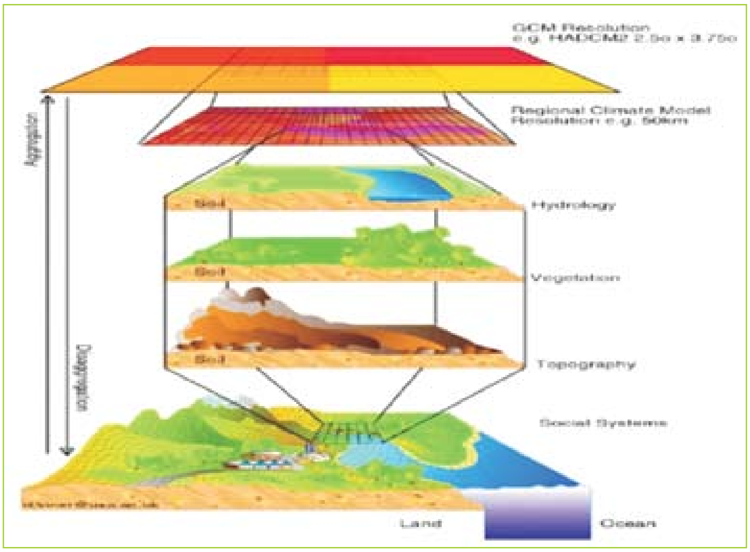

Fig. 5: A schematic illustrating the general approach and need for downscaling (Wilby & Dawson 2007).

tackles the causes of climate change, adaptation tackles its effects. The potential to adjust to minimize negative impact and maximize any benefits from changes in climate is known as adaptive capacity.

In general, the more the mitigation, the less will be the impacts to which the society will have to adjust, and the less the risks for which people will have to be prepared. Conversely, the greater the adaptation, lesser will be the impacts associated with any given level of CC. Adaptation should be viewed as an active adjustment in response to expected changes. Less mitigation means greater climatic change, requiring more adaptation. This is the basis for the urgency surrounding reductions in emission of GHGs. Climate mitigation and adaptation should not be seen as a combined set of actions in an overall strategy to reduce GHG emissions.

Economic diversification within sectors to reduce dependence on climate-sensitive resources, particularly for countries that depend on limited and climate-sensitive economic activities, such as the export of climate-sensitive crops, is an important adaptation strategy. Farmers in India may diversify to tasks related to agriculture, such as dairy business, fish cultivation, fruit preservation, animal husbandry, etc.

Renewable energy systems such as hydro-electricity can help attaining energy security and protect environment. One means of reducing carbon emissions is by larger use of new technologies such as renewable energy (say wind power). Most forms of renewable energy generate no appreciable amounts of GHGs.

Land-use Change and Management

Land management practices implemented for climate change mitigation may also have different impacts on water resources. Many of the practices advocated to conserve soil carbon– reduced tillage, more vegetative cover, greater use of perennial crops – also control erosion and help improve water quality. These practices may also have other potential adverse effects, e.g., enhanced contamination of groundwater with nutrients or pesticides via leaching under reduced tillage. These possible negative effects, however, have not been widely confirmed or quantified, and the extent to which they may offset the environmental benefits of carbon sequestration is uncertain.

Afforestation or Reforestation

Plants are known to take up carbon dioxide in the process of photosynthesis and are sinks of carbon. Therefore, if forests are developed in a region, they will help mitigate climate change. Besides, forests have numerous other benefits including improved environment. It may also be added that the role of forests in the hydrologic cycle is highly context dependent and there are several myths surrounding forests.

In general, forests use more water (transpiration plus evaporation of water intercepted by canopies) than crops, grass, or natural short vegetation. This effect, in lands that are subjected to afforestation or reforestation, may be related to increased interception loss, especially where the canopy is wet for a large proportion of the year or, in drier regions, to the development of more massive root systems, which allow water extraction and use during prolonged dry seasons (IPCC Technical papers).

Newly planted forests can use more water (by transpiration and interception) than the annual rainfall, by mining stored water. Extensive afforestation or reforestation in the dry tropics can therefore, have a serious impact on supplies of groundwater and river flows.

Afforestation and reforestation have many good hydrological effects. After afforestation in wet areas, the amount of direct runoff initially decreases rapidly, then gradually becomes constant, and baseflow increases slowly as age of trees increases (Calder 1990). This suggests that reforestation and afforestation help to reduce small floods and enhance water conservation. In water-limited areas, afforestation involving species with high water demand can significantly reduce streamflow. This may reduce water to other ecosystems elements and affect recharge. In addition, some possible changes in soil properties are largely driven by changes in hydrology. The hydrological benefits of afforestation are highly context dependent. Afforestation of previously eroded or otherwise degraded land may have a net positive environmental impact.

Impact of Climate Change on Indian Water Resources

Availability of numerous water bodies and perennial river systems makes the Indian sub-continent one of the wettest places in the world. Large Himalayan Rivers including Indus, Ganga and Brahmaputra are perennial sources of freshwater though the flow is reduced during non-monsoon periods. Flow in the peninsular rivers mainly depends on the monsoon rainfall and ground water recharge. Changes in temperature, precipitation and other climatic variables are likely to influence the amount and distribution of runoff in Indian rivers. The impact of future climatic change is expected to be more severe in developing countries such as India, whose economy is largely dependent on agriculture and is under stress due to population increase and associated demands for energy, fresh water and food.

The importance of Himalayan river systems can be gauged from the fact that these three river systems contribute more than 60 per cent to the total annual runoff from all the rivers of India. These rivers carry substantial contribution from the melting of snow and glaciers. The runoff of the Himalayan rivers is expected to be highly vulnerable to climate change because warmer climate will increase the melting of snow and ice. Melting of glaciers, and reduction in solid precipitation in mountain regions would have a direct impact on water resources affecting the drinking water, irrigation, hydropower generation and other uses of water. Glacial melt is expected to increase under changed climate conditions, which would lead to increased summer flows in some river systems for a few decades, followed by a reduction in flow in case glaciers retreat continuously.

With an economy closely linked to its natural resource base and climatically sensitive sectors such as agriculture, water and forestry, India may face a major threat because of the projected change in climate. It is likely that the frequency of floods and droughts will increase during the 21st century. Changes in the amount, patterns and intensity of rainfall would affect stream flow and the demand for water. High flood levels can cause substantial damage to key economic sectors: agriculture, infrastructure and housing. Although, floods affect people of all socio-economic status, the rural and urban poor are the hardest hit. Flood and drought management schemes have to be planned keeping in view the increase in severity of floods and droughts. It would be prudent to incorporate possible effects of climate changes in the design and management of water resources systems. The high magnitude floods are also likely to bring more sediment which may fill reservoir space. The design and management of both structural and non-structural water-resource systems should allow for the possible effects of climate change. Despite uncertainties, possibility of changes in such extreme events is quite alarming.

Actions Needed:

1. Improve hydro-meteorological network for better monitoring.
2. Update basin wise water availability in the current situation.
3. Determining extent of current climatic/hydro-meteorological variability and future projections in variability due to climate change including the impact on rainfall frequency and intensity.
4. Generate reliable downscaling of GCM projections to regional and basin level.
5. Assess impact of CC on surface and ground water availability and their interaction (with specific emphasis on coastal areas).
6. Assess impact of CC on Land-Use/Land-Cover and their coupled impact on water resources.
7. Assess impact of CC on rainfall Intensity-Duration-Frequency relationships in urban areas.
8. Assess impact on magnitude-duration-frequency of drought (agricultural, meteorological and hydrological).
9. Assess impact on sediment loads and management implications.
10. Review hydrological planning design, and operating standards in view of changed scenario.
11. To cope up with enhanced scarcity and variability in the water sector, develop adequate infrastructure.
12. Develop databases and tool-boxes and practice Integrated Water Resources Management (IWRM).

Conclusion

Scientific understanding of the causes of climate change has progressed dramatically in the past few years. Natural internal variability is an inherent feature of the climate system, but it cannot account for the net gain of energy that has been detected within the climate system as a whole. Based on physical principles, the modern increase in the heat content of the global ocean demonstrates that positive external forcing of the climate is underway. Changes in natural external forcings cannot explain the observed global warming of recent decades. Records of observed climate change at the Earth's surface, in the global ocean, and in the atmosphere, bear the fingerprint of the enhanced greenhouse effect, which is caused by human activities associated with fossil fuel burning and land use.

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(E-mail: s_k_jain@yahoo.com)

Safe Water for Good Health

S K Sarkar

...sanitation, hygiene and safe water are the basic requirements for good health. Our national policies and state policies in these areas should complement each other. In addition, there should be institutional synergy as well, for administering these policies at various levels

Globally, only 0.4 per cent of total water on mother Earth is at our disposal for meeting our needs, of which, roughly 70 per cent is used for agriculture, 22 per cent for industry and 8 per cent for domestic purposes. By 2030, an estimate by 2030 Water Resources in its report "Chartering Our Water Future" shows that the global fresh water demand would be about 40 per cent above the existing reliable and sustainable supply of fresh water. Due to climate change, there could also be variability of water availability across nations over time.

India's water sector is showing a sign of water stress in terms of per capita availability and heading towards water scarcity in the near future. Severe water crisis would imply, inter alia, more water borne diseases, low agricultural and industrial productivity, and drinking water shortage. Today, the water sector in India presents a dismal scenario when one looks at its quality, which reduces further availability of safe water. About 70 per cent of the surface water and ground water are contaminated.

The quality of water is measured by the presence of some'beyond threshold level' parameters in water. In the case of fresh water, these parameters, inter alia, include biological oxygen demand (BOD) level, level of total coliform and faecal coliform, while for ground water, level of trace elements,extent of saline-fresh water interface, inter alia, determine the level of contamination.Such trace elements may include arsenic, heavy metals, etc. A recent report of Central Pollution Control Board (CPCB 2013)points out contamination of river water at identified points when measured, inter alia, in terms of BOD, and coliform bacterial count, thus indicating the extent of water quality degradation in different parts of India. In the case of ground water, inland salinity, coastal salinity, fluoride, arsenic, iron, nitrates are some of the contaminants. States such as Rajasthan, Gujarat, Bihar, Assam, amongst others, are affected by such contamination.

The river water gets contaminated mainly due to inefficient functioning of ETPs (Effluent Treatment Plants), CETPs (Common Effluent Treatment Plants), STPs (Sewage Treatment Plants) resulting in dumping of untreated industrial wastes into the river; discharging of untreated municipal wastes into rivers; lack of onsite treatment of contaminants; non point sources of pollution including pesticide contaminated agricultural run off, piling up of materials at most river banks for religious uses, etc.

The author is Distinguished Fellow and Director, Water Resources and Forestry Division in TERI, New Delhi and a former Secretary, Ministry of Water Resources, Govt. of India. He has several publications to his credit in national dailies and national and international journals and also in the form of mimeograph. He has also authored and edited books on infrastructure issues.

In the case of ground water, contamination takes place due to excessive drawal of ground water resulting in inland salinity, due to saline water overlying fresh water acquifer, the presence of fluoride minerals in both igneous and sedimentary rocks, and use of arsenic and its compounds in pigments as pesticides and herbicides, etc. For example, against all India average of ground water withdrawal of 61 per centage, Punjab and Haryana withdraw more than 100 per cent, and thus, inland salinity is more prevalent in the arid/semi arid region of these states. The presence of arsenic is seen in the intermediate aquifers of 200-100 meter range while deep aquifer is free from this problem.

In case of most cities and the towns situated on the river side, discharge of untreated municipal waste into the river is a regular phenomena. For example, the Rajpur drain in Patna running parallel to the Ganga, discharges the drainage of the entire city into the river, thus contributing to the high faecal coliform content of the river. Similarly, in the case of Gurgaon city, which claims to treat about 50 per cent sewerage generated daily before discharging them into the Yamuna river, the remaining 50 per cent are left on open land, thus allowing them to seep into the ground, resulting in contamination of water. The real challenge is how to motivate the municipal authorities which are starved of expertise and financial resources, for treatment of all city sewerage after intercepting the same at suitable points, before discharging them into the river or otherwise.

The non point pollution coming from varied sources (e.g run off from agricultural fields) carries sediments, chemicals or pesticides. There is a need to arrest generation of contaminants before they become mobile or treat pollutants already in transit before they reach the river. Preventive measures such as structural, non-structural methods, source control measures, or treatment of pollutants in transit, can be used depending on the situation.

...there should be conservation and refurbishing of old surface water sources such as ponds, lakes, etc. There is a need to invest in a portfolio of technology options after adopting the pilot testing of new technologies before their implementation, As regards implementation of arsenic removal program, community scale approach should be better adopted. Public private partnership for implementation should be attempted with adequate supervision by agencies like PHED (Public Health Engineering Department) for ensuring quality, quantity and transparency.

Arsenic Menace

In order to protect health and prevent sickness and mortality, water supply should be of good quality and accessible to all users. Quality of water as stated earlier is often affected due to natural contamination such as arsenic chloride. Arsenic is probably the most dangerous component out of all the natural contaminants. Asia is the most arsenic affected area due to various reasons: about 90 per cent of people known to be affected due to arsenic in drinking water, live in Asia. The most seriously affected countries in South East Asia are situated in the river basins of Ganga, Brahmaputra and Mekong covering countries such as India, Bangladesh, Nepal, Myanmar, Thailand, Laos, Cambodia and Vietnam. The two Asian countries which are also seriously affected are China and Taiwan. It is reported that more than 150 million people live in the arsenic prone areas.

Drinking of arsenic rich water over a long period is unsafe as arsenic is a documented carcinogen. The common symptoms of chronic arsenic poisoning include hyper pigmentation, dye pigmentation and keratosis, which may turn into skin cancer and even lung cancer. Secondly,the food chain is also likely to get affected resulting in toxic implications affecting communities who do not even live in arsenic polluted zones. Reports show that there is a significant level of arsenic which goes into the body through food products (such as grains, vegetables, fruits) being cultivated using arsenic contaminated water or food being cooked using arsenic contaminated water.

Arsenic Remedial Strategy

First, adequate steps should be taken for framing policies on mitigation of arsenic contamination. The policies may include use of rain water, or safe surface water or safe sub surface water resources. As far as possible, there should be conservation and refurbishing of old surface water sources such as ponds, lakes etc. There is a need to invest in a portfolio

of technology options after adopting the pilot testing of new technologies before their implementation. As regards implementation of arsenic removal program, community scale approach should be better adopted. Public private partnership for implementation should be attempted with adequate supervision by agencies like PHED (Public Health Engineering Department) for ensuring quality, quantity and transparency.

Second, there is a need for proper monitoring, surveillance and risk management for the mitigation of arsenic menace. Water quality monitoring should include source coding, depth of well and use of GPS (Geographic Positioning System). There should be involvement of the community. Surveillance of arsenic contaminants should include testing of PH, iron, phosphate, bicarbonate, manganese, and sulphate. There should be protection of sources through artificial recharge and *in situ* dilution of contaminants and monitoring of water levels.

Third, food safety needs should be given the maximum attention to control entry of arsenic in the food chain. Specification of arsenic in various foods is urgently required. FSSAI (Food Safety and Standards Authority of India) limits of metal contaminants in food products should be strictly followed. The entire food safety chain needs to be routinely monitored by assessing entry of arsenic through water used for cultivation as well as through water used for cooking. People living in non-endemic areas are also at risk due to food import from endemic areas. Infants are more at risk due to higher consumption of arsenic per body mass. Pharmacists and health care workers should take active participation in public health programmes. There is a need for use of GIS (Geographic Information System) model for discovering new arsenic contaminated areas.

Fourth, is the need for adequate investment for ensuring water quality and water safety at national and state levels. The marginal population should also be included under the arsenic mitigation scheme. There is a need for creating peoples' awareness and they have to be involved at every step. A proper communication strategy should be developed. Also, behavior change of the population in the affected areas and the community mobilization are critical.

Open defecation implies a lack of safe disposal of human excreta, thereby affecting the health of people. In particular, ground water is contaminated in addition to contamination of surface water. Of human excreta, faeces are most dangerous to health; diarrhoeal diseases are the most faeco-oral diseases globally, causing more than one million deaths annually. There is a need for safe management of faecal waste: right from emptying, transport, and treatment to reuse or disposal.

Open Defecation

More than 50 per cent open defecators of the world live in India. India was not able to meet the MDG (Millenium Development Goals) Target 2015 for improved sanitation. The Joint Monitoring Program (JMP) of the United Nations (2015) show that about 564 million people practise open defecation in India out of 964 million open defecators of the world. India's urban slums and rural areas both suffer from this problem. About 17 per cent of urban notified slum population and more than 50 per cent in non notified slum areas do not have access to improved sanitation facilities. Thus, they defecate in open areas.

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The problem of open defecation is bigger in smaller cities (cities with population below 100,000).As per 2011 Census, there are 81.4 per cent households, with toilets of various types: septic tanks (38.2 per cent), pit latrines (8.8 per cent), insanitary latrines (1.7 per cent), sewerage connection (32.7 per cent), while 18.6 per cent have no household toilets-they use community toilets (6 per cent) or defecate openly (12.6 per cent). Improved sanitation together with safe water and good hygiene is necessary for good health and sustainable development. The Swachh Bharat Mission (urban) program of the central government, which intends to eliminate open defecation completely by 2019, is a right step in this direction.

Need for Holistic Approach

First, sanitation, hygiene and safe water are the basic requirements for good health. Our national policies and state policies in these areas should complement each other. In addition, there should be institutional synergy as well, for administering these policies at various levels.

Second, as regards ground water, the central government's initiative for mapping the entire acquifer during the 12 th Five Year Plan and thereafter, is a timely initiative if implemented, but this needs to be supplemented with participatory management by various stakeholders. This is a gigantic task, as stakeholders need to be convinced on the efficacy of this approach and be involved. By knowing the acquifer status of ground water, various remedial actions such as recharging, rain water harvesting, removing ground water contamination can be undertaken in a joint collaborative arrangement between stakeholders and the government. On the regulatory side, the existing "Easement Act" which allows any land owner to extract ground water in spite of the fact that such a withdrawal may affect adversely other users, needs to be relooked and modified.

Third, there is a need to implement the basin level water management concept, rather than river centric approach. Also, the synergy between surface water and ground water has to be appreciated and recognized. Sources of contamination, point sources such as industries, and non point sources such as agricultural run off, should be identified, and arrested. The Namami Gange program of the central government is a good example for applying the above concept to some extent. Under this program, there are initiatives in areas such as having clean effluent discharges from nearby industries, river front development, arresting non-point sources of pollution, monitoring on real time basis, solid waste management, conservation of wetlands, rural sanitation facilities along the river Ganga, pious refuse management and improved methods of last rites, afforestation-conservation of flora, conservation of biodiversity including acquatic life, etc. A replication of such initiatives should be introduced in other rivers as well.

Fourth, a massive awareness building program for various stakeholders is called for at the central, state, and sub national levels for understanding the extent of health hazards being posed by the degraded water quality, absence of sanitation, poor hygiene, and poor faecal waste management. Towards this campaign, civil society can play a big role to supplement the efforts of the governments.

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(E-mail: sksarkar@teri.res.in)

CONSEQUENCES

Water Scarcity: Affecting the Vulnerable

Vandana Shiva

A Folk Song of Rajasthan

She sends me to fetch water, Very early in the morning, Oh! Grandfather it is very difficult for me My pot never fills up fully, The water is so deep, That my rope hardly reaches it, The sun rises and also sets, By the time, I return, Unable to collect even one pot-full of water"

Throughout history and across the world, water rights have been shaped both by the limits of ecosystems and by the needs of people. In fact, the root of the Urdu word abadi, or human settlement, is ab, or water, reflecting the formation of human settlements and civilization along water sources. The doctrine of riparian rights – the natural rights of dwellers supported by a water system, especially a river system, to use water-also arose from this concept of ab. Water has traditionally been treated as a natural right – arising out of human nature, historic conditions, basic needs, or notions of justice. Water rights as natural rights do not originate with the state; they evolve out of a given ecological context of human existence

Water has become the most scarce and commodified product of the 21st century. This may sound bizarre, but true. In fact, water is to the 21st century, what oil was to the 20th century. The stress on the multiple water resources is a result of a multitude of factors. On one hand, the spread of water intensive Green Revolution agriculture, the rapidly rising population and changing lifestyles have increased the need for fresh water. On the other hand, intense competition among users-agriculture, industry and domestic sector is pushing the ground water table deeper, diversion of river waters for intensive irrigation and urban industrial use has left our rivers dry. What remains is polluted with dumping of industrial and urban wastes, making our lifelines like the Ganga and Yamuna unfit for drinking.

To get a bucket of drinking water is a struggle for most women in the country. The virtually dry and dead water resources have led to acute water scarcity, affecting the socio-economic condition of the society. The drought conditions have pushed villagers to move to cities in search of jobs. Whereas women and girls are trudging still further. This time lost in fetching water can very well translate into financial gains, leading to a better life for the family. If opportunity costs were taken into account, it would be clear that in most rural areas, households are paying far more for water supply than the often-normal rates charged in urban areas. Also, if this cost of fetching water which is almost equivalent to 150 million women day each year, is covered into a loss for the national exchequer, it translates into a whopping 10 billion rupees per year.

Most women and girl children in Rajasthan find themselves in difficulties for most part of the year. They trudge bare foot in the hot sun for hours over wastelands, across thorny fields, or rough terrain in search of water, often the colour of mud and brackish, but still welcome for the parched throats back home. On an average, a rural woman walks more than 14000 km a year just to fetch water. Their urban sisters are only slightly better off- they do not walk such distances, but stand in the long warding queues for hours on end to collect water from the roadside taps on the water lorries.

The author is Founder, Research Foundation for Science, Technology and Ecology (RFSTE) and Navdanya, meaning "Nine Seeds," or "New Gift" in Hindi. She has written books on the Green Revolution, corporate led globalization,and gender issues. Was a founding Board Member of the Women Environment and Development Organization (WEDO). She has also initiated Diverse Women for Diversity, an international movement of women working for food and agriculture. She is on the National Board of Organic Standards of India, serves on Prince Charles's expert group on Sustainable Agriculture and she is a member of President Zapatero's Scientific Committee in Spain.

In every household, in the rural areas in Rajasthan, women and girl children bear the responsibility of collecting, transporting, storing, and managing water. In places, where there is no water for farming, men migrate to urban areas in search of work leaving women behind to fend for the old and the children. Women spend most of their time, collecting water with little time for other productive work. This impacts on the education of the girl child. If the girl is herself not collecting water, she is looking after the home and her siblings when her mother is away.

The government has accorded the highest priority to rural drinking water for ensuring universal access as a part of policy framework to achieve the goal of reaching the unreached. Despite the installation of more than 3.5 million hand pumps and over 116 thousand piped water supply schemes, in many parts of the country, the people face water scarcity almost every year thereby meaning that our water supply systems are failing to sustain despite huge investments.

In India, there are many villages either with scarce water supply or without any source of water. If there is no source of potable water in 2.5 kilometres, then the village becomes no source water village or problem village. In many rural areas, women still have to walk a distance of about 2.5 kms to reach up to the source of water. She reaches home carrying heavy pots, not to rest, but to do other household chores of cooking, washing, cleaning, caring of children and looking after livestock. Again in the evening she has to fetch water. Thus, a rural woman's life is sheer drudgery.

In the cases of villages of Plachimada in Kerala, Raja Talab in UP and Kala dera in Rajasthan, ground water mining of millions of litres per day by some multi-nationals has created a water famine. Apart from the water scarcity caused in Plachimada, the other districts in the state are also facing the water crisis. For instance, in Kottayam district at some places, the water scarcity is so acute that people hesitate to offer a glass of water to the visitor, which hitherto was a common custom. In the upper Kuttanadu area of the district, during summer a people collect water from a distance of 3-4 kms. Water supply from public taps is erratic and very often even after standing for an hour in the queue, people are not able to get a bucket of water.

For Maharashtra, water is an abiding concern. In many villages women have to walk more than 3 kilometres everyday to fetch two huge vessels of water illegally from a government reservoir. They have to make at least three trips everyday.

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The state government does not send tankers to the villagers. At some places, women spend Rs 5 for two cans of water. Images of women carrying the pots of water, walking miles and miles for one single pot are common in the state of Maharashtra. Women in Maharashtra have carried the water burden both as a result of scarcity and abundance. Drought displacement due to dams and irrigation have contributed to increasing water burden of women. Women in Nandurbar district of North Maharashtra share their woes "forget about getting safe drinking water from wells, we spend most of our time locating streams and springs that quench our thirst". Many women came as a bride, their hair have gone dry, but the search for water has not ended.

We have violated our duty to protect our soil and water. Now the violence committed on nature is translating into an emergency for humans. And nowhere is this more evident than in Maharashtra's Marathwada. This year, the Godavari river in Nashik went dry. There is no water in Ramkund — the sacred pond in Nashik where devotees come to bathe in during the Kumbh. In the town of Latur in Marathwada, water scarcity is so severe that the district collector has imposed Section 144 of the CrPC (making assembly of more than 10 people unlawful) for two months to prevent law and order problems arising from the water crisis. The administration has taken over 150 wells and tubewells near the city because the dam that supplied water to Latur's population of 4.5 lakh and adjoining rural areas dried up in March 2016.

In Bundelkhand, women have no work but to collect drinking water on their heads from long distance. The grim situation of water may be best illustrated by one Bundelkhandi saying which roughly translated as "let the husband die but the earthen pot of water should not be broken".

The scenario is worst in Patha in Chitrakut district where women have to travel a long distance to collect water for drinking. Half of the time of women is spent to collect water, which affects their health and the well being of their children. The paucity of time due to water crisis aggravates the domestic problem.

In brief, at an estimate about 150 Million-Woman Days and Rs 10 Billion are lost in fetching water.

Water is the biggest crisis India is facing in terms of spread and severity, affecting one in every three persons. Over 33 crore Indians are affected by the drought in 2016. Even in Chennai, Bengaluru, Shimla and Delhi, water is being rationed and India's food security is under threat. With lives and livelihood of millions at risk, urban India is screaming for water.

Water was being supplied by tankers after a water train brought water all the way from Kota. While the drinking water emergency will be addressed in the short run through these measures, rejuvenating our water systems needs a fundamental shift in the agriculture paradigm. In the 1980s, I was asked by the then Planning Commission to look at why Maharashtra's requests for budgets to provide drinking water kept increasing, and yet the water crisis never got solved. My research showed that the drought of 1972 was used by the World Bank to promote sugarcane cultivation, requiring intensive irrigation based on water mining through tubewells and borewells, just as the drought of 1965 was used to force the Green Revolution on India.

Marathwada lies in the rain shadow of the Western Ghats and receives an average of 600-700 mm of rainfall. Given the hard rock bed of the Deccan Trap, only 10 per cent of this water goes into the ground to recharge wells. Sugarcane requires 1,200 mm of water, which is 20 times more than the annual recharge. When 20 times more water is withdrawn from the ground than available, a water famine is inevitable, even when the rainfall is normal.

More than 300,000 farmers have committed suicide in India since 1995 — most of them in the Bt cotton areas. Marathwada and Vidarbha account for 75 per cent of farmer suicides in Maharashtra. Between January and December 2015, 3,228 farmers committed suicide in Maharashtra, including 1,536 in Vidarbha and 1,454 in Marathwada. In 2001-2002, before Bt cotton was commercially approved, the area under cotton in Marathwada was 0.89 lakh hectares. Within one year, between 2003-2004 and 2004-2005, the area under Bt cotton in Marathwada jumped 11 times from 0.89 to 10 lakh ha. In the following decade, the area under Bt cotton has increased 18.386 lakh ha.

Bt cotton hybrids are not suited to regions like Vidarbha and Marathwada. They need more water and, therefore, fail more frequently when assured irrigation is not available. Bt cotton is also killing beneficial soil organisms which degrades organic matter and turns it into humus. Soils are becoming sterile. Our studies show that more than 50 per cent beneficial soil organisms have been destroyed by Bt toxins in Bt cotton areas. Unlike the crops it displaces, such as jowar, it returns no organic matter to the soil.

The increase in Bt cotton came at the cost of jowar which holds the answer to drought in Maharashtra. Jowar requires only 250 mm water and would have survived the drought, giving farmers food and livelihood security even with a deficient monsoon. Between 2004-05 and 2011-12, while Bt cotton in Beed (in Marathwada) increased from 1.01 to 3.290 lakh ha, the area under "Rabi Jowar" decreased from 2.567 to 1.704 lakh ha. Bt cotton has displaced the mixed and rotational cropping of jowar, tur, mung, urad, wheat and chana. During the 1984 drought in northern Karnataka, an old farmer told us, "Bring me the old seeds of the native jowar, and I will drive away the drought".

Not only do indigenous crops like jowar use less water, they increase the water-holding capacity of soil by producing large quantities of organic matter which, when returned to the soil, increases the soil's fertility and water-holding capacity.

Native seeds and organic farming are the answer to drought and climate change, to farmers' suicides and to the agrarian distress. They are also the answer to hunger and malnutrition. Care for our seeds, our soil and our water are the real test of our love for our land and our commitment to our future, not slogans. The same processes that are killing our soil, water and climate balance are also killing our farmers. This is an emergency. Yet, the responses are not addressing the roots of the crises.

While women carry the water burden as water providers, they are excluded from decisions about how water will be used, how it will be distributed, how it will be managed, how it will be owned. These decisions are being increasingly made by International Financial Institutions and Multinational Corporations.

Giant water projects, in most cases, benefits the powerful and dispossess the weak. Even when such projects are publically funded, their beneficiaries are mainly construction companies, industries, and commercial farmers. While privatization is generally couched in rhetoric about the disappearing role of the state, what we actually see is increased state intervention in water policy, subverting community control over water resources.

Increasingly, the term "Water Providers" is being used not for the women who work to provide water, but for the water giants who take water from communities and sell it back to them at high cost for profit. The water traders, water profiteers are positioning themselves as "water providers" while increasing women's burden in water provisioning.

To mitigate the women-water burden the study suggests the following measures.

Recommendations and suggestions:

1. Restore the conventional methods of water conservation like Baolis, Jhods, Ponds, Tankas.
2. Introduce rainwater harvesting.
3. Change the cropping pattern of agriculture. Instead of growing water intensive crops like Green Revolution paddy and sugarcane,

introduce crops like millet, ragi, which consume less water.

4. In cities, instead of Public Private Partnership (Privatisation of water) Public-Public partnership (Public and Government) is an alternative for water crisis.
5. Proper water conservation measures should be used. People should be made aware and trained on the techniques of water conservation.
6. Government schemes should be implemented properly.
7. Involve Panchayati Raj Institutions (PRIs) and NGOs in the management of rural water supply.
8. Women should have community control over water so that they can manage water as a common resource for the sustainability of the eco-system, their families and villages. They should be trained as water managers for the better utilization of water.
9. Future programmes/projects should be designed, keeping in view the women as water users.

More than any other resource, water needs to remain a common good and requires community management. In fact in most societies, private ownership of water has been prohibited. However, the emergence of modern water extraction technologies has increased the role of the state in water management. With globalization and privatization of water resources, efforts are under way to erode people's rights over water.

Throughout history and across the world, water rights have been shaped both by the limits of ecosystems and by the needs of people. In fact, the root of the Urdu word *abadi*, or human settlement, is *ab*, or water, reflecting the formation of human settlements and civilization along water sources. The Doctrine of Riparian Rights – the natural rights of dwellers supported by a water system, especially a river system, to use water-also arose from this concept of *ab*. Water has traditionally been treated as a natural right – arising out of human nature, historic conditions, basic needs, or notions of justice. Water rights as natural rights do not originate with the state; they evolve out of a given ecological context of human existence.

There are nine principles underpinning water democracy:

1. Water is nature's gift. We receive water freely from nature. We owe it to nature to use this gift in accordance with our sustenance needs, to keep it clean and in adequate quantity. Diversions that create or waterlogged regions violate the principles of ecological democracy.
2. Water is essential to life. Water is the source of life for all species. All species and ecosystems have a right to their share of water on the planet.
3. Life is interconnected through water. Water connects all beings and all parts of the planets through the water cycle. We all have a duty to ensure that our actions do not cause harm to other species and other people.
4. Water must be free for sustenance needs. Since nature gives water to us free of cost, buying and selling it for profit violates our inherent right to nature's gift and denies the poor of their human rights.
5. Water is limited and can be exhausted. Water is limited and exhaustible if used non sustainably. Non-sustainable use includes extracting more water from ecosystems than nature can recharge (ecological non-sustainability) and consuming more than one's legitimate share, given the rights of others to a fair share (social non-sustainability).
6. Water must be conserved. Everyone has a duty to conserve water and use water sustainably, within ecological and just limits.
7. Water is a common resource. Itis not a human invention. It cannot be bound and has no boundaries. It cannot be owned as private property and sold as a commodity.
8. No one holds a right to destroy water. No one has a right to overuse, abuse, waste, or pollute water systems. Tradable- Pollution permits violate the principle of sustainable and just use.
9. Water cannot be substituted. Water is intrinsically different from other resources and products. It cannot be treated as a commodity.

This World Environment Day, we need to make a clear choice for the future of the planet and our survival — whether we want to step deeper into ecological and social emergencies as slaves of giant corporations, or we want to live as free and caring members of the earth family, Vasudhaiv Kutumbakam, following our dharma in the creation. ❑

(E-mail: vandana.shiva@gmail.com)