WATER MANAGEMENT IN INDIA: CHALLENGES AND PROSPECTS

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Abstract
Over the past 50 years, managing India's water resources has become increasingly difficult for a number of reasons, most notably the country's increasing demand and deteriorating environmental conditions. In general, the majority of India's water management issues can be divided into the following categories: (a) water availability, variability, and rising withdrawals; (b) environment and quality; (c) project construction; (d) disputes over water sharing; (e) water governance and institutions; and (f) issues brought on by changes in land-use cover and climate. Here, we go into great depth about each of these difficulties. It is stated that the two main pillars of India's water resource management should be variability management and water conservation. This paper also discusses new initiatives by the Government of India (GoI) and offers solutions to the problems.
***Keywords**: Artificial Recharge, Biodiversity, Climate Change, Water Governance, Water Resources.*

Water Availability, Variability and Increasing Withdrawals

The rivers of India can be categorized into four classes: (i) Himalayan rivers, (ii) Deccan rivers, (iii) coastal rivers, and (iv) rivers of the inland drainage basin. The Himalayan rivers are nourished by precipitation in the form of rain, snow, and the melting of glaciers. The primary Himalayan River systems in India are the Indus, Ganga, and Brahmaputra, collectively responsible for almost two-thirds of the country's water resources. Regulating the flow of the Himalayan rivers is crucial for water conservation and to protect society and infrastructure from flood damages. It should be noted that the three rivers in the Himalayas cross national boundaries. These rivers or its primary tributaries have their source in nations adjacent to India. Following their course through India, these rivers then enter either Pakistan or Bangladesh. India serves as a downstream country in certain situations and as an upstream country in others. The primary rivers within the Deccan region include the Mahanadi, Godavari, Krishna, Narmada, Tapi, and Cauvery. These rivers are solely dependent on rainfall and transport far less silt in comparison to the rivers originating from the Himalayas. The majority of peninsular rivers, with the exception of the Narmada and Tapi, flow in an easterly direction and converge with the Bay of Bengal. Coastal rivers in India generally exhibit short lengths and tiny catchment regions. The rivers on the West Coast exhibit a significantly high volume of water flow.

The annual precipitation in India is approximately 4000 billion cubic meters (bcm), while the potential water resources amount to 1869 bcm. The available water resources are limited by topographical and other factors. Specifically, there is a potential of 690 billion cubic meters (bcm) of surface water and 447 bcm of groundwater, resulting in a total of 1137 bcm. In 2011, the per capita yearly water availability in India was approximately 1544 cubic meters. However, this has since decreased even more due to the increase in population. The Falkenmark Index is a widely employed metric for quantifying water shortage. A nation is considered to be experiencing water stress if its per capita yearly renewable water falls below 1700 m. While this criterion may not be directly relevant to India due to significant differences in lifestyle and water usage compared to European and American countries, a decrease in per capita water availability indicates a need for stricter water management. There are three primary concerns regarding the fluctuations in water resources in India:

1. India experiences significant temporal fluctuations in water supply, resulting in several

problems, including the occurrence of natural disasters such as floods and droughts.

2. There is a significant disparity between the amount of water available and the amount of water needed in different regions. The demands for water in many sectors are growing rapidly, while the availability of water remains relatively constant.
3. The extraction of water from surface and subterranean water bodies to fulfill increasing demands is escalating and reaching a point where it is no longer sustainable.

Variability in Water Availability

India experiences significant fluctuations in water availability over time, resulting in various problems, including natural disasters like floods and droughts. India experiences a monsoon climate, resulting in about 70% of the yearly rainfall occurring within a short span of approximately four months. During this period, the rivers transport more than 70-75% of the total annual water volume, often surpassing their capacity to handle this water safely. The remaining eight-month period constitutes around 25-30% of the total river flows, during which several rivers experience a temporary cessation of flow throughout the summer months. Groundwater levels also exhibit a roughly analogous fluctuation, albeit with a slight time lag. The wide range in water availability leads to many issues, such as floods and droughts. Water availability in India exhibits significant spatial differences, in addition to temporal variability. This leads to an abundance of water in certain river basins/regions, while others experience periodic water scarcity, often concurrently. It is advisable to consider both sorts of variabilities simultaneously, as the tools required are identical. Effectively managing variabilities should be a fundamental aspect of water resources management in India. Jain has delineated the fundamental components of sustainable water resource management in the nation.

Increasing Gap between Water Availability and Demands

The size of the population is the primary factor that determines the amount of water needed. With the growing population and evolving lifestyles in India, along with the expanding economic activity, there is a significant surge in the demand for water. The agriculture industry represents almost 85% of the country's yearly water requirements. Due to the absence of a significant pattern in the yearly precipitation in India, the disparity between the need for water and its availability is growing. Water scarcity is prevalent in numerous locations due to an imbalance between demand and supply, with demand surpassing supply.

Unsustainable Water Withdrawals

In order to satisfy the growing need for water, bigger amounts of water are being extracted from both surface and underground water sources. The health of numerous rivers has been negatively impacted by the escalating withdrawals, leading to certain rivers ceasing to flow continuously throughout the year in various sections. This has a very harmful impact on both the river and the environment. Groundwater extraction in India has played a crucial role in meeting the demand for drinking water and ensuring food security. However, the excessive and unsustainable extraction of groundwater in many areas has led to a decline in water tables. This has resulted in wells running dry, increased pumping costs, reduced water flow in rivers, and contamination of water supplies with harmful substances like arsenic. Several districts in India have reported various forms of groundwater contamination. These contaminants encompass fluoride, iron, salinity, arsenic, and other substances. Overly extracting groundwater can cause the soil to sink, resulting in many negative outcomes. In the foreseeable future, India is expected to confront a scenario in which the amount of water available in a typical year will be approximately equal to or lower than the amount needed. The situation will become quite dangerous during years with subpar rains.

Suggested Remedies

When addressing the water problem, it is crucial to consider the entirety of water resources, which includes both surface water and groundwater, instead of managing them as distinct entities. Three separate steps must be taken: decrease demands, preserve water, and transport water across different locations. Prioritize exploring all possible alternatives to assess water requirements in a comprehensive manner, especially in areas experiencing a shortage of water. The agriculture sector in India accounts for over 80% of the overall demands, making it the greatest consumer of water. Consequently, this sector presents the most significant potential for water conservation. Estimations indicate that water utilization efficiencies in the agricultural sector are exceedingly low in India, with surface and groundwater utilization efficiencies approximately around 40% and 50% respectively. Undoubtedly, there is a significant potential to enhance these efficiency. With the current irrigation water usage in the country at approximately 550-600 bcm, a just 20% increase in these efficiencies will provide enough water to significantly fulfill the demands from the environment and municipal sectors. Significant savings can be achieved by implementing sprinklers, drip irrigation, and other water conservation measures. It is important to provide farmers with incentives to enhance water usage efficiency (getting more crop per drop), especially in areas with limited water resources.

Conserving Flood Flows

India possesses a monsoon environment, wherein the rivers transport about 70% of the yearly water flow throughout four months of monsoon. Therefore, it is imperative to preserve flood flows and utilize them to a greater extent during the low-demand season. In regions with restricted access to groundwater, it is imperative to regulate river flows based on the water needs of crops in order to provide food security for the country. This is because rain-fed agriculture has significantly lower water and land productivity compared to irrigated agriculture. Aquatic resources can be stored either on the surface or beneath it. Interventions are required at different levels. At a large-scale level, it is crucial to preserve excess monsoon or flood flows, either in above-ground or underground storage, as the flows during the rest of the year are insufficient to fulfill the different needs. In order to retain water on the surface, it is necessary to construct storage reservoirs. The availability of suitable storage sites in the country is scarce, and this scarcity leads to a multitude of difficulties such as the flooding of forests, the displacement of people, the endangerment of biodiversity, and many environmental challenges. In order to preserve water resources underneath, it is essential to have appropriate hydro-geology and provide infrastructure for large-scale managed aquifer recharge (MAR). Hence, it is evident that both alternatives possess certain advantages and disadvantages. It would be imprudent to completely dismiss any alternative. Considering the issue and viable alternatives, it is necessary to implement an alternative option, fully aware that any solution will involve expenses and negative repercussions. Moreover, choosing to take no action is also not a favorable decision, as problems never resolve themselves without intervention. Regulating groundwater withdrawals is crucial, especially in areas where the yearly withdrawals exceed the annual recharge, in order to prevent a continuous fall in the water table.

In order to develop strategies for artificial recharge, it is important to assess both the quantity of water suitable for recharge and the recharge capacity of aquifers. At present, there is only large-scale data available on the potential for recharging aquifers, but it is necessary to organize recharge actions at the local level. Therefore, it is imperative to identify and acquire aquifer data at a local level, and demarcate recharge sites through the collection and analysis of geological data. Furthermore, it is necessary to identify the aquifers that have lost saturation and accurately assess their capacity to hold water. Similarly, it is necessary to estimate the quantity of water that can be employed for recharging at the local level. Accurate hydrologic models that have been calibrated can provide such estimations. Preliminary calculations indicate that the magnitude of flood discharges in Indian rivers could amount to approximately 500 billion cubic meters (bcm). A significant portion of this might be preserved through extensive, moderate, and minor initiatives, as well as through forced recharge in the subsurface zone. Currently, the storage capacity in basins with high water potential, such as the Ganga, Brahmaputra, Indus, Godavari, Mahanadi, etc., is relatively insufficient. To optimize water usage, it is advisable to store excess water in these basins during the monsoon season and utilize it to fulfill water requirements for the rest of the year. Conserving flood waters can partially alleviate two water-related crises, specifically floods and droughts. At a small scale, residents and farmers can build or restore village and farm ponds to collect rainwater for agricultural water needs. Implementing check dams at local levels can contribute to the conservation of water and fulfill the water requirements of the community. Nevertheless, the creation of a substantial quantity of these buildings leads to a notable decrease in the availability of water in the areas located downstream. Hence, it is essential to coordinate the planning of interventions at the river basin level in order to consider and incorporate the effects of interventions in upstream areas into the overall river basin plans.

Managing Floods

In order to effectively handle floods, a variety of measures must be taken. High flows are expected to cause damage as they may be temporarily retained in reservoirs and later discharged at reduced rates. Several storage reservoirs have been constructed in India to manage floods, such as Hirakud, Rihand, Tehri, and others. Given the increasing challenges in developing storage projects that can offer comprehensive flood protection, it is imperative to also focus on the development of resilient flood forecasting and warning systems. These systems will enable timely relocation of people, livestock, and movable assets to safe areas prior to the occurrence of a flood. Flood forecasting facilitates improved regulation of reservoirs and enhances the efficient utilization of limited flood control capacity inside them. Implementing a reliable and resilient long-term flow prediction system will also contribute to improved management of fluctuations in inflow. In order to assess the extent of flood damage, it is imperative to exercise prudence in the utilization of floodplains along rivers. It is advised to refrain from constructing residential and commercial structures in close proximity to the river. In addition to their role in accommodating floodwaters, floodplains also serve other beneficial purposes. A portion of the floodwater replenishes the groundwater and revitalizes the plants along the riverbanks. Therefore, any development should not be designed in a way that hinders the advantageous functions of floodplains. The primary cause of extensive destruction during the 2013 Uttarakhand floods was the construction of several buildings in the floodplains, which were subsequently swept away by the floodwaters.

Rationalizing Cropping Patterns

The analysis of data reveals a significant shift in cropping patterns across the country during the past five or six decades. Sugarcane, a water-intensive crop, is now being farmed in locations with minimal rainfall where it was previously not grown. In a similar vein, rice is cultivated in other comparable locations. Hence, in order to manage the water requirements of agriculture, it is crucial to assess the cultivation patterns, especially in areas where the yearly precipitation is less than 600 mm or where the extraction of groundwater exceeds its replenishment, while still cultivating water-intensive crops like sugarcane and paddy. Nevertheless, implementing a significant alteration in the cropping pattern will provide challenges. There are numerous factors that contribute to farmers' preference for cultivating sugarcane. This plant offers a high rate of return, is simple to cultivate, demands minimal maintenance, and is relatively resistant to illnesses. A significant number of farmers have established contractual arrangements with manufacturers. While it is convenient for them to sell the harvest, it is important to note that payment may not always be readily available. One possible solution is to substitute high water-consuming crops with traditional crops that were historically produced in these regions, or with coarse grains and pulses. In regions susceptible to drought, it is imperative to prioritize the cultivation of crops that are resistant to drought. Deficit irrigation is an alternative approach for addressing water constraint. It has the potential to reduce agricultural water consumption by approximately 10-15% without significantly impacting crop yield. The crop price mechanism has also influenced the change in planting patterns. The provision of free energy to farmers contributes to the excessive use of water for irrigation and leads to water wastage. A more optimal approach would involve farmers being responsible for paying for the energy they consume at standard rates, while simultaneously receiving direct subsidies to their bank accounts to partially offset the associated expenses.

Long-Distance Water Transfer

India also experiences a significant spatial disparity between the demand for water and its availability, as the locations where water is required and those where it can be found are often distant from each other. An effective and proven method to address the issue of spatial imbalance between water supply and demand is through the implementation of long-distance water transfer, commonly referred to as river interlinking in India. This necessitates the construction of reservoirs for the purpose of storing excess water, as well as the establishment of transfer links, such as canals or pipes, to facilitate the movement of water. Interbasin water transfer encompasses a range of both technical and non-technical challenges. The expenses associated with these initiatives are increasing rapidly, and soon it may become challenging to financially justify many of these programs. However, despite the lack of alternative options, it may be difficult to maintain the needed level of water supply reliability. The experiences with projects like Ken-Betwa and others demonstrate that technical challenges are rather straightforward to address, but the complexities lie in resolving water-sharing, political, and finance obstacles. Furthermore, it is worth considering the exploration of short-distance water transfer, as it would involve relatively lower costs, shorter timeframes, and less resistance.

Recycle and Reuse

Currently, there is a minimal amount of water that is recycled and a significant quantity of water is wasted in urban water supply networks as a result of leaks and theft. Approximately 40% of the water supplied by municipalities for drinking reasons is lost as a result of leakage or theft in certain areas, according to estimates. Significant water conservation can be achieved by minimizing these leakages through the replacement of deteriorated pipes, valves, and other components, as well as by the recycling and reuse of water in both the municipal and industrial sectors. For example, the Arab states generate an annual volume of wastewater exceeding 10 cubic kilometers. Out of the total amount, approximately 55% undergoes treatment while 15% is utilized for purposes including as irrigation in farms and landscaping, environmental protection, and industrial cooling. Increasing the rate of water recycling in India has the potential to significantly alleviate the scarcity of potable water in many urban areas. Inadequately strategized urbanization is also accountable for water problems in certain cities. According to reports, the vast expanses of land around Chennai, which used to serve as aquifers replenishing and absorbing floodwaters until a few decades ago, have been covered with pavement in recent years. This has significantly decreased their ability to recharge, leading to a decrease in water availability and an increase in flooding. Any freely offered resource is typically squandered, and water is no different. Therefore, it is crucial to impose fees on consumers for the water they receive, which will cover the expenses associated with delivering services, maintaining facilities, and allowing for future growth. It is necessary to install water meters for all the provided water. Access to clean water for essential needs can be made available to disadvantaged populations at reduced prices. However, any additional consumption beyond the basic requirement (e.g., 50 liters per person per day) should be subject to tiered pricing, where the rates increase as consumption increases, in order to discourage wasteful usage. Water resource development plans must be created for every river basin, explicitly outlining the projects to be implemented in each basin, including their precise location and magnitude. These plans must guarantee that the combined effects of all the projects fall within an acceptable range and do not surpass the capacity of a river basin.

Quality of Water and Environment

High-quality water is beneficial and contributes to environmental and spiritual revitalization, whereas low-quality water is detrimental. The water in numerous natural water bodies, including rivers, lakes, and ponds, is heavily contaminated due to the disposal of untreated or partially treated trash from municipal and industrial regions, as well as the influx of dirty water from agricultural areas, orchards, and plantations. More than 50% of the sewage in metropolitan India is discharged into water bodies without undergoing any treatment, according to estimates. The disposal of industrial and other pollutants in the subsurface zone has led to the pollution of the uppermost 10-20 meters of the subsurface zone. The presence of highly contaminated water from hand pumps in numerous locations serves as clear evidence of this pollution. While several large and medium-sized enterprises are commendably treating wastewater with care, there are still industrial facilities that are injecting waste into aquifers in order to avoid the expenses associated with sewage treatment. Undoubtedly, polluted aquifers will have a detrimental impact on future generations. India's child stunting rate stands at 45%, with 600,000 children under the age of five dying annually. These alarming figures can be attributed primarily to insufficient access to clean water and inadequate sanitation facilities. Based on a research conducted by the World Health Organization (WHO) in 2002, inadequate water quality and inadequate sanitation were responsible for 7.5% of all deaths and 9.4% of all disability-adjusted life years in India. India experiences an annual loss of around 73 million working days due to water-borne diseases. The majority, if not all, of these fatalities can be averted by ensuring access to uncontaminated potable water for children and sufficient sanitary facilities.

Environment Impacts

Opposition to WRD initiatives sometimes stems from the belief that these projects have a negative impact on the environment. The WRD projects have negative environmental effects such as the flooding of lands, forests, and residential areas, the division of rivers, and the obstruction of fish and other aquatic life movement. During previous construction projects, significant numbers of people were relocated from their residences. There have been allegations that certain individuals who were displaced did not receive appropriate compensation, despite enduring lengthy delays. In this regard, two significant advancements have occurred in India. The Government of India implemented the Environment Impact Assessment Notification in 2006. The approach established a comprehensive framework for evaluating the environmental effects of WRD projects and developing a management strategy to minimize them. The Indian Parliament enacted The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 in order to ensure equitable compensation for those affected by the project. This legislation includes requirements to provide equitable remuneration for individuals whose properties have been bought for the purpose of constructing a project. As a result of the generous provisions of this Act, the opposition to WRD projects has significantly decreased. An unresolved matter of utmost importance pertains to the development activities in a region where a project is being proposed. If an area is determined to be inside the submergence zone of a project, no development activities are undertaken. Often, there is a time gap of 2-3 decades between the identification of a project and its actual completion. During this extended period, the local populace is deprived of any progress or advancement. There are cases in which those who initially supported a project later become opponents due to this particular cause. It is imperative to accelerate the decision-making process for WRD initiatives.

Long Gestation Periods in Planning and Construction of WRD Projects

The WRD project typically begins with the development of a feasibility report. After approval of this study, a detailed project report (DPR) is generated and various approvals, such as technical clearance, forest clearance, environment clearance, investment clearance, interstate clearance, etc., are sought. At times, the process of acquiring these approvals can be lengthy and may endure for many years. Sometimes, a project is abandoned after a substantial amount of time and effort has been invested in creating the Detailed Project Report (DPR) and gaining the required clearances. Abandoning a poor project poses no problem, except that if this decision is taken after allocating substantial resources, all of those resources, which could be substantial, are squandered. Frequently, the expenses associated with a project might greatly increase by the time it obtains the necessary approvals and construction begins.

Water Governance and Institutions

Considering the scale, scope, and severity of water-related issues in the country, the institutions responsible for water resources development and management in India need substantial reform. The primary factor is that the field of water management has experienced significant transformations in the last forty years, leading to a steady shift towards a more interdisciplinary approach. In addition to possessing expertise in hydrological concepts, water professionals must also possess knowledge in other fields such as environmental science, forestry, agriculture, geology, meteorology, soil science, sociology, economics, law, and management, among others. In order to bring about necessary changes in current businesses, it would be imperative to recruit individuals with suitable expertise and outsource some jobs. In order to effectively carry out Water Resources Development (WRD), the Government of India (GoI) must assume several crucial responsibilities as a developer, assessor, and regulator. This necessitates the enhancement of institutions involved in water development and administration. A multitude of multidisciplinary teams will be required to offer specialized technical assistance on many diverging matters. An effective monitoring mechanism must be established by engaging government officials, specialists from academic and research institutions, non-governmental groups, and individuals. Singh has presented a thorough examination of the water governance difficulties in India.

In the mid-1990s, the Government of India established a National Commission for Integrated Water Resources Development and Management. The Commission conducted a thorough examination and evaluation of the water sector and presented its report8, which contained numerous valuable recommendations for resolving issues in WRD and management. Over the past 25 years, there has been a significant transformation in the current state of the water industry in India. It is now necessary to appoint a Commission to conduct a comparable evaluation and provide recommendations for the future at the national level. At present, there is no research and development organization or think-tank in the water sector that possesses a diverse team and necessary resources to do complex tasks like creating and executing a comprehensive strategy for managing water resources in a vast basin, such as the Krishna basin. The underlying causes of this issue should be thoroughly analyzed and appropriate measures should be implemented to ensure that the country has many teams capable of providing technically proficient integrated water resources development and management in India. Although there are various obstacles and opportunities in the water business in India, few exceptional students consider pursuing a career in this field. It is imperative and advantageous to attract skilled individuals to the water industry by offering comparable working conditions and incentives to those in other sectors. Mujumdar and Tiwari discuss the current state of research and technology in relation to water management in India.

Climate Change

India is exceptionally susceptible to the effects of climate change on water supplies because of its distinct climate, geography, and topography. Increased temperatures in the lower atmosphere will have an effect on the amount of snowfall. The presence of glaciers and snow cover, as well as the water needs of crops, will be affected. The occurrence of floods and droughts will be influenced by the increase in extreme weather events. Coastal areas will experience more flooding and intrusion of seawater due to increasing sea levels. The quality of water in rivers and lakes will be negatively impacted by rising temperatures. The remedies proposed here would effectively mitigate the vulnerabilities caused by climate change and enhance the resilience of society. Furthermore, there is a want for more targeted research and development to ascertain the anticipated modifications, as well as the precise locations and methods to implement certain adjustments.

Conclusion

This study paper provides a comprehensive overview of the primary obstacles in water resources management in India and proposes strategies to address them. These issues emerge as a result of various factors, including technical, socio-political, and financial causes. It is imperative to have a strong and immediate determination from political leaders to effectively tackle the issues and successfully execute the remedies. A promising indication is the dedication/strategy of the Government of India (GoI) to ensure water security for the whole population by 2022-23 through sufficient access to water for basic needs, agriculture, economic growth, ecological balance, and environmental preservation. The set goals encompass the following: achieving the provision of piped drinking water to every rural household by 2024; facilitating irrigation for all farms and enhancing water-use efficiency to maximize crop yield; promoting the utilization of recycled/treated water by industries and preventing the release of untreated effluents from industrial units; ensuring continuous and clean flow in the Ganga and other rivers and their tributaries; constructing additional water storage capacity to fully exploit the potential of 690 bcm of utilizable surface water resources; guaranteeing the long-term sustainability of finite groundwater resources; and ensuring the proper operation and maintenance of water infrastructure with active involvement from farmers/consumers. Many WRD initiatives that were previously delayed for various reasons have now resumed. The government's implementation of a sanitation push will greatly enhance the water sector in the future. The initiatives to revitalize the river are starting to have positive outcomes. Achieving specific objectives can be accomplished by implementing and embracing suitable technology in the water industry, together with increased participation of the public in water resource development and management.

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