THEORETICAL PAPER DOI: 10.21844/16202116205

Vol. XVI, No. 2; September 2023 - February 2024 Print ISSN: 0975-024X; Online ISSN: 2456-1371

Theoretical Underpinning of Groundwater situation in India: Search for Efficient Policy Mechanism

Alik Banerjee[1], Alka Parikh , Ashwani Kumar Gupta

[1]Research Scholar, Dhirubhai Ambani Institute of Information and Communication Technology (DAIICT), Gandhinagar, Gujarat, India

[2]Director, Center for Field Learning, Ahmedabad, Gujarat, India

[3]Assistant Professor, School of Management Sciences, Varanasi, Uttar Pradesh, India

Abstract

At the outset of the 21st century, water scarcity and water insecurity became inextricable in almost every world region. India, being a subcontinent, is not an exception because of its diverse geographical conditions. The paucity of water is severely impairing India's sectoral prosperity. Like many other natural resources, we have taken the availability of water for granted; we continue to expect bounty as soon as we turn on the tap. However, the recent dearth has raised a few questions, not on the right, instead of on the legal responsibility. The quest for an answer, thus, brings us to the polemics of economics, where anything scarce and demanding high needs a price. Effective water pricing policy brings an appropriate incentive to ensure enough clean water for all stakeholders who demand it and secures financial sustainability for urban water services providers to supply it. Water scarcity and its price mechanism can be addressed by refining ways, means, and models and considering the water sector's institutional structure. Since it is crucial to comprehend the issue of water shortage, the policy's goal should be to raise public awareness of the state of affairs and provide a framework of institutions and regulations that will allow the state to implement its policies in a coordinated way.

Keywords: Groundwater, Water Scarcity, Water Pricing, Policy Mechanism, Well-being, Sustainability

Introduction

At the outset of the 21[st] century, scarcity and insecurity of water became inextricable in almost every region of the world. Developed and developing countries are experiencing severe water problems, water conflicts, water-borne diseases, and water-related hazards. India, being the largest subcontinent, is no exception and instead of shrinkage, they are expected to escalate in the near future. The paucity of groundwater is severely impairing India's sectoral prosperity too, as it is one of the most important sources and accounting for 63% of all irrigation water and over 80% of the rural and urban domestic water supplies. UNESCO World Water Development Report states that India is the largest extractor of groundwater globally. 54% of India's groundwater wells have declined over the past seven years. Currently India is facing a dual challenge: to regulate the growing demand for groundwater, while replenishing its sources. For decades, we have turned on the tap and expected as much water as we need. It is, after all, a fundamental human right, i.e. who owns water, who can access it, and how much is allowed to be used. However, in scarcity situations, when water users interact in absence of effective instructions and defining rights and duties, substantial free riding is likely to occur. Under such circumstances, individual (or group) property rights regimes can help in more effective management of such a natural resource. But the recent dearth of water has raised a few questions, not on the right, rather on the liability. The quest for an answer, thus, brings us to the polemics of economics, in which anything scarce and in high demand needs a price. Quality of water, its deteriorating infrastructure, and an appropriate water policy framework are the crucial

(Corresponding Author: Alik Banerjee , Research Scholar, Dhirubhai Ambani Institute of Information and Communication Technology (DAIICT), Gandhinagar, Gujarat, India.
E-mail: alik.banerjee87@gmail.com
How to Cite the article: Banerjee, A.; Parikh, A.; Gupta, A. K. (2023). Theoretical Underpinning of Groundwater situation in India: Search for Efficient Policy Mechanism. Purushartha, 16(2), 65-76
Source of Support: Nil
Conflict of interest: None

topics that people should be concerned about. Thus, in the context of scarcity and insecurity, we have to find economic efficiency in terms of legal and price policy.

Objective of the Study

The economic structure supporting groundwater, and its related market is a complex system, and the calculation of it is a big challenge because of the difficulty in estimating groundwater. It is typically complicated because of its spatiality, heterogeneity, and data scarcity. Therefore, in the context of the estimation of groundwater, sustainability, and water conservation, this article seeks to understand the following objectives:

- To estimate the economic value of groundwater using its environmental conservation.
- To analyze the legislative framework of the groundwater situation in India.
- To outline a policy framework for sustainable water use.

Research Questions

- Does the economic structure consider the total cost of providing the resource and the entire environmental value?
- Does the legislative framework reflect what governments have accomplished and what needs to be done?
- What would be a pertinent policy framework that would work for the community's well-being?

Methodology

This study used doctrinal research methods as part of the methodology. A literature review examines the economic structure supporting the idea that groundwater should consider the total cost of providing the resource and the entire environmental value. Moreover, a policy framework is based on the community's well-being *to maximize opportunity cost*. The absence of such policies will decrease the groundwater levels, residential water infrastructure will deteriorate over time, and achieving economic efficiency will be a distant dream. The economic and legal statutes are the two methods used to attain the anticipated result related to groundwater using the collected information. Calculating the total cost of groundwater and its environmental value is a big challenge. Therefore, the researchers used secondary data, published experimental values/results, research articles, newspaper reports, websites etc., to understand the theoretical underpinnings of *the groundwater situation in India.*

Literature Review

Nowadays, groundwater contributes significantly to human sustainability and food security through irrigated agriculture (Aeschbach-Hertig & Gleeson, 2012). It is an incentive for unreliable rainfall; however, this has become inconsistent in some parts of the globe (Chakraborti et al., 2019). There is enough groundwater on the planet for 7 billion people, but due to uneven distribution, it needs to be more sustainably managed (WWAP, 2012). Growth and development, changing crop patterns, and other socio-economic parameters are the reasons for increasing water use (WWAP, 2018).

India, being the largest subcontinent, is no exception. Instead of shrinkage in the abovementioned issues, they are expected to escalate soon as more groundwater consumption than recharge has drastically reduced groundwater levels over the past 60 years (Chakraborti et al., 2019). CGWB (2014) data estimated that India's groundwater abstraction was 245 billion cubic meters (BCM) in 2011, and 90% of it was consumed by irrigation (Saha et al., 2018). This enormous consumption of groundwater for irrigation also depicts the dependence of the primary sector on the Indian Economy (Smilovic et al., 2015; Zaveri et al., 2016; Cao & Roy, 2020). Moreover, after the Green Revolution, farmers have shifted from low water-consuming crops such as maize, millet, and oilseeds to high water water-hungry crops such as paddy (Davis et al., 2018). This swing, followed by the digging of a vast number of bore wells/tube wells (from ~ 0.1 million in 1960 to ~ 1.27 million in 2008) in India, raised concerns about groundwater (Hira & Khera, 2000; Sharma et al., 2008;

Mishra et al., 2018). Too much dependence on irrigated agriculture throughout the country prerequisite for groundwater abstraction led to severe exploitation of the groundwater system and threatened the sustainability of aquifer and agricultural productivity (Gleeson et al., 2020).

The Indo-Gangetic basin's alluvial aquifers are extensively mined for groundwater, with 62% of regional irrigation, 50% of urban water supply, and 85% of rural water supply coming from that (Saha et al., 2018). Significant groundwater depletion has been observed in northern India during the past ten years; statistics for states such as Punjab, Haryana, and Rajasthan have been approximated from the Gravity Recovery and Climate Experiment (GRACE) satellite. For example, Rodell et al. (2018) estimated northern India's total water storage loss rate. Asoka et al. (2017) estimated a 2 cm/year decline in groundwater storage in northern India between 2002 and 2013. GRACE studies marked northwestern India as a region of high groundwater depletion (Alley and Konikow, 2015; MacDonald et al., 2016). Moreover, a few number of studies have used in situ measurements to examine the spatiotemporal variability of groundwater storage across India (Bhanja et al., 2017; Asoka et al., 2018; Mishra et al., 2018; Sinha et al., 2019; Asoka & Mishra, 2020; Shekhar et al., 2020; van Dijk et al., 2020; Dangar et al., 2021; Joshi et al., 2021; Tiwari et al., 2021). However, the data density of these studies was limited throughout the nation (e.g., see Fig. 1 of Bhanja et al., 2017, and Fig. 1b of Asoka and Mishra, 2020). In the majority of observation wells, Asoka et al. (2018) and Asoka & Mishra (2020) reported a drop in the water level between 1996 and 2013. However, the low density of their dataset prevents genuine evaluation of spatial variation in groundwater levels. MacDonald et al. (2016) mapped India's groundwater depletion in one of the few large-scale in situ studies. According to MacDonald et al. (2016), the depletion rates for Punjab and Haryana between 2002 and 2012 were 2.6 ±0.9 and 1.4 ±0.5 BCM/year, respectively. However, due to the changing crop patterns, the 11-year data set was limited in assessing multi-decadal trends. Asoka et al. (2018) used a data set of 5800 wells across India to examine the relationship between rainfall and groundwater recharge. They concluded that low-intensity monsoon rainfall dominates aquifer recharge in India, especially the northwestern part, although their study sample consisted of 139 wells. Thus, despite considerable progress, it does not permit quantification of the spatiotemporal pattern of groundwater level variability that is useful for effective groundwater resource management. It is a critical shortcoming because such information is needed to support sustainable groundwater resource management (Milman & MacDonald, 2020) and prevent damage to long-term agricultural production. If overlooked, continuous groundwater exhaustion may reduce agricultural production due to the related socio-economic effects (Aeschbach-Hertig & Gleeson, 2012; Barik et al., 2017).

Current Predicament of Water in India

The country-wise groundwater utilization list reveals that India, which consists of 30% irrigated land (Goldin, 2016), consumes the maximum amount of groundwater globally (Margaret al., 2013). The data of April 2015 reports that the water resource potential of the country (natural runoff) is estimated as 1,869 Billion Cubic Meter (BCM)/year (CWC, 2015). However, the estimated usable water of the country is only 1,123 BCM/year due to topography constraints and the uneven distribution of resources in various river basins. This uneven distribution is a significant concern that needs to be addressed for more equitable water resource management. The estimated usable water can be divided into surface water and groundwater, with the share becoming 690 BCM/year and 433 BCM/year, respectively. Furthermore, if we consider 35 BCM as natural discharge, the net groundwater availability for the entire country becomes 398 BCM (CGWB website, FAQ).

Nevertheless, groundwater resources in the country are assessed at different scales within districts, such as blocks/mandals/talukas/watersheds. The ratio of groundwater extraction to groundwater availability measured annually is the total groundwater available for society. Of the 5,723 blocks assessed across India by the Central Ground Water Authority, 839 are overexploited, 226 are classified as critical, and 550 are deemed semi-critical, meaning that approximately 29% of India's groundwater blocks need better groundwater basin management (CGWB 2019).

In states like Delhi, Haryana, Punjab, and Rajasthan, groundwater development is more than 100%. In contrast, in states like Himachal Pradesh, Tamil Nadu, Uttar Pradesh, and the Union Territory of Puducherry, groundwater development is 70% and above. In the rest of the states, groundwater development is below 70%, a significant concern. Groundwater usage has increased in readily available areas over time, increasing groundwater by 4% from 2004 to 2011 (CGWB, PRS). The table below compares the country's groundwater development over the past two decades.

Table 1: Comparative status of the level of groundwater development in India over the past 25 years

Level of ground water development	% of districts in 1995	% of districts in 2004	% of districts in 2009	% of districts in 2011
0-70% (Safe)	92	73	72	71
70-90% (Semi-critical)	4	9	10	10
90-100% (Critical)	1	4	4	4
>100% (Over exploited)	3	14	14	15

(Sources: Central Ground Water Board; PRS)

Causes of groundwater depletion in India

Groundwater depletion, a complex issue influenced by several factors such as social, institutional, lifestyle, and water quality, is a pressing concern in India. The main factors contributing to this depletion are regional and climate discrepancies, high population growth, rapid urbanization, and water pollution. This urgent issue requires immediate attention and action.

The regional and climatic discrepancy:

This subcontinent is affected massively by regional and climatic disparities and the changing pattern of monsoons. The long-term average rainfall in this country is about 116.84 cm (UNICEF et al. 2013), along with the high variability. Data also claim that 2018 was the fifth consecutive year that deficit monsoon conditions were registered as below-average rainfall (Pandey & Sengupta 2018). This country's groundwater aquifer recharge system is two-fold: the contribution of rainfall and other resources. Data reports that the annual contribution of rainfall to the country's groundwater aquifers recharge is 68%, and the share of other resources, such as flow from irrigation, recharge from tanks, ponds, canals, and the other water conservation structures taken together is 32% (Ground Water Yearbook, 2014). Further, India's natural groundwater availability and recharge are hugely heterogeneous because of various hydro geological setups and climatic conditions (Mukherjee et al., 2015).

Population:

India is the second-highest populous country globally, having a population of more than 1.3 billion as of July 2018 (US Census Bureau Current Population 2019). The per capita accessibility of water in 1951 was about 6 (* 10-6) BCM, decreased to 2 (* 10-6) BCM in 1991, and by the year 2011, it had declined to 1 (* 10-6) BCM (app.) (Bhat2014, Sharma & Bharat 2009). It is also estimated by India's Ministry of Water Resources, River Development, and Ganga Rejuvenation that the per capita accessibility of water in 2025 and 2050 will decrease by 36 and 60%, respectively, compared to what it was in 2001 (Bhat2014, KPMG 2010). About 54% of Indians are living in a water stress situation, and approximately 600 million people in India across the northwestern and southern regions are under "extremely high" to "high" water stress conditions (Shiao et al., 2015).

Urbanization:

Currently, one-third of the Indian population lives in urban areas, and there is an increase of four percent in urban-centric migration compared to the last decade (Aaron O'Neill, 2022). There is always a strong linkage effect that exists between groundwater and urbanization as it can change the quality and quantity of the groundwater in several ways (Wakode et al., 2018), primarily water shortage, flooding, change in the river stream, and the overall aquifer system (Rogers, 1994; Strohschon et al., 2013). While 56% of urban India depends on groundwater, it constitutes only 48% of the share of groundwater supply for 71 metropolitan cities (Narain, 2012; CGWB, 2011).

Pollution:

Excessive use of vehicles by a vast population result in air pollution and enormous use of pesticides and fertilizers by the farmers; industrial and human waste dumped into the river contributes to a significant amount of water pollution in this country (Amarsinghe & Sharma 2009). In India, about 431 BCM of groundwater is refilled yearly from rainfall and river flows, out of which 82% is used for irrigation and agricultural purposes and 18% for domestic and industrial water use (Bhat, 2014). The untreated urban wastewater contaminated with the downstream water causes health problems and other related hazards. Poor sanitation and hygiene are standard here, and one-third of children under five died due to water-borne diseases such as diarrhea (UNICEF et al., 2013).

Economic Framework

The combination of essential and finiteness makes water scarce and strengthens the argument of an economic good; thus, a price is attached to it. Understanding the factors influencing water pricing policies is crucial, as wherever there are prices, policies will follow. The CGWB has already circulated a policy for pricing. However, the factors considered in pricing and the justification of each factor's price/cost values are unclear. Factors like royalty, administrative costs, infrastructure development, O&M for groundwater augmentation or recharge, and O&M costs of water abstraction and distribution service, wastewater treatment service, and wastewater conveyance service should also be considered.

Regarding water pricing policies, cities in India differ in terms of norms and guidelines, though their rationale is similar. Cities like Mumbai, Hyderabad, and Chennai pay more than a hundred percent of operating and maintenance costs, whereas people in Kolkata pay a mere percentage. Meanwhile, Mumbai charges a flat rate per kiloliter of water. On the other hand, several cities (including Delhi) charge a nominal price or provide water free of cost (Parikh, 2010).

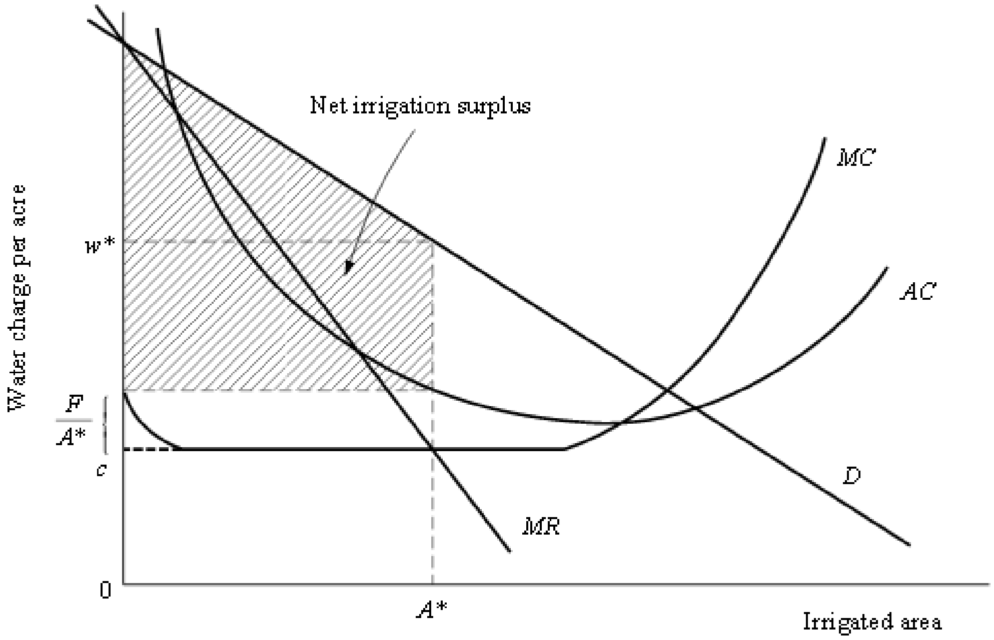
The difference between supply and demand potentially influences the cost-benefit structures of the water market. This portion needs a comprehensive examination in the context of the recommendations on allocations to farmers and agriculture. Along with pricing for agriculture, the tariff for pumping and other parameters needs to be discussed, i.e., when a tube wells (TW) owner sells irrigation water to several farmers not owning TWs, how is the water charge determined? Effective water pricing ensures enough clean water for all stakeholders who demand it and secures financial sustainability for water service providers to supply it.

The profit Π, which accrues to the TW owner during an irrigation season, is defined as follows;

$\Pi = PQ - VQ - F$, where Q is the acreage of the water sold (assuming that all the water is sold), P is the water charge per acre, V is the variable cost per acre, and F is the fixed cost. Assuming the water seller holds a monopoly and his behavior maximizes profits, the equilibrium water charges P* is obtained as follows:

$P^* = [e/(e - 1) \times V]$, where e represents the price elasticity of water demand.

Figure 1: Determination of Water Charge and Net Irrigation Surplus



***(Source:** K Soichi Fujita and Feroz Hossain)*

The above figure depicts that water demand (*D*) is derived from irrigation by non-owner farmers, and the marginal revenue curve for the TW owner (MR) is derived from *D* under the assumption of monopoly. The intersection of the MC (Marginal Cost) and MR depicts the acreage of water sold Q*, which is determined along with the water charge P*. We can define net irrigation surplus (NS) as the surplus from the difference between all the capital and labor costs and the gross production revenue; NS is equivalent to the shadowed area in Figure 1. Theoretically, it is composed of rent, interest, and profit.

An efficient price structure, a pricing system that accurately reflects the actual water cost, incentivizes safe access to clean water for all stakeholders according to their demand, and ensures financial sustainability for the water supply management. The demand-supply gap persuades society's cost-benefit mechanism; thus, determining water pricing is more policy than economic (Fujita & Hossain, 1995).

Legislative Framework

People in India consume water using a rights-based approach (Upadhyay, 2014). Case studies include Wasim Ahmed Khan vs. Govt. of AP (2002), Mukesh Sharma vs. Allahabad Nagar Nigam & Ors. (2000), and Vishal Kochi Kudivella Samrakshana Samithi vs. the State of Kerala (2006) established the norms for societies to treat water only as their right rather than a liability. Nevertheless, the recent dearth of water has raised a few questions, not on the right, but on the liability. The quest for an answer, thus, brings us to the polemics of legal infrastructure, where anything scarce and demanding high needs legal policies.

The groundwater availability of the entire country has already witnessed a law-and-order situation (The Hindu, 2016). Currently, 54% of India's population live in highly water-stressed conditions (WRI, 2015), demanding 712 BCM of water, and that is expected to increase up to 833 BCM by 2025, further up to 899 BCM in 2050 (UNICEF, 2013). Central Ground Water Board (CGWB) has already circulated a pricing policy. However, the factors considered in pricing and the justification of each factor's price/cost value needs to be clarified. Easement Act 1882 provides every landowner the right to use surface water within specific limits (Section 7 (g), Indian Easement Act, 1882). As the water falls under the State List of the Constitution, the state has to develop pertinent laws and regulations.

Furthermore, the central government has published specific Model Bills to provide broad guidelines on sustainable water usage. The government of India published the initial Model Bill in 2011 for water management in every state to enact the water laws appropriately. Then, in 2012, it implemented the National Water Policy by illustrating fundamental principles linked with the economic efficiencies of scarce resources.

Moreover, per the committee's recommendations, the government published the National Water Framework Bill in the subsequent year. Implementing these bills and policies falls under the public trust doctrine, which addresses groundwater governance. The public trust doctrine ensures that resources for public use cannot be enjoyed by any private parties (Regulation of Groundwater, 2011). The government must take care of the resources for its people (Singh & Tripathi, 1991).

The Model Bill has elicited a response from 11 states and 4 UTs adopting and implementing groundwater legislation (Ministry of Water Resources, 2015). Moreover, the By-laws of 2015, released by the Ministry of Urban Development, instruct all Government buildings of more than 100 sq. m area to implement rainwater harvesting as a mandatory measure.

Nevertheless, implementing a policy that aims to access safe and adequate water while achieving economic value and recovering total cost led to a conflicting interest. It remains to be seen that society can only reach an equitable distribution with appropriate modeling and enactment of policies, even if people are ready to pay for the entire cost.

Search for a Pertinent Policy Framework

This study indicates that none of the cities in our country can sustain their water supply for long. Even the conservative estimates indicate that these cities consume more water than they receive from nature. Serious steps need to be taken to address this threat. Government must take a comprehensive and integrated approach to water management, which includes a range of policies and strategies to conserve, protect, and sustainably use water resources. Based on the knowledge gathered from this article, we list below a few recommendations that would help develop policies and aid future research.

Incorporation of Remote sensing technology:

Water loss from the system is a significant problem, and addressing it requires specific technological parameters to target these areas' unique challenges. Authorities can invest in water monitoring systems such as smart water meters and remote sensing technologies to track proper water usage in water distribution systems. This can help to identify the areas where water is being unnecessarily lost and take corrective actions accordingly.

Introducing Startups in the Water Industry:

Startups can help prevent water loss through technologies by developing and implementing innovative solutions that address specific water loss challenges. Some examples include:

- Providing funding and support for start-ups working on water management practices better suited to the unique challenges of different regions, such as drought-tolerant crops and better irrigation systems.

- Offering tax incentives and grants for start-ups working on water conservation and water recycling technologies that can reduce water demand and improve water availability.

- Connect start-ups with government agencies, research institutions, and private sector organizations to help them access the resources and expertise needed to develop and implement their solutions.

- Providing mentorship and training programs for start-ups to help them navigate the regulatory and business landscape of the water sector.

- Start-ups can help prevent water loss through technologies by developing and implementing innovative solutions that address specific water loss challenges.

Implementing a few Specific Technological Parameters:

Addressing water loss requires specific technological policies, as many developed countries have already adopted. Therefore, to target the unique challenges that these areas face, the following are some standard technological policy recommendations for the government to prevent water loss:

- Implementing advanced metering infrastructure (AMI) to measure and track water usage accurately can help identify and address leaks and other sources of water loss.

- Develop a real-time water management system to monitor water levels, flow rates, and other vital parameters and provide early warning of potential water shortages.

- Collaboration between researchers, government agencies, and private sector organizations should be encouraged to develop innovative solutions for water loss prevention in these areas.

- Investing in research on water treatment technologies to improve the quality of water resources, such as removing pollutants and reducing water hardness.

- Encouraging research on the water-energy nexus and the development of new technologies that can help to reduce water loss and energy consumption.

Reducing Water Loss in the Primary Sector:

The above discussion demonstrated that agriculture is a primary water consumer sector. Once the significant water consumer is identified, efforts should be tailored to that sector. For example, water-efficient irrigation systems and drought-resistant crops should be promoted. Further, water use in livestock farming should be reduced.

Promoting Water Recycling and Reuse:

Water management and stakeholders should emphasize implementing water recycling and water reuse regulations to reduce water consumption in the household sector. Adapting the best practices pursued by other municipalities and government authorities (such as Surat Municipal Corporation) would be helpful.

Households Can Play a Pivotal Role in Addressing Water Scarcity:

Reducing water loss in households can also be critical in addressing water scarcity. Municipalities can implement policies to promote water-efficient appliances and practices, such as low-flow showerheads, faucet aerators, and greywater reuse. Using grey water for toilet flush can save a considerable amount of water. Mumbai has imposed such regulations for its multi-storeyed housing colonies. Nevertheless, many households in the studied municipalities can water the garden areas with grey water. Such water recycling can reduce the demand for freshwater by 40% for housing colonies.

Building Watershed to Reduce Runoff:

Rapid runoff can lead to soil erosion and allow little water retention. Hence, watershed and water harvesting structures such as afforestation, terracing, as well as soil and water conservation structures, should be built out of concrete, such as contour bunding, check dams, gabion walls, and other structures, to reduce runoff, and ensure proper water seepage into the soil, regulate water flow and decrease water storage.

Promoting Rainwater Harvesting Mechanism:

This study shows that few areas in our country often receive high amounts of precipitation; however, it is found that much of it is lost as runoff. Therefore, authorities should increase their focus on building rainwater harvesting systems to capture and store rainwater for later use. It can help increase water availability during times of scarcity and reduce the demand for surface water resources.

Maintenance of Database and Information:

One genuine problem we faced while doing the surveys was that each studied municipality needed to be more willing to maintain and distribute its data set. Therefore, all hydrological data should be available to the public except for information classified due to national security concerns. However, a recurring evaluation may be done for future data declassification. A National Water Informatics Centre should be established to collect, combine, and process hydrologic data nationwide. A GIS platform could handle the initial processing and maintain those data openly and transparently. All the data about water management, including rainfall, snowfall, eomorphologic, climatic, geological, surface water, groundwater, water quality, ecological, water extraction and use, irrigated area, etc., should be made a part of a public repository to the extent possible. This has already been done in other data-intensive fields, such as physiology, and has allowed us to examine them and present meaningful insights and conclusions.

Conclusions

Groundwater, a resource of paramount importance, should be priced to encourage conservation and ensure effective use. After extensive consultation with all stakeholders, each panchayat/municipality should establish an independent statutory water regulatory authority. Legislative authority should manage the volumetric amount of water allotted to the public, collect and keep a share of water rates, and maintain the distribution network under their control. The water charges, calculated on a volumetric basis, adhere to equality, efficiency, and economic principles. Such fees ought to be examined regularly. Each panchayat/municipality should be permitted to set different water rates depending on what they adhere to. This authority will play a crucial role in saving groundwater to egalitarian access to water should be maintained for everyone for drinking, sanitation, and agricultural purposes. Keeping all these, this study used an intensive literature review to examine India's recent advancement in groundwater. It reports adequate knowledge regarding:

- The economic structure supporting groundwater and its related market should consider the total cost of providing the resource and the entire environmental value.

- The legislative framework mentioned above is another perspective, reflecting what governments have accomplished and what needs to be done.

- Moreover, a policy outline based on the community's well-being has been illustrated. The absence of such policies will decrease the groundwater levels, and residential water infrastructure will deteriorate over time.

Like many other natural resources, we have taken the availability of water for granted; we continue to expect bounty as soon as we turn on the tap. In this era of global warming, we have to realize the actual value of water and the apparent effects of its scarcity. The evidence mentioned above articulates the current predicament of water scarcity. Furthermore, to mitigate the problem, the government must act wherever it is likely to be necessary. Government should aim to achieve the goal of providing an equitable distribution and sustainable use of resources. In a nutshell, this study provides a specific direction to supplement the evaluation of effective water pricing, analyze the legislative frameworks globally, and determine policy decisions. All these are the novelty of this article.

References

Asian Development Bank (2007). *Benchmarking and Data Book of Water Utilities in India*. http://hdl.handle.net/11540/222 (accessed Jan. 15, 2019).

Aeschbach-Hertig, W., & Gleeson, T. (2012). Regional strategies for the accelerating global problem of groundwater depletion. *Nat. Geosci.,* 5 (12), 853 861.

Alley, W.M., & Konikow, L.F. (2015). Bringing GRACE down to earth. *Groundwater*, 53 (6), 826–829.

Amarsinghe, U. & Sharma, B., 2009. Water Productivity of Food Grains in India: Exploring Potential Improvements. In *Strategic Analysis of National River Linking Project (NRLP) of India* (D. Kumar & U. Amarsinghe, editors), 4:13. International Water Management Institute, New Delhi.

Ashok, S. (2018). 95% of Monsoon Rain Falls in Only a Few Days, Show IMD Data. *Indian Express*, Sept. 4. https://indianexpress.com/article/india/95-of-monsoon-rain-falls-in-only-a-few-days-show-imd-data-5335664 (accessed Feb. 21, 2019).

Asoka, A., & Mishra, V. (2020). Anthropogenic and climate contributions on the changes in terrestrial water storage in India. *Journal of Geophysical Research: Atmospheres*, 125(10), p.e2020JD032470.

Asoka, A., Gleeson, T., Wada, Y., & Mishra, V. (2017). Relative contribution of monsoon precipitation and pumping to changes in groundwater storage in India. *Nat. Geosci.*, 10, 109–119. https://doi.org/10.1038/NGRO2869.

Asoka, A., Wada, Y., Fishman, R., & Mishra, V. (2018). Strong linkage between precipitation intensity and monsoon season groundwater recharge in India. *Geophys. Res. Lett*., 45, 5536–5544. https://doi.org/10.1029/2018GL078466.

Barik, B., Ghosh, S., Sahana, A.S., Pathak, A., & Sekhar, M. (2017). Water–food–energy nexus with changing agricultural scenarios in India during recent decades. *Hydrol. Earth Syst. Sci.,* 21 (6), 3041.

Bhanja, S. N., Mukherjee, A., Saha, D., Velicogna, I. & Famiglietti, J. S. (2016). Validation of GRACE based groundwater storage anomaly using in-situ groundwater level measurements in India. *Journal of Hydrology,* 543, 729–738.

Bhanja, S.N., Rodell, M., Li, B., Saha, D., & Mukherjee, A. (2017). Spatio-temporal variability of groundwater storage in India. *J. Hydrol*., 544, 428–437.

Bhat, T.A. (2014). An Analysis of Demand and Supply of Water in India. *Journal of Environment and Earth Science*, 4:11:67.

Cao, Y., & Roy, S.S. (2020). Spatial patterns of seasonal level trends of groundwater in India during 2002–2016. *Weather*, 75 (4), 123–128.

CAWMA (Comprehensive Assessment of Water Management in Agriculture). (2007). *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture* (D. Molden, ed.). Earthscan and Colombo, Sri Lanka; International Water Management Institute, London. www.iwmi.cgiar.org/assessment/files_new/synthesis/Summary_SynthesisBook.pdf (accessed Feb. 21,2019).

Central Ground Water Board. (2011). *Groundwater Scenario in Major Cities of India*. Ministry of Water Resources, Govt. of India.

Central Ground Water Board. (2014). *Dynamic Groundwater Resources of India*. Central Ground Water Board, Ministry of Water Resources. River Development & Ganga Rejuvenation, Government of India, Faridabad

Chakraborti, R. K., Kaur, J., & Kaur, H. (2019). Water shortage challenges and a way forward in India. *Journal-American Water Works Association*, 111(5), 42-49. DOI: 10.1002/awwa.1289.

Dangar, S., Asoka, A., & Mishra, V. (2021). Causes and implications of groundwater depletion in India: A review. *J. Hydrol*., 126103.

Davis, K.F., Chiarelli, D.D., Rulli, M.C., Chhatre, A., Richter, B., Singh, D., & DeFries, R. (2018). Alternative cereals can improve water use and nutrient supply in India. *Science advances*, 4(7), p. eaao1108.

Fujita, K. S., & Hossain, F. (1995). Role of the Groundwater Market in Agricultural Development and Income Distribution: A Case Study in A Northwest Bangladesh Village. *The Developing Economies*, XXXIII-4 (December 1995).

Gleeson, T., Cuthbert, M., Ferguson, G., & Perrone, D. (2020). Global groundwater sustainability, resources and systems in the Anthropocene. *Ann. Rev. Earth Planet. Sci.*, 48, 431–463.

Goldin, T. (2016). Groundwater: India's drought below ground. Nature Geoscience, 9, 98.

Central Ground Water Board (2014). *Ground Water Yearbook 2013-14*. Central Ground Water Board, http://www.cgwb.gov.in/documents/Ground%20Water%20Year%20Book%202013-14.pdf

Hira, G., & Khera, K. (2000). *Water resource management in Punjab under rice-wheat production system*. Punjab Agricultural University, Ludhiana, Department of Soils.

Joshi, S.K., Tiwari, A., Kumar, S., Saxena, R., Khobragade, S.D., & Tripathi, S.K. (2021). Groundwater recharge quantification using multiproxy approaches in the agrarian region of Bundelkhand Central India. *Groundwater Sustain. Develop.* 100564 https://doi.org/10.1016/j.gsd.2021.100564.

Joshi, S., Gupta, S., Sinha, R., Densmore, A., Rai, S., Shekhar, S., Mason, P., & Van Dijk, W. (2021). Strongly heterogeneous patterns of groundwater depletion in northwestern India. *Journal of Hydrology*. https://doi.org/10.1016/j.jhydrol.2021.126492

KPMG International (2010). *Water Sector in India: Overview and Focus Areas for the Future*. PanIIT Conclave. www.kpmg.de/docs/Water_sector_in_India.pdf (accessed Dec. 6, 2018).

MacDonald, A., Bonsor, H., Ahmed, K., Burgess, W., Basharat, M., Calow, R., Dixit, A., Foster, S., Gopal, K., & Lapworth, D. (2016). Groundwater quality and depletion in the Indo-Gangetic Basin mapped from in situ observations. *Nat. Geosci*., 9 (10), 762.

Madaan, S. (2018). What Is Water Scarcity?. *Earth Eclipse*, Dec. 6. www.eartheclipse.com/environment/causes-effects-and-solutions-to-water-scarcity.html (accessed Feb. 14, 2019).

Milman, A., & MacDonald, A. (2020). Focus on interactions between science-policy in groundwater systems. *Environ. Res. Lett.,* 15, 090201.

Mishra, V., Asoka, A., Vatta, K., & Lall, U. (2018). Groundwater depletion and associated CO2 emissions in India. *Earth's Future*, 6 (12), 1672–1681.

Mukherjee, S., Joshi, R., Prasad, R.C., Vishvakarma, S.C., & Kumar, K. (2015). Summer monsoon rainfall trends in the Indian Himalayan region. *Theor. Appl. Climatol*., 121 (3–4), 789–802.

Narain, S. (2012). *Excreta Matters, Vol 1*. Center for Science and Environment, New Delhi.

National Climate Centre, India Meteorological Department (2013). *Monsoon report 2012*.

P. Rogers, Hydrology and water quality. Changes in land use and land cover: A global perspective, 4 (1994), p. 231.

Pandey, K., & Sengupta, R. (2018). India Had a Deficit Monsoon in 13 of the Last 18 Years. *Down To Earth*, Oct. 1. www.downtoearth.org.in/news/water/india-had-a-deficit-monsoon-in-13-of-the-last-18-years-61772 (accessed Feb. 21, 2019).

Parikh, A. (2010). For a Few Pots of Water, *In search of Economic Alternatives for Gender and Social justice: Voices from India*, Edited by Christa Wichterich, WIDE, Belgium.

Prakash (2005). *The Dark Zone - Groundwater Irrigation, Politics and Social Power in North Gujarat*. Orient Longman.

Strohschon, R., Wiethoff, K., Baier, K., Lu, L., Bercht, A.L., Wehrhahn, R., & Azzam, R. (2013). Land use and water quality in Guangzhou, China: A survey of ecological and Social vulnerability in four urban units of the rapidly developing megacity, *International Journal of Environmental Research*, 7 , 343-358.

Rodell, M., Famiglietti, J., Wiese, D., Reager, J., Beaudoing, H., Landerer, F., Lo, M.H. (2018). Emerging trends in global freshwater availability. *Nature*, 557 (7707), 651.

Saha, D., Marwaha, S., & Mukherjee, A. (2018). *Clean and Sustainable Groundwater in India*. Springer.

Sharma, B., Mukherjee, A., Chandra, R., Islam, A., Dass, B., & Ahmed, M.R. (2008). *Groundwater governance in the Indo-Gangetic Basin: an interplay of hydrology and socio-ecology.* Conference Paper, International Water Management Institute.

Sharma, D. & Bharat, A. (2009). Conceptualizing Risk Assessment Framework for Impacts of Climate Change on Water Resources. *Current Science*, 96(8), 1044.

Shekhar, S., Kumar, S., Densmore, A.L., van Dijk, W.M., Sinha, R., Kumar, M., Joshi, S.K., Rai, S.P., Kumar, D., 2020. Modelling water levels of northwestern India in response to improved irrigation use efficiency. *Sci. Rep*., 10 (1), 1–15.

Shiao, T.; Maddocks, A.; Carson, C.; & Loizeaux, E. (2015). *3 Maps Explain India's Growing Water Risks*. World Resources Institute, Feb. 26. www.wri.org/blog/2015/02/3-maps-explain-India-s-growing-water-risks (accessed Dec. 6, 2018).

Singh, C., & Tripathi, N. M. (1991). *Water Rights and Principles of*

Water Resource Management.

Sinha, R., Joshi, S.K., & Kumar, S. (2019). Aftershocks of the Green Revolution in Northwest India. *Geography and You*, 19 (24), 12–19.

Smilovic, M., Gleeson, T., & Siebert, S. (2015). The limits of increasing food production with irrigation in India. *Food Security*, 7 (4), 835–856.

The Hindu (2016). http://www.thehindu.com/news/national/other-states/maharashtra-water-crisis-section-144-imposed-in-ahmednagar-district/article8508750.ece accessed on 07 July, 2016.

Tiwari, A., Joshi, S.K., Saxena, R., & Tripathi, S., K. (2021). Spatial pattern of groundwater recharge in Jhansi district in the Bundelkhand region, central India. Environment, Development and Sustainability: A Multidisciplinary Approach to the Theory and Practice of Sustainable Development, Springer, vol. 23(12), pages 18618-18630. https://doi.org/10.1007/s10668-021-01405-0.

Upadhyay, V. (2014). *A Rights-Based Approach to Water User Associations in India*.
http://www.ielrc.org/activities/workshop_0612/content/d0620.pdf.

US Census Bureau (2019). *U.S. Census Bureau Current Population*. www.census.gov/popclock/print.php?component=counter (accessed Feb. 21, 2019).

Van Dijk, W.M., Densmore, A.L., Jackson, C.R., Mackay, J.D., Joshi, S.K., Sinha, R., Shekhar, S., Gupta, S. (2020). Spatial variation of groundwater response to multiple drivers in a depleting alluvial aquifer system, northwestern India. *Progr. Phys. Geogr.: Earth Environ*., 44 (1), 94–119.

Wakode, H. B., Baier, K., Jha, R., & Azzam, R. (2018). Impact of urbanization on groundwater recharge and urban water balance for the city of Hyderabad, India. *International Soil and Water Conservation Research*, 6(1), 51-62.

Water and Related Statistics, April 2015, Central Water Commission,

WRI (2015). http://www.wri.org/blog/2015/02/3-maps-explain-india%E2%80%99s-growing-water-risks accessed on 20 September, 2016.

World Water Assessment Program (2018). *The United Nations World Water Development Report 2018: Nature-Based Solutions for Water. United Nations Educational, Scientific and Cultural Organization*. Paris. https://unesdoc.unesco.org/ark:/48223/pf0000261424_eng (accessed Dec. 7, 2018).

WWAP (2012). *Managing Water Under Uncertainty and Risk. World Water Development Report 4*. United Nations Educational, Scientific and Cultural Organization, Paris. https://unesdoc.unesco.org/ark:/48223/pf0000215644 (accessed Feb. 13, 2019).

Zaveri, E., Grogan, D.S., Fisher-Vanden, K., Frolking, S., Lammers, R.B., Wrenn, D.H., Prusevich, A., & Nicholas, R.E. (2016). Invisible water, visible impact: groundwater use and Indian agriculture under climate change. *Environ. Res. Lett.*, 11 (8), 084005.