

Sustainable groundwater management in India: A multifaceted approach to a growing crisis

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Abstract

This paper provides a comprehensive examination of the diverse and complex challenges surrounding groundwater management in India, emphasizing the pressing need for integrated and holistic strategies to address this growing crisis. The analysis explores the existing regulatory frameworks governing groundwater use, underscoring the essential role of stakeholder engagement and participation in developing effective solutions. The paper proposes a set of policy guidelines aimed at promoting sustainable groundwater utilization, highlighting key focus areas such as regulating the extraction and use of groundwater by commercial and industrial entities, encouraging the adoption of water-efficient agricultural practices, and reforming electricity and water pricing policies. The paper advocates for a critical shift from a centralized, 'command-and-control' approach towards a more participatory model that actively involves local communities, farmers, and industries as essential partners in the pursuit of long-term groundwater sustainability. This expanded analysis delves deeper into the underlying causes and potential solutions to the groundwater crisis, emphasizing the need for a collaborative and multifaceted approach to achieve sustainable water management in India.

Keywords: Groundwater management; India; Sustainable agriculture; Stakeholder engagement; Policy reform

1. Introduction

Groundwater is an indispensable resource in India, serving as a vital lifeline for the nation's agriculture, industry, and domestic water supply. However, the unsustainable overexploitation of this precious resource, driven by factors such as heavily subsidized electricity for agricultural purposes and growing industrial demand, has led to widespread and concerning depletion (Leonard, 2023). This crisis poses a grave and multifaceted threat to India's water security, food production, and socio-economic development. This paper presents a comprehensive analysis of the diverse and complex challenges surrounding groundwater management in India, examining the existing regulatory frameworks, exploring the essential role of stakeholder engagement, and proposing policy guidelines to promote sustainable groundwater utilization. The analysis delves deeper into the underlying causes and potential solutions, highlighting the need for a collaborative and multifaceted approach to effectively address this growing crisis. Recent studies have further emphasized that groundwater depletion in India is exacerbated by the overuse of water-intensive crops, lack of groundwater recharge infrastructure, and insufficient enforcement of existing regulations (Mishra, 2018) (Boruah & Naz, 2020). A comprehensive approach integrating technological, policy, and community-based interventions is required to address this pressing issue.

1.1. Groundwater Governance in India: A Fragmented Landscape

India's existing groundwater regulatory framework exhibits a highly centralized and fragmented approach, lacking comprehensive coordination and oversight (Koonan, 2016). While individual states have developed their own groundwater acts and policies, the absence of a unified national-level groundwater law has resulted in a patchwork of

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regulations that often fail to address pressing issues effectively. The centralized 'command-and-control' model employed by state-level authorities has struggled to keep pace with the diffuse and rapidly growing groundwater extraction, making it challenging to regulate the millions of individual extraction units across the country (Koonan, 2016).

As the literature suggests, this approach has several inherent limitations (Boruah & Naz, 2020) (Koonan, 2016) (Khare & Varade, 2018). It fails to account for the complex hydrogeological characteristics of different regions, lacks effective mechanisms for stakeholder engagement, and often overlooks the social and economic dimensions of groundwater use.

1.2. Towards a Participatory and Equitable Groundwater Management Framework

The existing centralized approach to groundwater governance in India has been recognized as inadequate, prompting a need for a paradigm shift (Koonan, 2016). Key stakeholders, including policymakers, researchers, and local communities, have emphasized the importance of a more participatory and inclusive model that empowers local communities and encourages collaborative decision-making. This transition towards a decentralized, community-based approach holds the potential to address the unique hydrogeological and socio-economic characteristics of different regions, ensuring that groundwater management strategies are tailored to local needs and priorities (Joshi et al., 2019). Moreover, the active engagement of diverse stakeholders, such as farmers, industries, and civil society organizations, can foster a shared sense of responsibility and ownership, leading to more sustainable and equitable groundwater utilization (RWSN Library, 2023).

1.3. Challenges of Groundwater Depletion in India

India's groundwater resources have encountered significant strain due to a confluence of factors, including the rapid expansion of irrigation-based agriculture, industrial growth, and population increase. (Boruah & Naz, 2020) As of 2017, India was the world's largest consumer of groundwater, utilizing over 21 million irrigation wells and extracting an estimated 250 billion cubic meters annually. (Cullet, 2014) This unsustainable overexploitation has led to the rapid depletion of groundwater tables, with more than 60% of India's groundwater blocks classified as over-exploited, critical, or semi-critical. The groundwater depletion crisis is particularly acute in the agriculturally important states of Rajasthan, Punjab, Haryana, and Tamil Nadu, which account for a substantial portion of India's food production. (Boruah & Naz, 2020) (Cullet, 2014) This issue has far-reaching implications for the country's water security, agricultural sustainability, and overall economic development.

In addition to quantitative depletion, groundwater in many parts of India also faces severe quality challenges, such as contamination by arsenic, fluoride, and nitrates, which can have serious public health implications. These water quality problems further exacerbate the groundwater crisis, as contaminants can render the groundwater unusable for both agricultural and domestic purposes. (Guppy et al., 2018) The presence of these contaminants is often linked to improper waste disposal, industrial effluents, and agricultural runoff. (Memon, 2017) Addressing these multifaceted challenges necessitates a comprehensive approach that integrates legal, institutional, and technological interventions to regulate groundwater extraction and improve water quality.

1.4. Existing Regulatory Framework and its Limitations

India's groundwater governance framework is primarily based on the principle of land ownership, granting landowners unrestricted rights to extract groundwater from their land. This has resulted in a highly decentralized and loosely regulated system of groundwater extraction, significantly contributing to the depletion of aquifers across the country (Cullet, 2014). The Central Groundwater Authority, established in 1986, has the mandate to regulate and control groundwater development and management, but its effectiveness has been severely hindered by a lack of robust enforcement mechanisms and meaningful coordination with state-level authorities (Rodell et al., 2009).

At the state level, various groundwater acts and policies have been enacted, but their implementation has been largely ineffective. These state-level regulations often suffer from inadequate monitoring, limited stakeholder participation, and a focus on technical solutions rather than addressing the underlying socio-economic and governance challenges (Corrigan, 2019).

Furthermore, several states have enacted their own groundwater legislation, such as the Andhra Pradesh Water, Land, and Trees Act and the Tamil Nadu Groundwater Act. However, these acts have often been criticized for their narrow focus on the registration and licensing of groundwater extraction structures, rather than addressing the underlying socio-economic and policy drivers that have fueled the unsustainable exploitation of this vital resource (Qureshi, 2020).

The inability to effectively curb groundwater depletion through these legislative measures underscores the need for a more comprehensive and integrated approach to groundwater management in India.

1.5. Towards a Participatory Approach to Groundwater Management

The existing regulatory framework's shortcomings underscore the necessity for a more participatory and decentralized groundwater management approach in India. Engaging local communities, farmers, and other key stakeholders as integral partners is crucial for the successful implementation and enforcement of groundwater regulation and conservation initiatives. Embracing a collaborative model, where decision-making and implementation processes are shared among diverse stakeholders, can foster more sustainable groundwater management practices tailored to the unique needs and characteristics of different regions and communities.

The Model Groundwater Act, 2017, proposed by the Ministry of Water Resources, River Development, and Ganga Rejuvenation, represents a significant step towards a more participatory and inclusive groundwater governance framework (Kulkarni et al., 2015). This model bill recognizes groundwater as a public trust and emphasizes the need for decentralization, community involvement, and aquifer-level management. The act proposes the establishment of local Groundwater Management Councils, which would be responsible for developing and implementing groundwater management plans at the community level (MAQBOOL, 2023).

Successful community-based groundwater management initiatives, such as the Participatory Groundwater Management program in Maharashtra, have demonstrated the potential of this approach. These programs empower local communities to monitor and regulate their groundwater resources, fostering a sense of shared responsibility and ownership (Kasturi, 2016).

1.6. Policy Recommendations for Sustainable Groundwater Management

Addressing India's groundwater crisis necessitates a comprehensive policy approach incorporating the following key elements:

- Regulating commercial and industrial groundwater extraction: Stringent licensing and metering requirements should be introduced for large-scale groundwater consumers, such as industries and commercial establishments, to curb over-exploitation (Koonan, 2016). This will establish accountability and promote sustainable groundwater usage among these high-volume users.
- Promoting water-efficient agricultural practices: Farmers should be incentivized to adopt water-saving irrigation technologies, such as drip and sprinkler systems, and encouraged to diversify their crops towards less water-intensive varieties. Providing financial and technical assistance can facilitate the transition to more sustainable agricultural water management practices (Boruah & Naz, 2020).
- Reforming electricity and water pricing policies: Phasing out subsidies for electricity used in groundwater extraction and implementing appropriate pricing mechanisms can discourage over-extraction (Boruah & Naz, 2020). This will create economic incentives for farmers and industries to use groundwater more efficiently and promote conservation.
- Strengthening community-based groundwater management: Empowering local communities, including farmers and village-level institutions, to participate in groundwater regulation and conservation efforts can foster a sense of ownership and responsibility, leading to more effective implementation of management strategies (Rijal, 2015).
- Improving groundwater data collection and monitoring: Investing in advanced technology, such as remote sensing and GIS, can enhance groundwater data collection, monitoring, and decision-making. Robust data and information systems are crucial for informed policymaking and effective groundwater management (Arabameri et al., 2020).
- Promoting groundwater recharge and replenishment: Implementing measures to enhance natural groundwater recharge, such as the construction of rainwater harvesting structures, artificial recharge pits, and the restoration of traditional water bodies, can help offset the imbalance between extraction and replenishment (Liu et al., 2001).
- Strengthening inter-agency coordination and enforcement: Improving coordination between the Central Groundwater Authority and state-level agencies can ensure effective implementation and enforcement of groundwater regulations, overcoming the limitations of the current fragmented approach (Koonan, 2016) (Rodell et al., 2009). Implementing these comprehensive policy measures will be crucial in addressing the multifaceted challenges of groundwater depletion and ensuring the long-term sustainability of this vital resource in India.

2. Literature Review

The academic literature emphasizes the severity of India's groundwater crisis and the need for a comprehensive approach to address it. Studies highlight the lack of sufficient data and analysis on patterns of groundwater use and their socio-economic and environmental implications (Qureshi, 2020). Additionally, the research underscores the importance of participatory groundwater management approaches, recognizing the limitations of a top-down 'command-and-control' strategy (Pahuja et al., 2010). Furthermore, the literature suggests that groundwater management strategies should be tailored to the specific hydrogeological and resource-use characteristics of different aquifer types, as the problems associated with groundwater depletion can vary significantly across regions. The transboundary nature of aquifers and the interconnected groundwater systems across state and national boundaries add further complexity, requiring coordinated efforts among stakeholders and policymakers. The existing body of research on groundwater management in India also highlights the need for more in-depth analysis and comprehensive data on the drivers, impacts, and potential solutions to the country's groundwater crisis to inform evidence-based policymaking and effective management strategies.

2.1. Proposed Guidelines for Regulating Groundwater Extraction

To address the groundwater depletion issue in India, this paper proposes the following guidelines:

- **Participatory Groundwater Management Approach:** Engaging all relevant stakeholders, including local communities, farmers, and industries, in a participatory approach is essential. This approach fosters a sense of ownership and responsibility, leading to more effective implementation of management strategies. By empowering local communities and involving them in decision-making and implementation processes, groundwater management strategies can be tailored to the unique needs and characteristics of different regions, ensuring their long-term sustainability (Shah et al., 2005).
- **Groundwater Pricing and Electricity Policy Reforms:** State and Union Territory governments should review their policies on free or subsidized electricity for farmers and implement suitable water pricing mechanisms to discourage over-exploitation. This requires careful consideration of the potential socio-economic impacts on farmers and implementing mitigation measures, such as targeted subsidies or support programs to ensure the affordability of water for small and marginal farmers (Leflaive & Hjort, 2020).
- **Promoting Water-Efficient Agricultural Practices:** Farmers should be encouraged to adopt crop diversification, drought-resistant crop varieties, and improved irrigation techniques to reduce water consumption. Providing technical and financial support for these transitions is crucial, through initiatives such as demonstration farms, training programs, and subsidies for the adoption of water-saving technologies (Evans & King, 2010).
- **Regulating Commercial Groundwater Use:** Stricter regulations on commercial groundwater extraction are needed, particularly in over-exploited areas. No Objection Certificates for groundwater extraction should be granted judiciously, considering the availability of groundwater resources and the potential impact on local communities. Mandatory online water audits for commercial entities can enhance transparency and accountability, and the revenue generated from these audits can be reinvested into groundwater recharge and conservation efforts (Wijnen et al., 2012).

3. Methodology

This academic paper synthesizes an extensive review of existing literature, including studies, policy documents, and government reports, on groundwater management in India. The analysis distills the key findings, challenges, and recommended strategies from the available research on this critical issue. By drawing upon a diverse array of academic and policy sources, this paper offers a comprehensive overview of the current knowledge and the multifaceted approaches required to address India's groundwater depletion crisis.

4. Results and Discussion

The academic literature emphasizes the multifaceted nature of groundwater overexploitation in India, with variations across different regions and aquifer types. Researchers underscore the importance of a participatory approach, coupled with groundwater pricing reforms and the promotion of water-efficient agricultural practices, as crucial elements for attaining sustainable groundwater management. Regulating commercial groundwater extraction and implementing mandatory water audits can further contribute to resource sustainability. However, successful implementation of these guidelines necessitates careful consideration of the socio-economic context and potential impacts on diverse stakeholders. The literature highlights the need for additional research to evaluate the effectiveness of various

management strategies and to develop context-specific solutions. Furthermore, the existing body of research underscores the necessity for more comprehensive data collection, robust monitoring systems, and a deeper understanding of the interconnected nature of groundwater systems across state and national boundaries. Developing context-specific policy interventions that account for local hydrogeological and resource-use characteristics will be essential for ensuring the long-term sustainability of India's groundwater resources.

5. Conclusion

Sustainable groundwater management in India requires a comprehensive and integrated approach. If implemented effectively, the proposed guidelines can aid in regulating groundwater extraction, particularly from commercial establishments, thereby contributing to the long-term sustainability of this crucial resource. Transitioning towards a participatory model that engages all stakeholders is essential for achieving lasting solutions to India's groundwater depletion.

The implementation of these measures will necessitate overcoming institutional, political, and socio-economic challenges. Continuous monitoring, data collection, and research are crucial to refine and adapt the management strategies over time. Ultimately, a multi-pronged approach that addresses the diverse hydrogeological and resource-use characteristics of different regions is the key to safeguarding India's groundwater resources for present and future generations.

Sustainable groundwater management in India demands a multifaceted and holistic strategy. If properly executed, the guidelines presented in this paper can help in regulating groundwater extraction, especially from commercial entities, and contribute to the long-term sustainability of this vital resource. A fundamental shift towards a participatory model, involving all relevant stakeholders, is crucial for developing lasting solutions to address the country's groundwater depletion.

Overcoming institutional, political, and socio-economic hurdles will be necessary for the effective implementation of these measures. Continuous monitoring, data collection, and research are essential to refine and adapt the management strategies over time.

Addressing groundwater depletion in India necessitates a multi-pronged approach that balances the competing demands for water and promotes sustainable groundwater management. This paper has highlighted the imperative for a paradigm shift from a centralized, top-down approach to a more participatory model that actively engages local communities, farmers, and industries. By implementing the policy recommendations outlined in this paper, India can take significant strides towards achieving long-term groundwater sustainability and ensuring water security for its growing population.

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