

Water Resource Management, Rainwater Harvesting & Sustainability Practices: An Analytical Study of Bahraich District, Uttar Pradesh

Pradeep Kumar Tiwari¹, Dr. Lalit Kumar Dubey²

¹Research Scholar, Department of Geography, R. P. P. G. College, Kamalganj, Farrukhabad (U.P.),

²Assistant Professor, Department of Geography, R. P. P. G. College, Kamalganj, Farrukhabad (U.P.),

Abstract

This paper presents a comprehensive analysis of water resource management practices, rainwater harvesting initiatives, and sustainability approaches in Bahraich District, Uttar Pradesh. Located in the Terai region with unique hydrogeological characteristics, Bahraich faces complex water challenges including groundwater quality deterioration, arsenic contamination, and the need for sustainable agricultural water management. The study examines recent government initiatives, including the achievement of 100% rooftop rainwater harvesting installation in government buildings under the "Catch the Rain 2025" campaign, and community-led interventions such as solar-powered irrigation systems supported by the Aga Khan Foundation. Primary data from farmer collectives demonstrates significant economic and environmental benefits, including collective savings of ₹5 lakh in farming costs through reduced diesel dependence. However, the research also identifies critical challenges, particularly the finding that 42% of groundwater samples exceed WHO arsenic limits of 10 µg/l, with over 80% of samples falling into "poor" or "unfit" categories for drinking purposes. The paper evaluates the interplay between water conservation efforts and agricultural practices, including the tension between promoting water-efficient crops and farmers' preference for water-intensive paddy cultivation. Policy recommendations include strengthening institutional frameworks for groundwater governance, promoting crop diversification, scaling up successful community models, and integrating water quality monitoring with conservation efforts.

Keywords: Water resource management, rainwater harvesting, groundwater quality, arsenic contamination, solar irrigation, sustainable agriculture, Bahraich district

1. Introduction

Water resource management in the 21st century represents one of the most pressing challenges facing developing economies, particularly in regions characterized by high population density, agricultural dependence, and vulnerability to climate variability. India, with 18% of the world's population but only

4% of its freshwater resources, exemplifies this challenge (Cullet, 2014). Within India, the Indo-Gangetic Plain—the nation's breadbasket—faces acute water stress due to intensive irrigation, groundwater depletion, and deteriorating water quality. Uttar Pradesh, India's most populous state, occupies a critical position in this water-security nexus. The state's agricultural economy, which sustains millions of livelihoods, depends heavily on groundwater extraction. Recent estimates indicate that approximately 46 billion cubic meters (BCM) of groundwater were withdrawn for agriculture in 2023 alone—sufficient to submerge the entire area of Agra under water equivalent to a three-story building. This extraction rate, coupled with groundwater table depletion of up to 10 cm per year (Singh et al., 2019), signals an impending crisis that demands urgent analytical attention and policy intervention. Bahraich District, situated in the Terai region of Uttar Pradesh along the Nepal border, presents a particularly instructive case study for water resource management analysis. The district's hydrogeological profile—characterized by a shallow water table of 20-30 feet—might suggest water abundance. However, this apparent plentitude masks complex challenges: geogenic arsenic contamination affecting a significant portion of groundwater sources, seasonal variability in water availability, and the sustainability implications of agricultural practices that increasingly favor water-intensive crops.

This study undertakes a multidimensional analysis of water resource management in Bahraich District, examining three interconnected domains: rainwater harvesting infrastructure and policy implementation, groundwater quality and its implications for drinking water security, and sustainable agricultural practices that mediate the relationship between water availability and food production. The research integrates secondary data from government sources, scientific studies, and development organizations with primary observations from community-level interventions to construct a holistic understanding of water governance challenges and opportunities. The analytical framework adopted herein recognizes that water resource management cannot be divorced from broader questions of institutional capacity, community participation, technological innovation, and policy coherence. By examining Bahraich District through this multidimensional lens, the study aims to generate insights applicable not only to this specific context but to similar agro-ecological regions confronting the challenge of reconciling development aspirations with resource sustainability.

2. Study Area: Bahraich District Profile - Geographical and Demographic Context

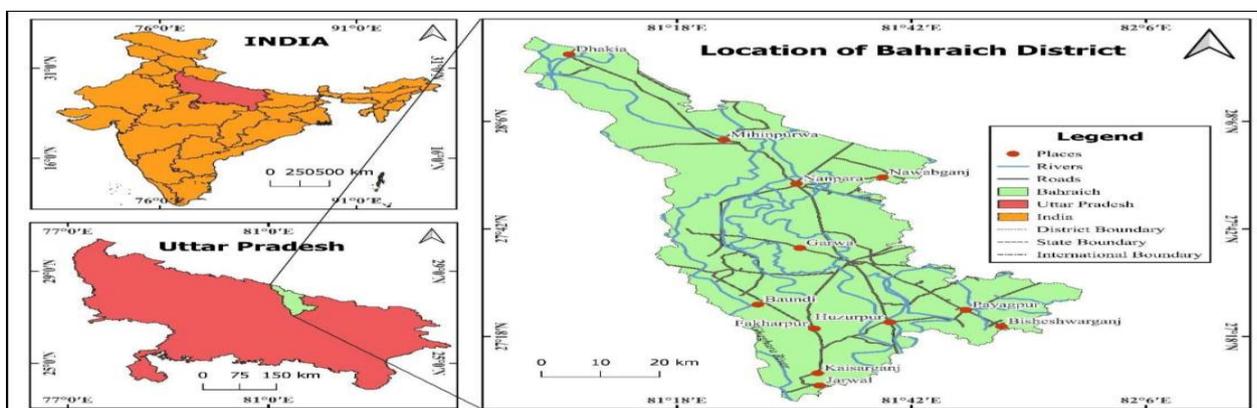


Fig :- Location of Study Area

(source – <https://www.jetir.org/papers/JETIR2406A66.pdf>)

Bahraich District is located in the Devipatan Division of Uttar Pradesh, sharing an international border with Nepal to the north. The district extends between latitudes 27°20' to 28°24' North and longitudes 81°05' to 82°42' East, encompassing an area of approximately 5,237 square kilometers. Administratively, the district comprises six tehsils—Bahraich, Nanpara, Mahsi, Kaiserganj, Payagpur, and Mihinpurwa—subdivided into 14 development blocks. The district's population, according to the 2011 Census, stands at 3,487,731 persons, with rural population constituting 94.7% of the total—significantly higher than the state average of 77.7%. This rural predominance underscores the centrality of agriculture to the district's economy and livelihoods, and by extension, the critical importance of water resources for sustainable development.

Hydrogeological Characteristics: Bahraich forms part of the central Ganga Plain, characterized by Quaternary alluvial sediments deposited by the Ganga and its Himalayan tributaries. The district's location in the Terai belt—the transitional zone between the Himalayan foothills and the plains—endows it with distinctive hydrogeological features. The water table is remarkably shallow, typically ranging from 20 to 30 feet below ground level, a consequence of high recharge rates from precipitation and influent seepage from Himalayan rivers. The Ghaghara River (also known as Saryu) constitutes the primary drainage system, flowing from northwest to southeast through the district. This perennial river, fed by Himalayan snowmelt and monsoon rainfall, exerts significant control over the district's surface water hydrology and groundwater dynamics. The river-aquifer interaction in this setting creates complex flow patterns and geochemical gradients that influence groundwater quality across spatial scales.

Climatic Regime: The district experiences a humid subtropical climate, modulated by its proximity to the Himalayan foothills. Mean annual rainfall ranges from 1,100 to 1,300 mm, with approximately 85% occurring during the southwest monsoon months (June to September). This precipitation regime creates distinct seasonal patterns in water availability: surplus during the monsoon months, followed by progressive decline through the post-monsoon and summer periods. Temperature variations are pronounced, with summer maxima reaching 40°C and winter minima dropping to 7°C. This thermal regime influences evapotranspiration rates, crop water requirements, and the seasonal dynamics of surface water bodies.

3. Research Methodology

Analytical Framework: This study employs a mixed-methods research design, integrating quantitative analysis of secondary data with qualitative assessment of policy implementation and community-level interventions. The analytical framework encompasses three interconnected dimensions: infrastructure and technology assessment, water quality evaluation, and institutional analysis.

Data Sources:

Secondary Data:

- Government reports and policy documents from the Ministry of Jal Shakti, Government of India
- Scientific publications on groundwater quality in Bahraich District (peer-reviewed journal articles)
- Development organization reports (Aga Khan Foundation)

- Census data and district statistical handbooks
- Legislative responses and parliamentary proceedings

Primary Data:

- Case study documentation from farmer producer organizations and self-help groups
- Community-level intervention data from solar irrigation collectives
- Water quality monitoring reports from groundwater sampling studies

Analytical Methods

Water Quality Assessment: Analysis of hydrogeochemical data employing Water Quality Index (WQI) methodology, comparing observed parameters with Bureau of Indian Standards (BIS) and World Health Organization (WHO) guidelines. Hydrogeochemical facies characterization using Piper diagram analysis and Gibbs diagram interpretation for source apportionment.

Policy Analysis: Examination of policy implementation through documentary analysis and assessment of achievement against stated targets, particularly regarding rainwater harvesting infrastructure installation.

Socio-Economic Impact Assessment: Evaluation of community-level interventions using cost-benefit analysis framework, examining direct economic impacts (cost savings, income enhancement) and indirect benefits (environmental externalities, social capital formation).

Limitations: The study acknowledges certain limitations: reliance on secondary water quality data rather than primary sampling; temporal constraints in assessing long-term sustainability of interventions; and the challenge of attributing observed outcomes to specific policy interventions given the multiplicity of concurrent programs and initiatives.

4. Water Resources Status and Challenges

Groundwater Availability and Extraction Patterns: The shallow aquifer system in Bahraich presents both opportunities and vulnerabilities. The water table depth of 20-30 feet implies relatively low energy requirements for groundwater extraction compared to regions experiencing secular decline. However, this apparent advantage masks emerging concerns about extraction sustainability and quality deterioration. Agricultural groundwater extraction in the district follows cropping patterns dominated by paddy (rice), wheat, sugarcane, and increasingly, summer rice. The progressive adoption of triple cropping systems—rice-mustard-rice or rice-pulses-rice—intensifies pressure on groundwater resources. While the district has not yet experienced the dramatic water table declines documented in western Uttar Pradesh (Singh et al., 2019), the trajectory of agricultural intensification warrants careful monitoring.

Groundwater Quality: The Arsenic Challenge: Perhaps the most significant water quality challenge facing Bahraich District is geogenic arsenic contamination. A comprehensive assessment of groundwater quality conducted in the district analyzed 40 groundwater samples and 5 surface water samples from the Ghaghara River during the post-monsoon season. The findings are deeply concerning:

Arsenic Contamination: Arsenic concentrations exceeded the WHO recommended value of 10 µg/l in approximately 42% of groundwater samples. This level of contamination poses serious public health risks, as chronic arsenic exposure is associated with skin lesions, cardiovascular disease, neurological effects, and cancers of multiple organs.

Iron and Manganese: Elevated concentrations of iron (Fe) and manganese (Mn) were detected, exceeding permissible limits in a substantial proportion of samples. While these elements are less toxic than arsenic, they affect palatability, cause staining, and may indicate reducing conditions that facilitate arsenic mobilization.

Water Quality Index: The computed Water Quality Index (WQI) for samples ranged from 45 to 1,219, with a mean value of 273. Critically, more than 80% of samples fell into categories classified as "poor" or "unfit" for drinking purposes. This finding has profound implications for drinking water security and public health planning.

Hydrogeochemical Characterization: Piper diagram analysis revealed the dominance of Ca-Cl and Mg-Cl facies, followed by Na-Cl, Mg-SO₄, and Ca-HCO₃ types. The ionic abundance sequence—cations: Ca²⁺ > Mg²⁺ > Na⁺ > K⁺; anions: Cl⁻ > SO₄²⁻ > HCO₃⁻—indicates significant geochemical evolution from the simple bicarbonate-type waters typical of recharge areas.

Source Attribution: Gibbs diagram interpretation indicates the predominance of rock-water interaction in controlling groundwater chemistry, while isotopic signatures suggest local precipitation as the primary recharge source with limited evaporation effects. These findings support the interpretation of arsenic contamination as geogenic in origin, likely derived from Himalayan sediments deposited in the Ganga Basin.

Surface Water Resources: The Ghaghara River constitutes the primary surface water resource, supplemented by numerous smaller streams, ponds, and wetlands characteristic of the Terai landscape. These surface water bodies play multiple roles: irrigation sources, groundwater recharge zones, fisheries habitat, and domestic water supplies in riparian communities. However, surface water quality monitoring along the Ghaghara remains limited. Unlike the Ganga mainstem, which benefits from intensive monitoring under the National Mission for Clean Ganga, tributary systems receive less systematic attention. This monitoring gap constrains comprehensive assessment of surface water quality trends and their implications for dependent communities.

5. Rainwater Harvesting: Policy and Implementation

National and State Policy Framework: Rainwater harvesting in India operates within a multi-layered policy architecture. At the national level, the National Water Policy (2012) explicitly advocates rainwater harvesting and conservation, emphasizing "augmenting the availability of water through direct use of rainfall". The Ministry of Housing and Urban Affairs' Model Building Bye-laws (2016) recommend rainwater harvesting systems for all buildings with plot sizes of 100 square meters or more, provisions that 35 States and Union Territories—including Uttar Pradesh—have incorporated into their respective building regulations. The Government of India has also circulated a Model Bill to all States/UTs enabling them to enact groundwater legislation incorporating rainwater harvesting provisions. Uttar Pradesh is

among the 21 States that have adopted and implemented such legislation, providing the legal foundation for mandatory rainwater harvesting in appropriate contexts.

The "Catch the Rain 2025" Campaign: The Jal Shakti Department, Government of Uttar Pradesh, launched the "Catch the Rain 2025" campaign as a flagship initiative to promote rainwater harvesting statewide. The campaign's primary objective involves equipping 2.35 lakh government and semi-government buildings across Uttar Pradesh with rooftop rainwater harvesting systems. This initiative represents one of the most ambitious rainwater harvesting programs undertaken by any Indian state, reflecting recognition of groundwater depletion as a critical policy challenge requiring structural intervention. The campaign's scale—targeting over 200,000 public buildings—demonstrates commitment to mainstreaming rainwater harvesting as a standard feature of built infrastructure rather than an exceptional intervention.

Bahraich District Achievement: Bahraich District has achieved notable success in implementing the "Catch the Rain" campaign objectives. Official records confirm that the district has reached 100% of the target for rainwater harvesting installation in all eligible government buildings. This accomplishment places Bahraich among 16 districts in Uttar Pradesh—including Ayodhya, Ambedkar Nagar, Barabanki, Gonda, Balrampur, Shravasti, and others—that have achieved full target coverage.

The achievement carries multiple implications:

Infrastructure Density: With all eligible government buildings now equipped with rooftop rainwater harvesting systems, the district has established a distributed network of recharge structures capable of capturing and directing monsoon rainfall to aquifer systems.

Demonstration Effect: Government buildings serving as visible examples of rainwater harvesting implementation may encourage adoption in the private sector, including residential, commercial, and institutional properties.

Institutional Learning: The process of achieving 100% coverage has generated implementation experience—including technical, financial, and administrative lessons—that can inform future phases of the program and potential expansion to additional building categories.

Beyond Government Buildings: Pond Rejuvenation

Parallel to rooftop rainwater harvesting in government buildings, the district has witnessed interventions targeting traditional water bodies. Under the central government's Mission Amrit Sarovar scheme, which envisions a pond on each acre of land, existing ponds are being desilted and their percolation capacity strengthened. The Aga Khan Foundation (AKF), working in Bahraich under its Low Carbon Agriculture Programme initiated in 2020-2021, has contributed to this effort by rejuvenating 16 ponds in the district. These interventions enhance rainwater capture, improve groundwater recharge, and restore the ecological and social functions of traditional water bodies that have often fallen into disrepair.

6. Sustainable Agriculture and Water Management

Solar-Powered Irrigation: A Community-Based Approach: The most innovative water management intervention in Bahraich District involves the introduction of community-managed solar-powered irrigation systems. Under the Aga Khan Foundation's Low Carbon Agriculture Programme, 97 solar irrigation systems have been installed across the district, benefiting 8,700 farmers and irrigating 1,872 acres. The Unnat Sichai Solar Vikas Samiti in Imamnagar Village, Balbhaddrapur block, exemplifies this approach. This collective of 17 small farmers adopted innovative farming practices on 83 bighas (approximately 16.6 acres), replacing diesel pump sets with five solar irrigation units. The transition generated immediate economic benefits: collective savings of ₹5 lakh in farming costs through elimination of diesel expenses.

The operational model incorporates several design features conducive to sustainability:

Cost Sharing: Farmers pay ₹2 per unit of power consumed, receiving 1,000 liters of water for this amount. This payment mechanism creates financial sustainability while maintaining affordability.

User Discipline: Farmers must inform the solar power operator of water requirements in advance, specifying duration. Water is distributed on a first-come, first-served basis, though the group has developed flexibility to accommodate urgent needs.

Financial Management: Over two years, the Samiti utilized 64,000 units of solar power, collected ₹1,28,000, and after expenditures on pump house construction, operator fees, land rent, and maintenance, deposited ₹36,000 in the bank. This financial discipline demonstrates the viability of community-managed irrigation infrastructure.

Governance Structure: Monthly meetings of all members ensure collective decision-making and conflict resolution, building social capital alongside physical infrastructure.

Water-Efficient Irrigation Technologies: Complementing the shift in energy source, farmers in Bahraich have adopted water-efficient irrigation technologies including laser land leveling, sprinkler systems, and drip irrigation. These technologies address the demand side of water management, reducing the volume of water required per unit of agricultural output.

Farmer testimonies indicate awareness of groundwater conservation benefits: "To conserve ground water, laser sprays, sprinklers, and drip irrigation are being used and the land remains soft and productive". This consciousness, linked to direct experience with solar irrigation systems, suggests potential for behavioral reinforcement between technological adoption and conservation awareness.

Crop Diversification: The Millet Initiative: A critical tension in sustainable water management involves cropping patterns. Despite the availability of solar irrigation and water-efficient technologies, farmers continue to prefer water-intensive crops, particularly paddy. The Aga Khan Foundation has actively promoted diversification toward less water-demanding alternatives: mustard, millets, pulses, and other crops requiring less irrigation. The millet initiative demonstrates measurable progress: from 30 farmers motivated to grow millet in the previous year to 282 farmers cultivating millet in the current year. This tenfold increase in adoption, while still modest relative to total farming population, indicates potential for scaling if appropriate incentives and extension support are maintained. The policy significance of crop

diversification extends beyond Bahraich. Statewide analysis indicates that approximately 350,000 hectares are under summer rice cultivation—far exceeding official estimates of 50,000 hectares—with associated groundwater extraction of 2,730 million cubic meters in 2023 alone. This discrepancy between official figures and ground reality underscores the importance of accurate monitoring and targeted intervention.

Women's Participation and Empowerment: Solar-powered irrigation has facilitated women's participation in agriculture. Four of the 17 farmers in the Unnat Samiti are women, and testimonies indicate that technological change has reduced the physical burden of farming. Praveen, a woman farmer managing two acres while her sons work in cities, notes that "with solar-powered irrigation and tractors, farming has become easier for women". Beyond direct farming, women's self-help groups (SHGs) in Bichhala village (Chittaura block) and Nibiya Begumpur village (Risya block) have engaged in producing organic fertilizers and bio-pesticides from cow dung and urine. Products include Mrida Sanjeevani (biodynamic fertilizer), Paudh Verdhak (plant growth stimulant), and Paudh Rakshak (bio-pesticide). This enterprise development contributes to sustainable agriculture while generating livelihoods for women, representing an integrated approach to environmental and social sustainability.

7. Integrated Analysis and Discussion: The Paradox of Abundance and Scarcity

Bahraich District presents a paradoxical water profile: shallow groundwater tables suggest relative abundance, yet water quality deterioration—particularly arsenic contamination—creates effective scarcity for drinking purposes. This paradox has profound implications for water resource management paradigms that focus exclusively on quantity without integrating quality considerations. The finding that over 80% of groundwater samples fall into "poor" or "unfit" categories for drinking indicates that conventional indicators of water availability (water table depth, aquifer extent, recharge rates) provide incomplete pictures of water security. For households dependent on untreated groundwater, contamination renders physically available water inaccessible for domestic use, necessitating either treatment or alternative sources. This quantity-quality nexus demands integrated policy responses. Rainwater harvesting, traditionally justified on quantity grounds (groundwater recharge), assumes additional significance in quality-affected areas: captured rainwater, appropriately stored and treated, can provide alternative drinking water sources bypassing contaminated aquifers. The achievement of 100% rooftop rainwater harvesting installation in government buildings thus contributes not only to groundwater replenishment but potentially to drinking water security if harvested water is appropriately managed.

Community Institutions and Water Governance: The solar irrigation collectives in Bahraich demonstrate the potential of community institutions to address water management challenges that resist purely technological or market-based solutions. Key success factors include:

Collective Action: Farmers organized into formal Samitis with elected leadership, regular meetings, and transparent financial management. This institutional structure enables coordination that individual action cannot achieve.

Shared Investment: While the Aga Khan Foundation provided initial capital for solar panels and pipe networks, farmers contribute through user fees and operational management. This shared responsibility model fosters ownership and sustainability.

Conflict Resolution Mechanisms: The first-come, first-served system, combined with flexibility for urgent needs and monthly meetings, provides mechanisms for resolving competing water demands. These social technologies are as important as physical infrastructure.

Scale and Replicability: With 97 systems benefiting 8,700 farmers across 1,872 acres, the model demonstrates scalability beyond pilot project status. The involvement of a development organization (AKF) as catalyst rather than permanent manager suggests potential for replication by government agencies or farmer cooperatives.

These community institutions address what Ostrom (1990) identified as core design principles for common-pool resource management: clearly defined boundaries, collective-choice arrangements, monitoring mechanisms, graduated sanctions, and conflict-resolution mechanisms. The Bahraich experience thus contributes to broader understanding of institutional requirements for sustainable groundwater governance.

Policy Implementation: Achievements and Gaps: The achievement of 100% rainwater harvesting installation in government buildings represents a significant policy implementation success. However, several gaps warrant attention:

Coverage Scope: Government buildings constitute a subset of total built infrastructure. Expansion to residential, commercial, and institutional buildings—potentially through building bye-law enforcement and incentive mechanisms—would substantially increase rainwater harvesting impact.

Maintenance and Functionality: Installation statistics measure infrastructure creation, not continued functionality. Systematic assessment of system maintenance, cleaning, and repair would complement installation data with performance metrics.

Water Quality Integration: Rainwater harvesting programs typically focus on quantity (recharge volume) without explicit integration with water quality objectives. Linking harvested rainwater to drinking water supply in arsenic-affected areas could enhance program impact on public health outcomes.

Monitoring and Evaluation: Robust monitoring systems tracking both implementation progress and outcome indicators (groundwater levels, water quality trends, adoption rates) would strengthen evidence-based policy refinement.

Agricultural Transformation and Water Sustainability: The trajectory of agricultural change in Bahraich and Uttar Pradesh more broadly carries profound implications for water sustainability. The expansion of summer rice cultivation, triple cropping systems, and groundwater-dependent irrigation threatens the long-term viability of the very aquifers on which this agricultural model depends. The policy workshop on Summer Rice convened by the Uttar Pradesh Department of Agriculture in March 2025 signals growing official recognition of this challenge. Bringing together policymakers, scientists, extension officials, and farmers, the workshop underscored the urgency of crop diversification and strengthened groundwater management. However, translating recognition into action requires addressing structural factors that perpetuate water-intensive cropping: minimum support price regimes favoring paddy and wheat, established supply chains and market infrastructure, farmer familiarity with existing crops, and risk perceptions regarding diversification. The millet initiative in Bahraich, demonstrating

tenfold increase in participating farmers, suggests potential for change when appropriate support is provided.

8. Policy Recommendations: Based on the analytical findings, the following recommendations are proposed for strengthening water resource management in Bahraich District and similar contexts:

Strengthening Groundwater Governance

Institutional Framework: Establish a dedicated groundwater management authority at district level with responsibility for monitoring, regulation, and coordination among departments (irrigation, agriculture, rural development, public health). This body should include farmer representatives and draw on scientific expertise from institutions like the Central Ground Water Board.

Regulatory Mechanisms: Implement the provisions of the Model Bill adopted by Uttar Pradesh, including registration of groundwater abstractions, metering of high-capacity wells, and graduated restrictions in areas experiencing significant decline or quality deterioration.

Data Infrastructure: Strengthen groundwater monitoring networks, integrating water level measurement with systematic quality sampling. Real-time data availability would support adaptive management and early warning of emerging quality threats.

Scaling Rainwater Harvesting

Beyond Government Buildings: Expand rainwater harvesting requirements to all new construction through building bye-law enforcement, with appropriate provisions for different building types and plot sizes. Retrofit programs for existing buildings could be supported through subsidy mechanisms or revolving funds.

Quality Integration: Link rainwater harvesting to drinking water security in arsenic-affected areas through appropriate treatment and storage systems. Rooftop harvesting, combined with first-flush diversion and filtration, can provide safe drinking water sources independent of contaminated aquifers.

Water Body Restoration: Accelerate pond rejuvenation under Mission Amrit Sarovar, prioritizing water bodies in areas with high groundwater recharge potential and those serving multiple community functions (drinking, livestock, fisheries, cultural uses).

Promoting Sustainable Agriculture

Crop Diversification Incentives: Reform agricultural pricing and procurement policies to reduce bias toward water-intensive crops. Expand minimum support price coverage to millets, pulses, and oilseeds, and strengthen market infrastructure for these alternatives.

Water-Efficient Technology Diffusion: Scale up adoption of sprinkler, drip, and laser land leveling technologies through subsidy mechanisms, extension services, and farmer-to-farmer learning networks. The solar irrigation collectives provide existing platforms for technology demonstration and peer learning.

Knowledge Partnerships: Strengthen linkages between agricultural universities, research institutions (such as ICRIASAT, IRRI), and farmer organizations to adapt and disseminate location-specific sustainable

practices. The ongoing collaboration between UPCAR and ICRISAT on watershed management provides a model for such knowledge partnerships.

Addressing Water Quality

Treatment Infrastructure: Invest in community-level arsenic removal plants in affected habitations, with appropriate institutional arrangements for operation, maintenance, and cost recovery. Under the Jal Jeevan Mission, priority is already accorded to quality-affected habitations ; this focus should be sustained and strengthened.

Monitoring and Information: Expand water quality monitoring networks, ensure public accessibility of monitoring data, and develop early warning systems for emerging contaminants. The practice of issuing Ground Water Quality Alerts to State Governments since June 2024 should be strengthened and extended to district-level dissemination.

Health Linkages: Strengthen coordination between water management and public health systems, ensuring that arsenic-affected populations receive appropriate screening, diagnosis, and treatment for arsenicosis and related conditions.

Community Participation and Capacity Building

Farmer Institutions: Support the formation and strengthening of farmer producer organizations, water user associations, and irrigation collectives based on the Unnat Samiti model. These institutions provide platforms for collective action, knowledge sharing, and sustainable resource management.

Women's Empowerment: Build on the demonstrated engagement of women in solar irrigation and organic input production to strengthen women's participation in water governance institutions at all levels. Targeted support for women's leadership in farmer organizations and water user associations would enhance both equity and effectiveness.

Awareness and Education: Conduct systematic awareness programs on water conservation, rainwater harvesting, water quality, and sustainable agriculture, targeting schools, community institutions, and general public. The Public Interaction Programs organized by CGWB provide a model that could be scaled and sustained.

9. Conclusion

This analytical study of water resource management, rainwater harvesting, and sustainability practices in Bahraich District, Uttar Pradesh, reveals a complex picture of achievements, challenges, and opportunities. The district has made notable progress in rainwater harvesting infrastructure, achieving 100% installation in government buildings under the "Catch the Rain 2025" campaign. Community-led initiatives, particularly solar-powered irrigation collectives supported by the Aga Khan Foundation, demonstrate the potential of participatory approaches to deliver economic, social, and environmental benefits. Farmers have realized significant cost savings, women have gained new opportunities for participation and enterprise, and adoption of water-efficient technologies has increased. However, these positive developments coexist with serious challenges that demand continued attention and intervention.

Groundwater quality deterioration—most critically, arsenic contamination affecting 42% of samples and rendering over 80% of sources poor or unfit for drinking—poses public health risks and undermines drinking water security. Agricultural practices, including expansion of summer rice cultivation and triple cropping systems, threaten the long-term sustainability of the aquifers on which farming livelihoods depend. The gap between official estimates and actual extent of water-intensive cropping highlights limitations in monitoring and governance capacity.

The integration of these findings suggests several cross-cutting insights. First, water resource management must address both quantity and quality dimensions simultaneously; interventions focused exclusively on one dimension may prove inadequate if the other is neglected. Second, community institutions, appropriately designed and supported, can play crucial roles in sustainable water governance, complementing state interventions with local knowledge, social capital, and collective action. Third, policy implementation requires attention not only to infrastructure creation but to maintenance, functionality, and integration with complementary objectives. Fourth, agricultural transformation toward sustainability demands structural reforms in pricing, procurement, and market systems, not merely farmer education or technology diffusion. As climate change amplifies hydrological variability and development pressures on water resources intensify, the lessons from Bahraich District assume broader significance. The interplay of groundwater quality challenges, rainwater harvesting infrastructure, community-managed irrigation, and agricultural practices exemplifies the multidimensional nature of contemporary water governance. Success in this context—defined as sustainable, equitable, and resilient water management—will require sustained commitment, adaptive learning, and institutional innovation. The foundations exist; the task ahead involves building upon them systematically and strategically.

References

1. Aga Khan Foundation. (2023). Solar powered irrigation units propel sustainable agriculture in Bahraich. *The Sunday Guardian*, December 16, 2023.
2. Government of Uttar Pradesh, Jal Shakti Department. (2025). 2.35L govt buildings in U.P. to have rooftop rainwater harvesting system. *Hindustan Times*, June 25, 2025.
3. Press Institute of India. (2024). Solar-powered irrigation units propel sustainable agriculture in Bahraich. February 14, 2024.
4. Deb, P., & Dubey, S. (2025). Shaping policy changes for a sustainable cropping system in Uttar Pradesh, India. *The Gurgaon Story*, July 3, 2025.
5. Sharma, P., et al. (2022). *Assessment of hydrogeochemistry and arsenic contamination in groundwater of Bahraich District, Uttar Pradesh, India*. Springer.
6. Ministry of Jal Shakti, Government of India. (2025). *Water supply/quality/conservation in Amroha District of Uttar Pradesh*. Press Information Bureau, December 4, 2025.
7. ICRISAT. (2025). UPCAR team visits ICRISAT's Tahrauli project to explore scalable water solutions. September 25, 2025.
8. Ahmad, I., & Umar, R. (2023). *Groundwater depletion and water-energy nexus in extensively agricultural tracks of Western Uttar Pradesh*. Science and Engineering Research Board.

9. Ministry of Jal Shakti, Government of India. (2025). Contamination of water in Uttar Pradesh. Press Information Bureau, December 4, 2025.
10. Central Ground Water Board. (2020). Master Plan for Artificial Recharge to Groundwater-2020. Ministry of Jal Shakti, Government of India.
11. Singh, P., Sharma, V., Upadhyay, R.K., Kumar, N., Jadaun, S.P.S. (2019). Impact of summer rice cultivation on groundwater in Pilibhit district, Uttar Pradesh, India. International Conference on Intelligent Computing and Remote Sensing, Bhubaneswar.
12. Government of India. (2012). National Water Policy. Ministry of Water Resources.
13. Ostrom, E. (1990). Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press.
14. Census of India. (2011). District Census Handbook: Bahraich. Government of India.
15. Ministry of Housing and Urban Affairs. (2016). Model Building Bye-laws, 2016. Government of India.

Acknowledgements:

The author acknowledges the contributions of farmers, community organizations, and development practitioners in Bahraich District whose experiences and insights inform this study. Thanks are due to the Aga Khan Foundation for documentation of solar irrigation interventions, to the researchers whose water quality studies provided essential data, and to the various government departments whose policy documents and implementation reports enabled this analysis.