



Groundwater Crisis and Sustainable Development: A Sociological Analysis of Water Security in Uttarakhand

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Abstract

Groundwater has become an indispensable resource for ensuring drinking water supply, agricultural production, ecological stability, and socio-economic development. Although Uttarakhand is widely recognized as the source region of many perennial rivers, increasing pressure on groundwater resources has emerged as an important environmental and social concern. Rapid urban expansion, changing land-use patterns, population growth, tourism, and climate variability have influenced groundwater availability and quality across different parts of the state. These changes have significant implications for water security, public health, rural livelihoods, and sustainable development.

The present study analyses groundwater resources in Uttarakhand from a sociological perspective using secondary data obtained from the Central Ground Water Board (CGWB, 2025). Rather than treating groundwater merely as a hydrological resource, the study examines its relationship with environmental governance, social equity, community participation, and sustainable development. The findings indicate that the overall stage of groundwater extraction in Uttarakhand remains within the safe category; however, localized environmental stress is visible through semi-critical assessment units, groundwater quality deterioration in selected districts, and seasonal fluctuations in groundwater levels. Such trends directly affect vulnerable communities that depend upon groundwater for agriculture and domestic consumption.

The study argues that sustainable groundwater management cannot be achieved through technical interventions alone. It requires community participation, decentralized governance, scientific monitoring, environmental awareness, and policy integration. Strengthening traditional water conservation systems together with modern groundwater management strategies will contribute to long-term water security and sustainable development in Uttarakhand.

Keywords: Groundwater, Water Security, Sustainable Development, Environmental Sociology, Uttarakhand, Community Participation, Water Governance.

Introduction

Water is one of the most fundamental natural resources supporting human survival, economic growth, and environmental sustainability. Every society depends upon secure access to clean and sufficient water for drinking, sanitation, agriculture, industry, and ecosystem maintenance. However, increasing population, rapid urbanization, industrial expansion, changing consumption patterns, and climate change have intensified pressure on freshwater resources across the world. In this context, groundwater has emerged as one of the most reliable sources of freshwater because of its comparatively stable availability and relatively better quality than many surface water sources.

The importance of groundwater extends beyond hydrological significance. From a sociological perspective, groundwater represents a shared natural resource whose accessibility influences health, livelihoods, social equality, and quality of life. Communities that experience limited access to safe groundwater often face multiple forms of vulnerability including economic insecurity, health risks, agricultural instability, and gender-based

inequalities. Consequently, groundwater conservation has become an important issue not only for environmental management but also for sustainable social development.

Uttarakhand presents a distinctive geographical and social context for examining groundwater security. The state is characterized by fragile Himalayan ecosystems, steep mountainous terrain, scattered rural settlements, rapidly expanding urban centres, and agriculturally productive Tarai plains. Although the state receives relatively high annual rainfall, groundwater availability is uneven due to geological diversity and spatial variations in recharge. Mountainous regions primarily depend upon springs and weathered aquifers, whereas the Tarai and Bhabar regions rely extensively on groundwater extraction for irrigation and domestic use.

These regional differences demonstrate that groundwater availability is shaped not only by physical geography but also by social processes such as settlement expansion, agricultural intensification, infrastructure development, institutional management, and community behaviour. Therefore, understanding groundwater requires an interdisciplinary perspective integrating environmental science with sociology.

Water security has become an important component of the Sustainable Development Goals (SDGs), particularly SDG-6, which advocates universal access to safe water and sustainable management of water resources. Achieving this objective requires balancing environmental conservation with social and economic development. In ecologically sensitive Himalayan states such as Uttarakhand, sustainable groundwater management assumes even greater importance because environmental degradation may directly threaten community resilience and regional development.

The latest assessment of groundwater resources in Uttarakhand reveals encouraging as well as cautionary trends. At the state level, groundwater extraction remains within safe limits; however, the emergence of semi-critical assessment units, localized nitrate contamination, fluoride occurrence in selected districts, and seasonal groundwater fluctuations indicate increasing environmental stress. These developments highlight the need for preventive resource management rather than reactive interventions.

Environmental sociology argues that environmental problems are socially produced as well as socially experienced. Water scarcity, pollution, and unequal access to natural resources are influenced by institutional arrangements, governance structures, development priorities, and patterns of resource consumption. Therefore, groundwater conservation should be understood as a collective social responsibility involving government institutions, local communities, civil society organizations, and individual citizens.

This study examines groundwater resources in Uttarakhand through the broader framework of water security and sustainable development. Using secondary data published by the Central Ground Water Board, the paper analyses how groundwater conditions influence environmental sustainability, community well-being, and development planning. The study further explores the importance of participatory groundwater governance in promoting long-term ecological balance and equitable access to water resources.

The paper contributes to environmental sociology by demonstrating that groundwater management is not merely a technical challenge but also a social process involving resource equity, institutional accountability, environmental awareness, and community participation. Strengthening these dimensions is essential for achieving sustainable development in Uttarakhand and ensuring water security for future generations.

Groundwater governance has increasingly emerged as an interdisciplinary research area linking hydrology, environmental management, sociology, and sustainable development. Previous studies have examined groundwater from different perspectives, including resource sustainability, institutional governance, environmental justice, and community participation.

Ostrom (1990) argued that common-pool natural resources such as groundwater cannot be sustainably managed solely through centralized government control or market mechanisms. Instead, successful resource management depends upon collective action, local institutions, and community participation. Her work provides a theoretical foundation for understanding groundwater governance as a social process rather than merely a technical issue.

Shiva (2002) emphasized that water should be treated as a common ecological resource instead of a commercial commodity. According to her, increasing privatization and unsustainable exploitation of water resources intensify social inequalities and threaten environmental sustainability. She advocated decentralized and community-based water management systems that strengthen local participation.

Gleick (2003) introduced the concept of water security as an essential component of sustainable development. He argued that access to safe water is fundamental for public health, food security, environmental protection, and economic development. Sustainable water policies therefore require integration of environmental conservation with social welfare.

Shah (2009) examined India's groundwater economy and observed that groundwater has significantly contributed to agricultural growth while simultaneously creating problems of over-extraction and resource depletion. He highlighted that groundwater management should balance economic productivity with ecological sustainability through effective governance and institutional reforms.

Mukherji and Shah (2005) analysed groundwater governance in South Asia and reported that weak institutional coordination, increasing dependence on groundwater irrigation, and inadequate regulation have accelerated groundwater stress in many regions. They recommended participatory groundwater management supported by local communities and public institutions.

Agarwal and Narain (1997) stressed the importance of traditional rainwater harvesting systems in India. Their work demonstrated that community-managed water conservation structures improve groundwater recharge and strengthen long-term water security, particularly in ecologically fragile regions.

The United Nations (2015) incorporated sustainable water management within Sustainable Development Goal 6, recognizing that equitable access to safe water is fundamental for achieving broader social, economic, and environmental sustainability.

More recently, the Central Ground Water Board (2025) reported that Uttarakhand continues to remain within the safe category at the state level with a groundwater extraction stage of approximately 53.92%. Nevertheless, localized nitrate contamination, fluoride occurrence, semi-critical assessment units, and seasonal groundwater fluctuations indicate emerging environmental challenges requiring preventive management and community participation.

Although these studies have substantially advanced knowledge regarding groundwater management, relatively few have interpreted recent groundwater assessment data from Uttarakhand through the perspective of environmental sociology. The present study attempts to bridge this gap by analysing groundwater security within the broader framework of sustainable development, environmental governance, and social resilience.

Research Gap

Existing literature provides valuable information regarding groundwater availability, recharge, extraction, and quality. However, limited attention has been given to understanding groundwater as a social resource that influences community well-being, environmental justice, and sustainable development. There is also inadequate sociological interpretation of the latest groundwater assessment published for Uttarakhand. Therefore, this study bridges the gap by analysing the 2025 groundwater assessment through the concepts of water security, environmental governance, and community participation.

Objectives of the Study

1. To examine the present groundwater scenario in Uttarakhand using secondary data.
2. To analyse groundwater resources from the perspective of environmental sociology.
3. To assess the relationship between groundwater security and sustainable development.
4. To identify major social challenges associated with groundwater depletion and groundwater quality.

Research Methodology

The study is descriptive and analytical in nature. It is entirely based on secondary data. The principal source of data is the Central Ground Water Board (CGWB), Dynamic Ground Water Resources, Ground Water Level and Ground Water Quality of Uttarakhand, 2025. Additional conceptual understanding has been drawn from literature on environmental sociology, sustainable development, and water governance. The collected information has been analysed using qualitative interpretation supported by statistical information available in the report.

Data Analysis and Discussion

Groundwater Assessment Categories in Uttarakhand (2025)

Categorization of Assessment Units based on the 'Stage of Ground Water Extraction'													
S. No	Category	GWRA-2017		GWRA-2020		GWRA-2022		GWRA-2023		GWRA-2024		GWRA-2025	
		Num-ber of AUs	% of AUs	Num-ber of AUs	% of AUs	Num-ber of AUs	% of AUs	Num-ber of AUs	% of AUs	Num-ber of AUs	% of AUs	Num-ber of AUs	% of AUs
1	Safe	13	72	14	78	14	78	14	77.78	16	80	16	80
2	Semi-critical	5	28	4	22	4	22	4	22.22	4	20	4	20
3	Critical												
4	Over-exploited												
5	Saline												
Total number of AUs		18		18		18		18		20		20	

Source: Central Ground Water Board, 2025.

The groundwater assessment indicates that out of twenty assessment units in Uttarakhand, sixteen fall within the Safe category, whereas four have been classified as Semi-Critical. At first glance, this situation appears satisfactory because nearly eighty percent of the assessment units remain within sustainable extraction limits. However, environmental sociology encourages moving beyond aggregate statistics to understand emerging vulnerabilities.

The presence of semi-critical blocks reflects localized ecological stress where groundwater extraction is approaching unsustainable levels. If preventive measures are not adopted, these areas may gradually shift towards critical groundwater conditions. Such trends may increase social inequality because rural households, small farmers, and economically weaker communities generally possess limited adaptive capacity.

From the perspective of sustainable development, these findings suggest that groundwater governance should focus not only on maintaining the present safe status but also on preventing future environmental degradation through community participation, recharge enhancement, and decentralized planning.

Groundwater Availability and Water Security in Uttarakhand

The latest groundwater assessment prepared by the Central Ground Water Board (2025) indicates that Uttarakhand possesses an estimated 2.13 billion cubic metres (BCM) of annual groundwater recharge. The state's annual extractable groundwater resource has been estimated at 1.95 BCM, whereas annual groundwater extraction is 1.05 BCM. Consequently, the overall stage of groundwater extraction has been estimated at 53.92

percent, which places the state within the 'Safe' category according to the Ground Water Resource Estimation Committee (GEC) classification.

Groundwater Resource Status in Uttarakhand (2025)

	Attribute	GWRA -2017	GWRA- 2020	GWRA- 2022	GWRA- 2023	GWRA -2024	GWRA -2025
1	Total Annual Ground Water Recharge (in bcm)	3.04	2.02	2.01	2.02	2.14	2.13
2	Annual Extractable Ground Water Resources (in bcm)	2.89	1.85	1.86	1.85	1.96	1.95
3	Annual Ground Water Extrac-	1.64	0.87	0.89	0.95	1.05	1.05
4	Stage of Ground Water Extrac- tion (in %)	56.83	46.8	48.04	51.69	53.54	53.92

bcm: Billion Cubic Meters

Source: Central Ground Water Board (2025).

Although these figures indicate that Uttarakhand has not yet entered a groundwater crisis at the state level, environmental sociology suggests that aggregate statistics often conceal regional disparities. The existence of a favourable state average does not necessarily imply equal groundwater security for all communities. Different districts experience unequal access to groundwater because of variations in geology, population density, agricultural intensity, urbanization, and institutional capacity.

From a sociological perspective, water security is not determined solely by the quantity of available groundwater but also by equitable access, water quality, institutional governance, and the ability of communities to adapt to environmental change. Communities living in mountainous regions often depend upon springs and localized groundwater systems that are highly sensitive to climatic variability and land-use changes. Therefore, even where state-level groundwater availability appears satisfactory, localized water insecurity may continue to affect rural livelihoods.

The report further reveals that 16 assessment units (80%) remain in the Safe category, whereas 4 assessment units (20%) have already entered the Semi-Critical category.

4.2 Groundwater Quality and Public Health: A Sociological Perspective

Groundwater quality constitutes an equally important dimension of water security because the availability of groundwater alone cannot guarantee sustainable development unless the water is safe for human consumption. The CGWB (2025) assessment reveals that although the majority of groundwater samples in Uttarakhand satisfy the prescribed quality standards, localized contamination has emerged in several districts. Out of 248 groundwater samples analysed, 33 samples (13.31%) recorded nitrate concentrations above the permissible limit, while 3 samples (1.21%) exceeded the permissible limit for fluoride. No groundwater samples were found to contain arsenic or uranium beyond the prescribed limits.

Groundwater Quality Status in Uttarakhand (2025)

Groundwater Quality Scenario in Uttarakhand				
Parameters	No of samples	Permissible limit	No of Samples above permissible limit	% Samples above permissible Limit
EC	248	3000 μ S/cm	0	0
Fluoride	248	1.5 mg/L	3	1.21
Nitrate	248	45 mg/L	33	13.31
Arsenic	104	10 ppb	0	0.00
Uranium	103	30 ppb	0	0.00

Source: Central Ground Water Board (2025).

From a sociological viewpoint, groundwater contamination is not merely an environmental issue but also a question of social justice and public health. Access to safe drinking water determines the quality of life, productivity, educational attainment, and overall human development. The occurrence of nitrate contamination in districts such as Bageshwar, Champawat, Dehradun, Haridwar, Nainital, Pithoragarh, Udham Singh Nagar, and Uttarkashi suggests that environmental risks are unevenly distributed across the state.

Nitrate contamination is generally associated with intensive agricultural practices, excessive application of chemical fertilizers, inadequate sanitation systems, and unplanned urban expansion. These factors are not purely environmental; they reflect broader patterns of development, governance, and human behaviour. Therefore, groundwater pollution should be understood as a socially produced environmental problem.

Environmental sociology argues that vulnerable populations often experience disproportionate exposure to environmental risks. Rural households, economically weaker sections, women, children, and elderly persons are generally more dependent on local groundwater sources and therefore bear a greater burden when groundwater quality deteriorates. Limited financial capacity restricts their access to alternative drinking water sources or advanced water purification technologies.

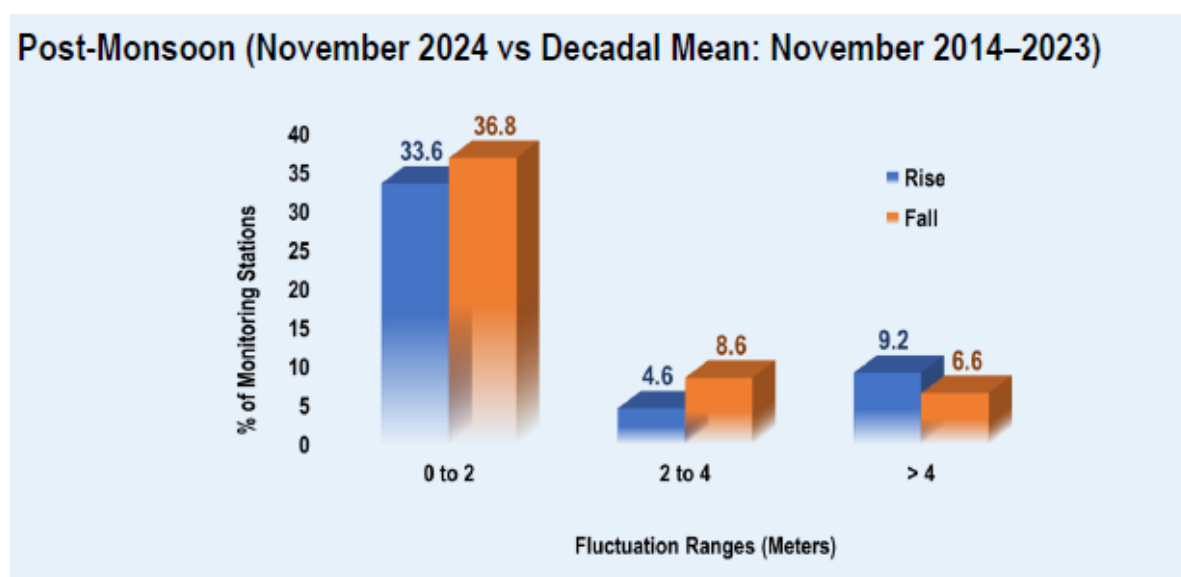
The absence of widespread arsenic and uranium contamination represents a significant strength of Uttarakhand's groundwater system. Nevertheless, the increasing occurrence of nitrate pollution should be interpreted as an early indicator of unsustainable environmental practices. Preventive interventions focusing on sustainable agriculture, scientific fertilizer management, improved sanitation infrastructure, and regular groundwater quality monitoring are therefore essential.

These findings demonstrate that groundwater quality management should be integrated with rural development, public health planning, environmental education, and local governance. Such integration directly contributes to Sustainable Development Goal 6 by promoting equitable access to safe and clean drinking water.

4.3 Seasonal Groundwater Fluctuation and Community Resilience

The groundwater level assessment presented in the CGWB (2025) report indicates noticeable seasonal variation between pre-monsoon and post-monsoon periods. During the pre-monsoon season, nearly 43.9% of observation wells recorded groundwater levels deeper than 15 metres below ground level, whereas following the monsoon, this proportion declined to 36.3%, reflecting partial groundwater recharge through seasonal rainfall.

Figure 3. Pre-Monsoon and Post-Monsoon Groundwater Levels



Source: Central Ground Water Board (2025).

The observed seasonal fluctuation illustrates the close relationship between climatic conditions and groundwater availability. Although monsoon rainfall temporarily improves groundwater levels, the persistence of deep groundwater in a substantial proportion of observation wells indicates that natural recharge alone may not be sufficient to meet future water demands.

From a sociological perspective, seasonal groundwater fluctuation directly influences household water security, agricultural productivity, and community resilience. In many parts of Uttarakhand, particularly in hill regions, households depend upon springs and shallow groundwater systems. Declining groundwater levels increase the time and effort required to collect water, disproportionately affecting women and girls who traditionally perform household water collection.

Seasonal water stress also influences agricultural decision-making. Farmers facing uncertain groundwater availability may reduce crop diversity, shift towards less water-intensive crops, or experience declining agricultural incomes. Such adjustments have broader implications for rural livelihoods, migration, and local food security.

Community resilience therefore depends not only on rainfall but also on institutional preparedness, watershed protection, groundwater recharge structures, spring rejuvenation programmes, and active participation of local communities. Strengthening these social and institutional capacities will improve long-term adaptation to climate variability while reducing future groundwater vulnerability.

Policy Implications

The findings of the present study indicate that Uttarakhand has not yet reached a critical stage of groundwater depletion; however, emerging environmental pressures demand immediate preventive action. Sustainable groundwater governance should therefore focus on long-term conservation rather than crisis management.

First, groundwater planning should adopt a decentralized and community-based approach. Village Panchayats, Urban Local Bodies, and Water User Associations should be actively involved in groundwater monitoring, spring rejuvenation, and recharge activities. Local participation enhances transparency, accountability, and environmental stewardship.

Second, the state government should strengthen rainwater harvesting programmes, particularly in rapidly urbanizing towns and institutional campuses. Artificial recharge structures, rooftop rainwater harvesting, and watershed management should become integral components of local development planning.

Third, agricultural policies should promote efficient water-use practices. Adoption of micro-irrigation systems, crop diversification, and balanced fertilizer application can reduce groundwater extraction while simultaneously minimizing nitrate contamination. Farmer awareness programmes should therefore become an important component of groundwater conservation.

Fourth, groundwater quality monitoring should be expanded across all districts through periodic scientific assessment. Areas reporting nitrate and fluoride contamination require continuous surveillance, public awareness campaigns, and safe drinking water interventions to minimize health risks.

Finally, environmental education should become an essential element of groundwater governance. Educational institutions, civil society organizations, and local communities should jointly promote awareness regarding groundwater conservation, responsible water consumption, and ecosystem protection. Sustainable groundwater management ultimately depends upon behavioural change alongside scientific and institutional interventions.

Conclusion

Groundwater represents one of the most valuable natural resources supporting environmental sustainability, public health, agriculture, and socio-economic development. The present study examined the groundwater situation in Uttarakhand using secondary data from the Central Ground Water Board (2025) and interpreted the findings through the perspective of environmental sociology.

The analysis demonstrates that Uttarakhand currently maintains an overall safe level of groundwater extraction, indicating that groundwater resources remain relatively secure at the state level. Nevertheless, the presence of semi-critical assessment units, localized nitrate contamination, fluoride occurrence in selected districts, and seasonal groundwater fluctuations reveal emerging environmental vulnerabilities that require proactive policy attention. These findings suggest that groundwater security should not be evaluated solely through aggregate hydrological indicators but also through social equity, institutional effectiveness, environmental governance, and community resilience.

From a sociological perspective, groundwater is a shared social resource whose sustainability depends upon collective responsibility. Unsustainable extraction, groundwater pollution, changing land-use patterns, and weak community participation may gradually intensify environmental inequalities. Vulnerable populations—including rural households, small farmers, women, and economically disadvantaged communities—are likely to experience the greatest consequences of groundwater insecurity because they possess limited adaptive capacity.

The study therefore argues that sustainable groundwater governance requires integration of scientific assessment with community participation, decentralized planning, environmental education, and evidence-based public policy. Traditional water conservation practices, combined with modern groundwater management strategies, can strengthen long-term water security while contributing directly to Sustainable Development Goal 6.

In conclusion, groundwater conservation should not be viewed merely as an environmental obligation but as an essential prerequisite for inclusive development, social justice, and intergenerational sustainability. The experience of Uttarakhand demonstrates that timely preventive measures and participatory governance can protect groundwater resources before localized environmental stress develops into a broader ecological crisis.

Limitations of the Study

The present study is based exclusively on secondary data published by the Central Ground Water Board (2025). Since no primary field survey was conducted, the analysis primarily reflects macro-level trends in groundwater availability and quality. Future research may incorporate household surveys, village-level case studies, and participatory assessments to better understand community perceptions of groundwater security and local water governance.

References

1. Agarwal, A., & Narain, S. (1997). Dying wisdom: Rise, fall and potential of India's traditional water harvesting systems. Centre for Science and Environment.
2. Central Ground Water Board. (2025). Dynamic ground water resources, ground water level and ground water quality of Uttarakhand, 2025. Ministry of Jal Shakti, Government of India.
3. Gleick, P. H. (2003). Global freshwater resources: Soft-path solutions for the 21st century. *Science*, 302(5650), 1524–1528. <https://doi.org/10.1126/science.1089967>
4. Mukherji, A., & Shah, T. (2005). Groundwater socio-ecology and governance: A review of institutions and policies in selected countries. *Hydrogeology Journal*, 13(1), 328–345.
5. Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge University Press.
6. Shah, T. (2009). *Taming the anarchy: Groundwater governance in South Asia*. Resources for the Future Press.
7. Shiva, V. (2002). *Water wars: Privatization, pollution, and profit*. South End Press.
8. United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development*. United Nations.
9. World Bank. (2010). *Deep wells and prudence: Towards pragmatic action for addressing groundwater overexploitation in India*. World Bank.
10. World Health Organization. (2017). *Guidelines for drinking-water quality (4th ed., incorporating the first addendum)*. World Health Organization.
11. Food and Agriculture Organization of the United Nations. (2016). *Coping with water scarcity in agriculture: A global framework for action*. FAO.
12. <https://cgwb.gov.in/cgwbpm/public/uploads/documents/1766747469640263754file.pdf>