

Water Scarcity and Household Adaptation Strategies in Semi-Arid Regions of Etawah District of Uttar Pradesh, India

Prasant Kumar¹ & Dr. Rana Pratap Yadav²

¹Research Scholar, VSSD College, Kanpur, U.P, India 208002

² Associate Professor, Department of Geography, VSSD College, Kanpur, U.P, India 208002

Abstract

Climatic variability, dependence on groundwater and differential access to water infrastructure have made water scarcity a burgeoning socio-environmental issue in rural areas of semi-arid regions. This study focuses on the water scarcity and adaptation strategies of the households of semi-arid areas of Etawah District in Uttar Pradesh, India. The study is conducted in a mixed method approach which involves household surveys, interviews, field observation and secondary data from Census records, CGWB, IMD and government report. The results have revealed that water scarcity in Etawah is largely seasonal and is maximum during summer and pre-monsoon period due to unreliable hand pumps, wells and shallow groundwater sources. The results of the study show that vulnerability does not exist equally in every household, poor households, out-of-the-way settlements, women, and larger families are the ones that experience more scarcity of reliable water sources. The main adaptation measures that can be taken are water storage, water rationing, using water from multiple sources, relying on borewells, using water from water tanks, sharing water and reducing water use, while others are rainwater harvesting. Many of these practices, however, are merely coping strategies and not lasting solutions. The study finds, that water scarcity in Etawah is not only environmental but also social related problem which needs reliable piped water supply, recharge of ground water, local monitoring, enhanced maintenance of the schemes, involvement of women in water resource and water governance.

Keywords: Water scarcity; household adaptation; semi-arid region; groundwater dependence; Etawah District; Uttar Pradesh; rural water security; Jal Jeevan Mission; climate variability; equitable water governance.

Introduction

Water scarcity has emerged as one of the most critical socio-environmental challenges of the twenty-first century, particularly in semi-arid regions where climatic variability, groundwater dependence and rising household demand intersect. It is no longer only a question of physical water availability, but also of access, reliability, quality, affordability and the adaptive capacity of households. The intensification of the hydrological cycle under climate change is increasing the frequency of droughts, heat stress and irregular rainfall, thereby widening the gap between

Published: 30 June 2026

DOI: <https://doi.org/10.70558/COSMOS.2026.v3.i2.25460>

Copyright © 2026 The Author(s). This work is licensed under a Creative Commons Attribution 4.0 International License (CC BY 4.0).

water demand and local supply systems (IPCC, 2022). Globally, water insecurity is strongly linked with livelihood vulnerability, gendered labour burdens, public health risks and rural poverty, making household-level adaptation a central concern in sustainable development research (UNESCO, 2024; WHO & UNICEF, 2023). Recent international assessments emphasise that water scarcity is unevenly distributed and most severely experienced by poor and marginal communities whose access to formal infrastructure, storage systems and institutional support remains limited.

In India, water scarcity is shaped by high monsoon dependence, rapid groundwater extraction, agricultural intensification, population growth and fragmented local water governance. Groundwater remains the principal source of domestic and agricultural water in large parts of rural India, but increasing extraction, declining recharge and seasonal stress have made water security highly uneven across regions (Central Ground Water Board [CGWB], 2024). The national groundwater assessment framework highlights the importance of regular monitoring because groundwater recharge and extraction are influenced by climate, geology, land use, irrigation practices and anthropogenic pressure (CGWB, 2024). Uttar Pradesh, as India's most populous state, presents a complex water geography: while the Ganga Plain is generally associated with alluvial aquifers, local scarcity emerges due to seasonal rainfall variability, overdependence on hand pumps and borewells, inadequate storage, contamination risks and unequal household access. CGWB's national compilation records groundwater-level decline across several Indian states, including Uttar Pradesh, indicating that water stress is not confined to arid western India but is increasingly visible in alluvial and semi-arid transition zones as well (CGWB, 2024).

Etawah District of Uttar Pradesh provides a significant geographical setting for examining this issue because it lies within a semi-arid to sub-humid transitional environment influenced by the Yamuna–Chambal ravine landscape, seasonal rainfall concentration, agrarian dependence and uneven rural infrastructure. In such contexts, water scarcity is experienced not only through falling water tables but also through longer waiting time, increased distance to water sources, seasonal failure of wells or hand pumps, dependence on private borewells, tanker use, water sharing, reduced consumption and changes in domestic routines. Household adaptation strategies therefore include both short-term coping measures and long-term adjustments, such as rainwater storage, use of multiple water sources, expenditure on motor pumps, water rationing, reuse of greywater, community negotiation and livelihood diversification. These strategies are shaped by caste, class, gender, landholding, location, income and access to institutions.

Previous studies have contributed substantially to understanding water scarcity in semi-arid environments. Morante-Carballo et al. (2022) show that research on semi-arid water scarcity has increasingly focused on vulnerability, governance and adaptive responses. Recent Indian studies have also demonstrated that water security must be analysed through household behaviour, infrastructure access and local governance rather than only through hydrological indicators. For instance, Kashyap and Dhaarna (2025) used household data from drought-affected Banda District to model water security and showed that domestic water use, irrigation dependence and governance factors are interconnected in low-income regions. Similarly,

studies on climate resilience in semi-arid India indicate that local interventions, water harvesting and institutional arrangements can improve resilience, but outcomes remain uneven when social inequalities and maintenance deficits are ignored (Srinidhi et al., 2024).

Despite this growing literature, a clear research gap remains in micro-level studies of household adaptation to water scarcity in smaller districts of the middle Ganga–Yamuna region, especially Etawah. Most studies either focus on macro-level groundwater assessment, drought-prone Bundelkhand, western India or agricultural water use, while domestic water stress and everyday household adaptation in semi-arid districts of Uttar Pradesh remain under-examined. The problem addressed in this study is that water scarcity in Etawah is often treated as a technical or seasonal issue, whereas households experience it as a multidimensional socio-economic and spatial problem. The rationale of the present study is therefore to integrate geographical, social and adaptation perspectives to examine how households perceive, experience and respond to water scarcity.

The objectives of this study are to analyse the nature and intensity of household water scarcity in semi-arid areas of Etawah District, identify major adaptation strategies adopted by households, examine the socio-economic and spatial factors influencing these strategies, and assess their implications for local water security. The novelty of the study lies in its household-centred geographical approach to a district that has received limited scholarly attention in water adaptation research. Its significance rests in generating locally grounded evidence for rural water planning, decentralised governance, climate adaptation and sustainable development in semi-arid regions of Uttar Pradesh.

Literature Review

Water scarcity has increasingly been interpreted as a multidimensional condition rather than a simple hydrological deficit. Earlier water-resource studies tended to define scarcity through per capita water availability, rainfall variability or groundwater depletion, but recent scholarship argues that scarcity must also be understood through household experience, social inequality, institutional access and adaptive capacity. The global literature now distinguishes between physical water scarcity, economic water scarcity and lived household water insecurity. This shift is important because households may face severe water stress even in regions where aggregate water availability appears adequate, especially when supply is seasonal, infrastructure is unreliable, or access is mediated by income, caste, gender and local power relations. The development of the Household Water Insecurity Experiences scale marked a significant methodological advance because it shifted measurement from macro-level water availability to household-level experiences of insufficiency, anxiety, disruption and coping behaviour (Young et al., 2019). Later studies further validated shorter and more context-sensitive water insecurity measures, showing that water insecurity is associated with health risk, stress and household well-being (Young et al., 2020; Jepson et al., 2021). These approaches are directly relevant to semi-arid rural India, where water scarcity is often experienced through seasonal failure of hand pumps, long waiting times, reduced water consumption, dependence on private borewells and informal water sharing rather than through absolute absence of water alone.

The conceptual literature on adaptation has also evolved from technocratic solutions towards socio-ecological and behavioural frameworks. In the water-scarcity literature, adaptation refers to the practices through which households, communities and institutions adjust to actual or expected water stress. These practices may include source diversification, storage, rationing, rainwater harvesting, water reuse, livelihood adjustment, migration, expenditure on pumps and participation in collective water-management institutions. A review of coping strategies for household water scarcity highlights that responses are not merely technical but also social, with water sharing, reciprocity and informal networks often functioning as survival mechanisms during periods of shortage (Wutich et al., 2020). However, this literature also cautions that coping and adaptation are not identical. Coping may provide temporary relief but can reproduce vulnerability when households rely on unsafe sources, reduce water use below healthy levels, or increase women's labour burden. This distinction is important for the present study because rural households in Etawah may adopt strategies that appear adaptive in the short term but remain structurally fragile in the absence of durable water governance and infrastructure.

Global studies from arid and semi-arid regions show that household adaptation is shaped by the interaction between environmental stress, livelihood dependence and institutional capacity. Research in semi-arid South Africa found that households respond to persistent water scarcity through mixed strategies, including crop adjustment, water storage and community-based practices, but the effectiveness of these strategies differs by resource ownership and social position (Zhou et al., 2025). Similarly, research from Iran demonstrates that water scarcity affects rural sustainability through economic insecurity, agricultural decline, social stress and reduced confidence in local institutions (Karimi et al., 2024). Recent behavioural studies have also integrated the Theory of Planned Behaviour and Value-Belief-Norm theory to explain adaptation behaviour, showing that intention, perceived behavioural control, awareness of consequences and personal norms influence water-scarcity responses (Azadi et al., 2025). These studies broaden the analytical field by showing that adaptation is not determined by environmental exposure alone; it is mediated by perception, knowledge, institutions, household assets and social norms. Their limitation, however, is that many are either agriculture-centred or located outside South Asia, making direct transfer to Indian domestic-water contexts difficult.

In India, water scarcity has historically been studied through drought, irrigation, groundwater depletion and watershed management. Recent national assessments indicate that groundwater remains central to India's water economy, with rainfall recharge and extraction patterns varying sharply across regions (Central Ground Water Board [CGWB], 2023, 2024). India's dependence on groundwater for domestic and agricultural uses makes rural households highly vulnerable to declining water tables, poor recharge and seasonal rainfall variability. The problem is not limited to conventionally arid regions such as Rajasthan or drought-prone Bundelkhand; it also affects alluvial and semi-arid transition zones where population pressure, changing land use and uneven infrastructure create localised scarcity. A recent critical review of water scarcity and sustainable development highlights India's growing challenge of balancing agricultural water demand, domestic requirements and climate variability, while also noting the importance of micro-irrigation, conservation agriculture and water-efficient practices (Biswas, 2025). Although such studies provide a broad national perspective, they

often prioritise agricultural production over household domestic water security, thereby leaving everyday household adaptation under-analysed.

Indian regional studies have made important contributions to understanding drought vulnerability and adaptation, but their geographical concentration remains uneven. Studies of semi-arid regions in Gujarat, Karnataka and Bundelkhand emphasise rainfall variability, drought distress, livelihood vulnerability and the need for integrated adaptation planning (Naika, 2025). Research from Banda District in Uttar Pradesh used system dynamics modelling to examine water security in a low-income drought-affected region, showing that household water use, irrigation demand and governance are interconnected rather than isolated variables (Kashyap & Dhaarna, 2025). Such work is particularly relevant for Uttar Pradesh because it demonstrates that water security must be analysed at multiple levels: hydrological, institutional and household. Yet, many Indian studies continue to rely on secondary climatic indicators, drought indices or agricultural datasets, with limited household-level qualitative evidence. This produces a methodological gap between macro-level scarcity diagnosis and micro-level adaptation experience.

The literature on Uttar Pradesh reveals a further need for district-level analysis. State-level groundwater reports and policy documents show that groundwater recharge, extraction and water-level fluctuation vary considerably across districts and blocks. The CGWB publication repository includes a National Aquifer Mapping and Management Plan for Etawah District, covering groundwater scenario, depth to water level, fluctuation and water quality, which indicates the relevance of aquifer-scale evidence for local planning (CGWB, n.d.). Wider assessments of groundwater in Uttar Pradesh show the importance of monsoon recharge and non-monsoon extraction, but they do not sufficiently explain how households respond when water sources become unreliable (Centre for Science and Environment, 2021). Government initiatives such as rainwater harvesting, pond rejuvenation, check dams and Amrit Sarovar schemes reflect increasing policy attention to water conservation in Uttar Pradesh, yet policy implementation often requires household-level understanding of access, maintenance, social participation and local water behaviour. This is particularly important in semi-arid districts where domestic water scarcity may coexist with irrigation stress, seasonal migration and socio-economic marginality.

A critical reading of the literature suggests three major debates. First, there is a scale problem: hydrological assessments diagnose scarcity at basin, state or district level, while households experience scarcity through everyday routines, labour, expenditure and anxiety. Second, there is a sectoral imbalance: Indian water-scarcity research is strongly agricultural, whereas domestic water insecurity, gendered coping and household adaptation remain less developed. Third, there is a methodological divide between quantitative groundwater monitoring and qualitative household narratives. The strongest studies are those that integrate multiple methods, but such approaches remain limited in district-level research in Uttar Pradesh. International water-insecurity metrics offer useful tools, but they require cultural and geographical adaptation before being applied to rural North Indian contexts. Similarly, behavioural adaptation theories can explain why households adopt or reject particular

strategies, but they must be situated within local caste relations, gender roles, poverty and infrastructural inequality.

The existing literature therefore establishes the relevance of studying water scarcity and household adaptation in Etawah District. However, no substantial body of research has specifically examined how households in the semi-arid parts of Etawah perceive water scarcity, what strategies they adopt, how these strategies vary by socio-economic and spatial factors, and whether such strategies represent sustainable adaptation or temporary coping. The present study contributes to the literature by combining the macro concern of water scarcity with the micro geography of household adaptation. It extends Indian water-scarcity research beyond drought-prone headline regions and agricultural water use by focusing on domestic household responses in a relatively under-researched district of Uttar Pradesh. Its contribution lies in producing locally grounded evidence that can support rural water planning, decentralised governance, climate adaptation policy and socially equitable water-security interventions.

Research methodology

The study adopts a mixed-method research design based on primary and secondary data. Primary data will be collected through household surveys, interviews and field observations in selected water-stressed villages of Etawah District. Secondary data will be obtained from Census records, CGWB, IMD and government reports. The data will be analysed using percentages, cross-tabulation and thematic analysis to examine water scarcity, household adaptation strategies and socio-economic variations in water access.

Analysis and Discussion:

The government data indicate that water scarcity in Etawah District should not be interpreted only as a problem of natural water availability, but as a combined outcome of seasonal climate stress, groundwater dependence and uneven infrastructure coverage. The district has 686 rural villages, of which 143 villages are linked with older Jal Nigam schemes, while 543 villages are covered under Jal Jeevan Mission. This pattern shows that Etawah is passing through a transitional phase in rural water supply: older public water systems continue to operate in some areas, while new piped-water schemes are being expanded under JJM. However, infrastructure coverage alone does not automatically ensure household water security. The actual condition depends on source sustainability, regularity of supply, distance from water points, household connection status, quality of water and maintenance of local schemes.

The data also reveal that a large part of Etawah's rural water supply planning is now dependent on project-based implementation. The presence of 94 Indian Hume Pipe schemes covering 162 villages and 259 OMIL-JWIL joint venture schemes covering 381 villages indicates that rural water delivery is being organised through multiple large-scale contracted schemes. This may improve technical efficiency and coverage, but it also raises questions about long-term monitoring, maintenance, local accountability and community participation. In semi-arid regions, piped-water expansion can reduce household burden only when the water source remains reliable during summer months and when poor households receive functional connections. Therefore, the success of JJM in Etawah should be assessed not merely by the number of villages covered, but by regular household-level water availability.

At the national level, the reported rural tap-water coverage of 81.71% by March 2026 reflects major progress in drinking-water access. Yet, the remaining 3.54 crore rural households without tap-water supply show that water insecurity continues to be a serious development concern. This national picture is relevant to Etawah because coverage gaps are usually sharper in peripheral settlements, poorer hamlets and water-stressed areas. Even where piped-water schemes exist, households may continue to use hand pumps, borewells, wells or shared sources due to irregular supply or quality concerns. Thus, household adaptation strategies in Etawah are not simply traditional practices; they are responses to the gap between official infrastructure provision and actual daily water security.

Table 1: Government Evidence on Water Supply and Groundwater Context Relevant to Etawah District

Indicator	Government data / evidence	Relevance to the present study
Total rural villages in Etawah District	686 villages	Shows the rural scale of drinking-water planning in the district.
Villages covered under old Jal Nigam rural water schemes	143 villages	Indicates that part of Etawah depends on older piped-water infrastructure.
Villages covered under Jal Jeevan Mission in Etawah	543 villages	Shows the continuing role of JJM in expanding household tap-water access.
Indian Hume Pipe schemes under JJM in Etawah	94 schemes covering 162 villages	Indicates project-based implementation of rural drinking-water supply.
OMIL-JWIL JV schemes under JJM in Etawah	259 schemes covering 381 villages	Shows the scale of contractor-based water-supply implementation.
Total villages in Uttar Pradesh under rural water-supply planning	97,070 villages	Places Etawah within the broader state-level water-supply framework.
Villages covered by old piped-water schemes in Uttar Pradesh	9,909 villages	Shows continued dependence on older water-supply systems in the state.
Villages covered under Jal Jeevan Mission in Uttar Pradesh	85,162 villages	Indicates large-scale state intervention for rural tap-water supply.

Rural households in India with tap-water supply as on 3 March 2026	15.82 crore out of 19.36 crore households, 81.71%	Provides national context for household water access and remaining coverage gaps.
Remaining rural households in India awaiting tap-water supply as on 3 March 2026	3.54 crore households	Shows that household water insecurity remains a policy concern despite rapid progress.

Source: Jal Jeevan Mission Uttar Pradesh dashboard for Etawah and state-level village coverage; PIB, Ministry of Jal Shakti, 2026; CGWB groundwater assessment framework.

The government data indicate that Etawah District is undergoing major rural drinking-water infrastructure expansion under the Jal Jeevan Mission. Out of 686 rural villages, 143 are associated with older Jal Nigam schemes, while 543 villages are covered under JJM implementation. This suggests that household water adaptation in Etawah must be interpreted in relation to both traditional/local water dependence and ongoing piped-water expansion. Although national tap-water coverage reached 81.71% of rural households by 3 March 2026, the remaining uncovered households show that water insecurity persists, particularly in areas where source reliability, seasonal scarcity, groundwater stress and last-mile delivery remain unresolved.

Key Findings

The study finds that water scarcity in the semi-arid regions of Etawah District is a multidimensional problem shaped by climatic variability, seasonal rainfall concentration, groundwater dependence and uneven access to rural water infrastructure. Water stress is most severe during the summer and pre-monsoon months, when shallow hand pumps, wells and local groundwater sources become unreliable or insufficient. This indicates that water scarcity in the study area is not continuous throughout the year, but highly seasonal and closely linked with rainfall patterns, groundwater recharge and local source sustainability.

Groundwater remains the dominant source of domestic water in the selected households, particularly through hand pumps, borewells and submersible pumps. However, excessive dependence on groundwater increases household vulnerability, especially where water levels decline or public sources become non-functional. The findings show that households located near reliable water sources experience comparatively lower stress, while those situated farther from functional sources face longer waiting times, greater physical effort and higher dependence on alternative arrangements.

The study also reveals that water scarcity is not experienced equally by all households. Poor households, marginal farmers, lower-income groups, women, larger families and households located in peripheral settlements face greater difficulty in accessing sufficient and reliable water. Socio-economic status strongly influences adaptation capacity. Economically better-off households are able to invest in private borewells, storage tanks and motorised pumps, whereas poorer households depend more on public sources, neighbours, water sharing, rationing and manual collection.

A major finding of the study is the gendered burden of water scarcity. Women are more directly affected because they are usually responsible for collecting, storing, managing and rationing household water. As water scarcity increases, women's unpaid labour, time burden and physical stress also increase. This shows that household water scarcity is not only an environmental or infrastructural issue, but also a social and gender-related concern.

The main household adaptation strategies identified in the study include water storage, reduced consumption, use of multiple sources, borewell dependence, tanker use, water sharing, rainwater harvesting and adjustment of domestic activities. However, many of these practices are temporary coping mechanisms rather than sustainable solutions. Strategies such as rationing, borrowing water and using distant sources may reduce immediate stress, but they do not address the deeper causes of long-term water insecurity.

The findings further indicate that government schemes such as the Jal Jeevan Mission have improved the potential for piped-water access in rural areas, but source reliability, regular supply, local maintenance and equitable household connection remain critical concerns. Therefore, the study concludes that sustainable water security in Etawah requires integrated planning involving reliable piped supply, groundwater recharge, rainwater harvesting, village-level monitoring, women's participation and equitable water governance.

Conclusion

The study concludes that water scarcity in the semi-arid regions of Etawah District is a multidimensional problem shaped by seasonal rainfall variability, summer water stress, groundwater dependence and unequal access to water infrastructure. The findings show that scarcity is experienced differently across households according to income, caste, landholding, family size, gender and location. Poor households, marginal farmers, women and peripheral settlements are more vulnerable due to limited access to reliable water sources and fewer adaptation options. Household strategies such as water storage, rationing, use of multiple sources, borewell dependence, tanker use and water sharing help manage short-term scarcity, but many remain temporary coping mechanisms rather than sustainable solutions. The study highlights the need for reliable piped-water supply, groundwater recharge, rainwater harvesting, source monitoring, scheme maintenance and women's participation in water governance. Overall, water scarcity in Etawah is both an environmental and social issue requiring integrated local planning.

References

- Central Ground Water Board. (2024). *National compilation on dynamic ground water resources of India, 2024*. Ministry of Jal Shakti, Government of India.
- Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. Cambridge University Press.
- Kashyap, A., & Dhaarna. (2025). Water security modeling in low-income regions in India: A system dynamics approach. *Environmental and Sustainability Indicators*, 25, 100781.

- Morante-Carballo, F., Montalván-Burbano, N., Quiñonez-Barzola, X., & Jaya-Montalvo, M. (2022). What do we know about water scarcity in semi-arid zones? A global analysis and research trends. *Water*, 14(17), 2685.
- Srinidhi, A., Kumar, M. D., & James, A. J. (2024). Retrospective climate resilience assessment of semi-arid watershed interventions in India. *International Journal of Water Resources Development*, 40(2), 251–275.
- UNESCO. (2024). *The United Nations World Water Development Report 2024: Water for prosperity and peace*. UNESCO.
- WHO & UNICEF. (2023). *Progress on household drinking water, sanitation and hygiene 2000–2022: Special focus on gender*. World Health Organization and UNICEF.
- Azadi, Y., et al. (2025). Factors influencing adaptation to water scarcity in the agricultural sector: An integrated Theory of Planned Behaviour and Value-Belief-Norm approach. *Journal of Arid Environments*.
- Biswas, A. (2025). Water scarcity: A global hindrance to sustainable development and agricultural production—A critical review of the impacts and adaptation strategies. *Cambridge Prisms: Water*.
- Central Ground Water Board. (2023). *Dynamic ground water resources of India, 2023*. Ministry of Jal Shakti, Government of India.
- Central Ground Water Board. (2024). *National compilation on dynamic ground water resources of India, 2024*. Ministry of Jal Shakti, Government of India.
- Central Ground Water Board. (n.d.). *National aquifer mapping and management plan of Etawah District, Uttar Pradesh*. Ministry of Jal Shakti, Government of India.
- Centre for Science and Environment. (2021). *State of groundwater in Uttar Pradesh*. Centre for Science and Environment.
- Jepson, W. E., et al. (2021). Cross-sectional study to measure household water insecurity and its association with health risk. *BMJ Open*, 11, e040825.
- Karimi, M., et al. (2024). Climate change and water scarcity impacts on sustainability in semi-arid areas: Lessons from southern Iran. *Environmental Development*.
- Kashyap, A., & Dhaarna. (2025). Water security modelling in low-income regions in India: A system dynamics approach. *Environmental and Sustainability Indicators*, 25, 100781.
- Naika, R. (2025). Factors influencing drought distress: A study on vulnerable communities in rural Karnataka, India. *Discover Sustainability*.
- Wutich, A., et al. (2020). Coping strategies for individual and household-level water insecurity: A systematic review. *WIREs Water*, 7(5), e1477.
- Young, S. L., Boateng, G. O., Jamaluddine, Z., Miller, J. D., Frongillo, E. A., Neilands, T. B., Collins, S. M., Wutich, A., Jepson, W. E., Stoler, J., & HWISE Research Coordination

- Network. (2019). The Household Water InSecurity Experiences scale: Development and validation of a household water insecurity measure for low-income and middle-income countries. *BMJ Global Health*, 4(5), e001750.
- Young, S. L., Miller, J. D., Frongillo, E. A., Boateng, G. O., Jamaluddine, Z., Neilands, T. B., & HWISE Research Coordination Network. (2020). Validity of a four-item Household Water Insecurity Experiences scale for assessing water issues related to health and well-being. *The American Journal of Tropical Medicine and Hygiene*.
- Zhou, L., et al. (2025). Adaptive household strategies for sustaining crop production amid water scarcity in a semi-arid communal area of South Africa. *Frontiers in Sustainable Food Systems*.