KEC Conference 2025

ISSN: 3021-940X (Print) DOI: https://doi.org/10.3126/injet.v2i2.78658

A Contextualized Groundwater Governance Framework for Sarlahi, Nepal

Ayushmita Pokhrel[1], Saurav KC[1, *]

[1]*Center of Research for Environment, Energy and Water (CREEW), Baluwatar, Kathmandu-4, Nepal, ayushmita@creew.org.np*
[1]*Center of Research for Environment, Energy and Water (CREEW), Baluwatar, Kathmandu-4, Nepal, saurav@creew.org.np*

Abstract

Effective groundwater governance is vital for sustainable resource management. This study presents a contextualized groundwater governance assessment framework applied to Barahathawa Municipality, Sarlahi, Nepal. The framework evaluates governance across four dimensions—technical, legal/institutional, cross-sector policy coordination, and operational—using 32 indicators to derive a composite Groundwater Governance Index (GGI). Barahathawa's GGI of 1.03 reflects an early acceptable governance state. The technical dimension (midway between non-existent and basic) highlights gaps in groundwater data collection and dissemination. Legal and institutional mechanisms are approaching a basic level but are limited by the absence of comprehensive regulatory frameworks. Cross-sector policy coordination has reached an acceptable state, reflecting efforts to collaborate with local units/departments and sectoral entities, although these efforts are often informal and ad hoc. The operational dimension demonstrates initial progress toward an acceptable state, with advancements in transparency, conflict resolution, and community engagement in groundwater management discussions. However, further efforts are needed to enhance inclusivity and to establish a community-focused groundwater management action plan. This assessment framework thus provides a holistic and context-specific approach to identifying strengths and gaps in groundwater governance. By integrating insights from both experts and community stakeholders, it serves as an effective tool for understanding governance dynamics and guiding targeted improvements.

Keywords: Governance assessment, Groundwater governance index, Groundwater management, Sustainability

1. Introduction

According to the United Nations (2022), groundwater constitutes 99% of Earth's liquid freshwater, supplying half of global domestic water, including most rural populations without piped systems, and 25% of irrigation needs. As surface and urban water supplies become increasingly scarce both globally and locally, groundwater serves as an alternative source to meet the needs of drinking water, agriculture, and industry (Howard, 2015). However, over-extraction in regions like South Asia and Southeast Asia threatens its sustainability. Water-intensive agriculture, unregulated land use (Mukherjee, 2018), and encroachment on recharge areas has contributed to the depletion of groundwater levels and deterioration of water quality (Sikdar, 2019). In the Global South, groundwater decline is acute, with seven Asian countries leading the world in groundwater extraction (United Nations, 2022).

In developing nations like Nepal, groundwater challenges are multifaceted. While cities like Kathmandu report alarming groundwater level declines (Closas and Molle, 2016), the Terai—Nepal's breadbasket—faces a paradoxical duality: localized decline in groundwater level coexists (Singh, 2016) with vast untapped reserves (Urfels *et al.*, 2020). Factors such as climate change, migration-driven population growth, changes in land use, governance reforms in Nepal, and shifting water demands amplify the need for effective groundwater management (Yadav, 2018). Nepal's recent federal transition further complicates governance, as decentralized structures remain understudied. Historically, weak governance has prioritized access over sustainability, perpetuating cycles of overuse in some areas and underuse in others. Inclusive and effective governance of groundwater resources is thus critical to ensuring sustainability, promoting equitable access, and enhancing productivity (Tucker *et al.*, 2023).

Given the pressing need for inclusive and effective governance in addressing groundwater challenges, analytical frameworks serve as essential tools for systematically exploring and understanding the multifaceted

**Corresponding Author*

nature of groundwater governance. This study adopts a contextual governance framework in Barahathawa Municipality, Sarlahi District, drawing on global governance indicators and contextualizing them to local conditions. Through a combination of expert consultations and community surveys, the study aims to provide a comprehensive assessment of the current state of groundwater governance.

2. Methodology

2.1. Study area

Barahathawa Municipality (Figure 1), located in Nepal's Terai region in Sarlahi district, Madhesh Province, was selected as the study area to assess groundwater governance under Nepal's federal transition. The municipality exemplifies the Terai's reliance on groundwater for agriculture, where localized depletion coexists with underutilized reserves. Post-federalization, the impacts of decentralized governance on groundwater management remain unexamined in Nepal's Terai, making Barahathawa a representative case for understanding evolving governance dynamics.

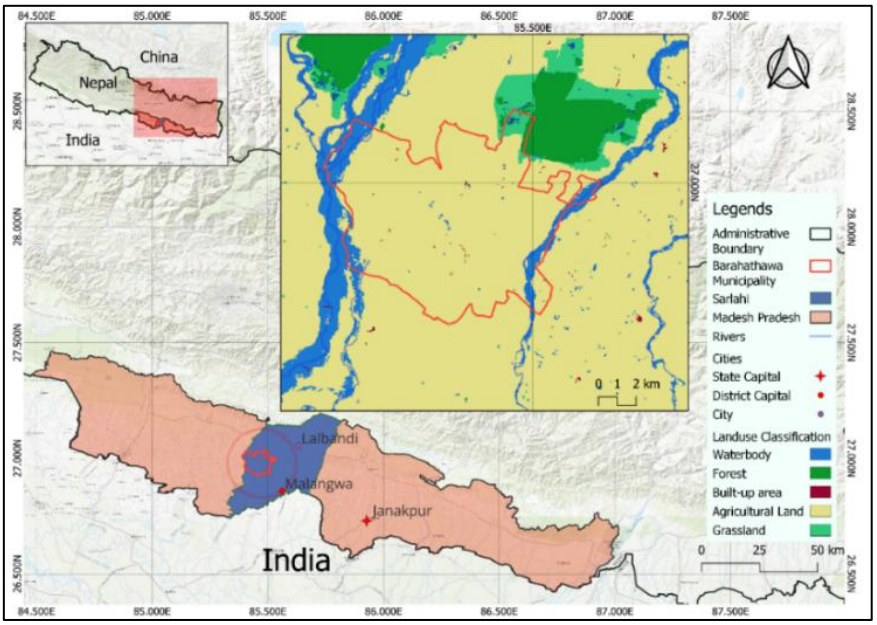

Figure 1. Study area map of Barahathawa Municipality

2.2. Methodological approach

The methodology (Figure 2) adopted in this study utilized a comprehensive, participatory approach to investigate groundwater governance strengths and gaps within Barahathawa Municipality. The extensive involvement of stakeholders, including the municipality, local communities, and multi-stakeholder engagement, was central to co-developing the context-specific groundwater governance framework.

The study began with a pre-consensus meeting with municipal authorities to introduce the research objectives and initiate the preliminary conceptualization. The draft indicators for the groundwater governance framework, derived from a literature review (Bruns and Meinzen-Dick, 2022; KC, 2023; Molle and Closas, 2020; Poudel, 2021; Shah et al., 2018; Zwarteveen et al., 2021), served as the foundation for stakeholder discussions. An inception workshop followed, where the framework and its elements were refined and contextualized for Barahathawa Municipality. This workshop engaged stakeholders from municipal and provincial sectors to gather insights and recommendations, which directly informed the development of the groundwater governance framework. The framework incorporates key indicators drawn from stakeholder inputs, ensuring context-specific metrics that reflect local realities. Next, a structured survey questionnaire was designed to collect field data. Surveyors underwent pre-training to ensure data accuracy before the field survey, which was carried out by a team of eight surveyors. The survey targeted two main groups:

groundwater management experts and local groundwater users. The study concluded with a dissemination workshop, where experts and stakeholders validated the findings and provided additional insights.

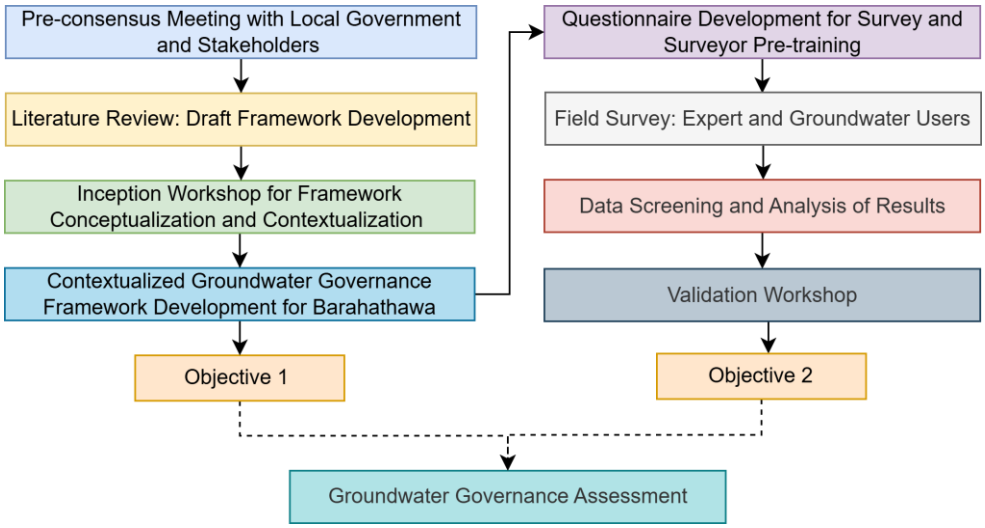

Figure 2. A methodological framework for the study

2.3. Framework description

This study extends the framework developed by KC (2023), which incorporates 30 benchmarking indicators drawn from a range of existing literature (Foster et al., 2010; KC, 2023; Miletto, Pangare and Thuy, 2019). KC's framework organizes these indicators into four key dimensions: technical, legal and institutional, cross-sector policy coordination, and operational. Within each dimension, multiple indicators are evaluated using two variables: the adequacy of provisions and the institutional capacity to implement them effectively.

Within the groundwater governance framework, the values for the variable associated with the indicators are determined through an expert survey. These values range from 0 to 3 (Figure 3), with the indicator value directly reflecting the corresponding variable value.

For each dimension, the indicator values are aggregated using equation 1 to compute the dimensional value, with equal weight assigned to each indicator.

$$D_i = \sum_{j=1}^{n} w_j \times I_{ij} \qquad \text{(Equation 1)}$$

where, D=Dimensions; I=Indicators; W_j=weightage of j^{th} indicator within the dimension; I_{ij}=Aggregated value of j^{th} indicator in i^{th} dimension; i,j= number of dimensions, indicators within each dimension

The GGI is determined by aggregating the values of each dimension within the framework using equation 2.

$$GGI = \sum_{i=1}^{n} w_i \times D_i \qquad \text{(Equation 2)}$$

where i= number of dimensions; D_i =Aggregated value of i^{th} dimension; W_i=weightage of i^{th} indicator within the dimension; GGI=Groundwater Governance Index

The value of GGI ranges from 0 to 3, where 0 is the non-existent state while 3 is the optimum state of groundwater governance (Figure 3).

2.4. Framework contextualization

The contextualized groundwater governance framework (Figure 3), adapted from existing literature (Foster, et al., 2010; KC, 2023; Miletto, et al., 2019), incorporates indicators from various sources, which were further refined through consultations with local stakeholders to ensure their contextual relevance. While the

framework developed by (KC, 2023) evaluates indicators using two variables—i) adequacy of provisions and ii) institutional capacity to implement them—this study focuses solely on assessing the adequacy of provisions. Stakeholder consultations emphasized that Nepal's recent federal transition has rendered local groundwater governance nascent, necessitating a foundational focus on the adequacy of provisions before addressing institutional capacity to implement them at the local level.

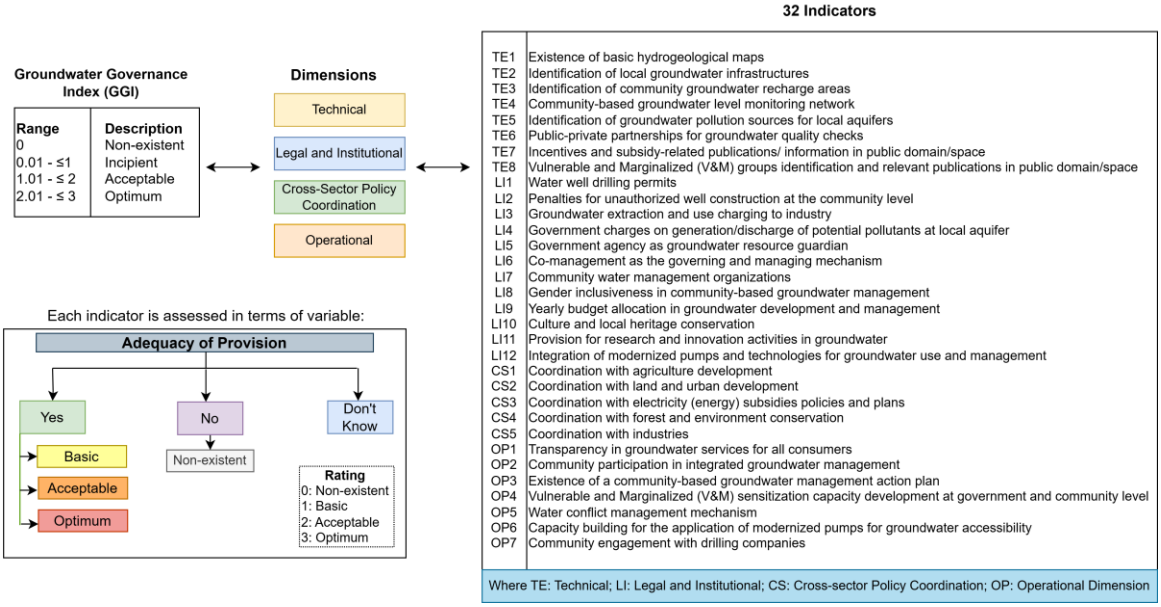

Figure 3. Groundwater governance framework used in the study

The framework evaluates groundwater governance with variable values derived from qualitative surveys. It primarily assesses governance through expert insights, including elected officials and bureaucrats, who participated in an expert survey to establish values for various indicators and dimensions. The survey employed purposive sampling to target key decision-makers, such as ward chairpersons, representatives from the municipality office (Mayor, Deputy Mayor, Chief Administrative Officer, and Head of the Agriculture Department), and officials from the Bagmati and Manushmara Irrigation Project. Their feedback provided essential information on groundwater governance provisions, shaping the framework's development and analysis. Additionally, a user survey was conducted involving individual water consumers, pump sellers, water jar sellers, members of forest user groups, youth club members, journalists, and college lecturers, using spatially distributed random sampling to capture diverse community perspectives on groundwater management practices and their effectiveness. Respondents were selected from all 18 wards, ensuring representation of Vulnerable and Marginalized Groups (V&M), and considering factors such as gender and caste representation.

3. Results and Discussion

3.1. Development of contextualized groundwater governance framework for Barahathawa Municipality

The outcomes of the inception workshop led to the identification of key indicators within the groundwater governance framework, specifically tailored for Barahathawa Municipality. The indicators that reflect local realities were identified through local-level consultations that incorporated diverse insights from stakeholders. The 32 contextualized indicators (Figure 3) are grouped into four dimensions: technical (8 indicators), legal and institutional (12 indicators), cross-sector policy coordination (5 indicators), and operational (7 indicators), forming a context-specific framework.

3.2. Application of the contextualized groundwater governance framework

Following the selection of 32 indicators across four dimensions, the groundwater governance framework was finalized. A total of 119 individuals were surveyed, comprising 83 groundwater users and 36 experts.

In the users' survey of 83 respondents, 63.86% identified as male and 36.14% as female. Among them, 20 respondents belonged to V&M groups, including Musahar, Dusadh, Chamar, Muslim, Dom, Mallaha, Sarki, Chaudhary, and Danuwar—communities historically disadvantaged due to caste-based discrimination. The "Others" category, representing 32.5% of respondents, included Terai Brahmin, Hill Brahmin, Newar, Rai, and Chhetri. Agriculture is the primary occupation for 68.67% of respondents. Among these, 78.57% were landowners, 8.57% tenants, and 12.86% both. Other occupations included sewing/manufacturing (9.64%), business (12.05%), government service (6.03%), private/NGO service (2.41%), and construction (1.20%). For drinking water, 92% relied on personal handpumps, 7% on public handpumps, and 1% on deep tubewells. Groundwater is the primary source for both drinking and irrigation, with 69% of respondents partially or fully dependent on it for irrigation. Wells, shallow tubewells (depth <100m), and the Bagmati Irrigation Project are the main irrigation sources, while none use deep tubewells/boreholes (depth >100m). Among pump users, 34.93% use electric pumps, 18.07% diesel pumps, and 46.98% use no pumps for irrigation.

In the survey of 36 experts, elected officials and government employees were equally represented, with most from government institutions and two from community-based organizations. The majority (47.22%) had secondary-level education, 41.66% held undergraduate degrees, and 5.56% each had postgraduate or primary education. Gender representation among experts was 91.67% male and 8.33% female.

3.3. Current state of groundwater governance in Barahathawa, Sarlahi

The groundwater governance index (GGI) for Barahathawa Municipality, Sarlahi, is 1.03 (value derived using (Equation 2), indicating an early acceptable state (Figure 4). While this reflects progress beyond the incipient stage (GGI $\leq$ 1), significant gaps remain, particularly in technical and legal dimensions. Key challenges include the lack of groundwater mapping, monitoring, data generation, and dissemination mechanisms, as well as the absence of local legal frameworks for sustainable groundwater use. Strengthening institutional capacity and operational management is also critical. Although transparency in groundwater services, conflict resolution, and cross-sector coordination shows promise, these practices require formalization and further improvement. Experts participating in the survey attributed governance shortcomings to the absence of groundwater-specific laws, limited stakeholder urgency, financial constraints, insufficient human resources, and weak political commitment. Addressing these issues is essential to advance groundwater governance and ensure sustainable resource management.

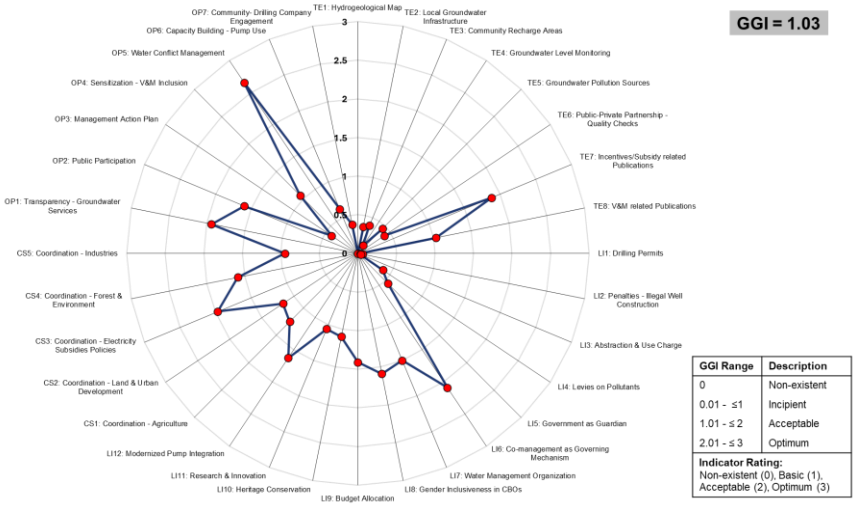

Figure 4. Average indicator ratings of the groundwater governance framework by experts in terms of provisions

Technical Dimension: The technical dimension of groundwater governance in Barahathawa Municipality averages 0.58, indicating a state between non-existent and basic. This dimension has the most room for improvement. There are significant data gaps, including the absence of hydrogeological maps and limited groundwater infrastructure mapping (0.35). While there are no dedicated monitoring wells, the local government does track complaints about groundwater fluctuations and quality. No specific policies address

pollution near water sources, despite community-led cleaning activities during festivals. Provisions for incentive-related publications are nearing an acceptable level (1.87), with information shared through citizen charters, municipal websites, and local announcements, but 41% of users are unaware of subsidies for pumps and motors, including 32% from V&M groups. Annual publications on V&M groups are limited and only available at the municipality office (1.03), with 69% of users unaware of these efforts.

Legal and Institutional Dimension: The dimension averages 0.95, nearing a basic state (range: 0.02 to 2.08). Regulatory gaps persist, with no permits for well drilling, penalties for unauthorized wells, or fees for groundwater extraction by industries. Although experts rate community engagement as acceptable (2.08), 59% of users feel excluded from groundwater management activities. Gender inclusivity remains limited, with women's participation in decision-making rated at 1.59, and 45% of users reporting unfair representation. Budget provisions are rated between basic and acceptable (1.4), but 59% of users report no allocation for groundwater development. The local government's role as a groundwater guardian is unclear, with half of users unaware of its responsibilities.

Cross-Sector Policy Coordination Dimension: The dimension averages 1.39 (range: 0.95 to 1.97). Key findings include minimal collaboration between agricultural and water-related departments, with 60% of users reporting no programs promoting sustainable groundwater use in agriculture. Coordination with the Nepal Electricity Authority (NEA) for electricity subsidies and grid establishment is rated highly (1.97), reflecting a proactive approach to addressing energy needs for groundwater utilization. Forestry coordination is limited, with only 39% of users aware of past afforestation programs. Additionally, there are no specific policies or coordination for groundwater use in industries, as the area lacks large industries.

Operational Dimension: The dimension averages 1.23, slightly above basic (range: 0.38 to 2.65). The groundwater service transparency is approaching acceptable levels (1.93), but 50% of users lack access to information, while community involvement in groundwater management is moderate (1.6), with occasional consultations and no formal action plans. Capacity-building efforts are minimal, as 77% of users receive no support for modernized pump operation, and data sharing between private drillers, the government, and the community is limited (0.38). Conflict resolution for canal irrigation disputes is well-established (2.65) through both informal and formal committees, but there is limited capacity-building for government officials on V&M group inclusion (1.05).

4. Conclusion

The assessment of groundwater governance in Barahathawa Municipality helps visualize the current state of governance, revealing both strengths and critical gaps that must be addressed to ensure sustainable and equitable management of this vital resource. The study reveals that while community-led initiatives and cross-sectoral coordination have advanced groundwater governance in Barahathawa, persistent gaps in technical capacity, legal enforcement, and institutional coherence require urgent attention. Key interventions such as comprehensive groundwater infrastructure mapping, systematic data collection, and stricter regulation of unauthorized extraction are essential to strengthen governance.

Further progress depends on formalizing collaboration among the agriculture, land use, and forestry sectors to adopt a unified approach to groundwater sustainability. Although transparency and public engagement have improved, more inclusive mechanisms are needed to ensure marginalized groups have a meaningful voice in decision-making. A community-driven groundwater action plan, supported by strategic private-sector partnerships, could enhance both equity and efficiency in governance.

Moving forward, immediate action should prioritize policy formulation, infrastructure mapping, and sustained multi-stakeholder engagement. The long-term security of Barahathawa's groundwater resources relies on the collective commitment of government institutions, local communities, and private actors.

Acknowledgements

The authors gratefully acknowledge NEXUS Gains - CGIAR: Realizing Multiple Benefits Across Water, Energy, Food and Ecosystem Initiative for their generous financial support, which enabled this research. We

would like to express our sincere gratitude to the International Water Management Institute (IWMI) for their expertise, collaboration, and invaluable support throughout the research process. We also extend special thanks to Barahathawa Municipality for the collaborative research opportunity and their steadfast cooperation, and to Work Plan Nepal for their assistance in supporting the overall coordination and facilitation of the research process.

References

Bruns, B.R. and Meinzen-Dick, R.S. (2022) *'*Combining and crafting institutional tools for groundwater governance*'*.

Closas, A. and Molle, F. (2016) 'Groundwater governance in Asia and the Pacific. [Project report of the Groundwater Governance in the Arab World - Taking Stock and Addressing the Challenges].'

Foster, S. *et al.* (2010) *'*Groundwater governance : conceptual framework for assessment of provisions and needs (English)*'*. *GW MATE strategic overview series ; no. 1Washington, DC*.

Howard, K.W.F. (2015) 'Sustainable cities and the groundwater governance challenge', *Environmental Earth Sciences*, 73(6), pp. 2543–2554.

KC, S. (2023) *'*Improving groundwater governance in rapidly urbanizing areas in areas under multiple stresses: A case of Khon Kaen, Thailand*'. (Doctoral dissertation). Asian Institute of Technology*.

Miletto, M., Pangare, V. and Thuy, L. (2019) *'*Tool 1- Gender-responsive indicators for water assessment, monitoring and reporting*'*. *Paris: UNESCO*.

Molle, F. and Closas, A. (2020) 'Why is state-centered groundwater governance largely ineffective? A review', *WIREs Water*, 7(1).

Mukherjee, A. (2018) 'Overview of the Groundwater of South Asia', in A. Mukherjee (ed.) *Groundwater of South Asia*. *Singapore: Springer Singapore*, pp. 3–20.

Poudel, A. (2021) *'Water security in Nepal – Analysis of the groundwater resource and governance'*.

Shah, T. *et al.* (2018) 'Solar pumps and South Asia's energy-groundwater nexus: exploring implications and reimagining its future', *Environmental Research Letters*, 13(11), p. 115003.

Sikdar, P.K. (2019) 'Problems and Challenges for Groundwater Management in South Asia', in P.K. Sikdar (ed.) *Groundwater Development and Management: Issues and Challenges in South Asia*. Cham: Springer International Publishing, pp. 1–18.

Singh, D. (2016) *'*Study of Effect of Chure Degradation on Water: A Case of Kamala Basin in Nepal (Briefing Paper No. 19)*'*. Kathmandu.

Tucker, C.M. *et al.* (2023) 'Governance of interdependent ecosystem services and common-pool resources', *Land Use Policy*, 127, p. 106575.

United Nations (2022) *'*The United Nations World Water Development Report 2022: Groundwater: Making the invisible visible*'*. Paris: UNESCO.

Urfels, A. *et al.* (2020) 'Drivers of groundwater utilization in water-limited rice production systems in Nepal', *Water International*, 45(1), pp. 39–59.

Yadav, S.K. (2018) 'Groundwater Challenges, Governance, and Management in Nepal', in A. Mukherjee (ed.) *Groundwater of South Asia*. Singapore: Springer Singapore, pp. 707–734.

Zwarteveen, M. *et al.* (2021) 'Transformations to groundwater sustainability: from individuals and pumps to communities and aquifers', *Current Opinion in Environmental Sustainability*, 49, pp. 88–97.