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TECHNICAL REPORT

Mapping the Invisible: Groundwater Use, Access, Equity, and Governance in Nepal's Southern Plains

Policy Pathways for Equitable and Sustainable Groundwater Use

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May 2026

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Acknowledgements

The work was conducted under the CGIAR Initiative on NEXUS Gains and finalized with support from the CGIAR Policy Innovations Program. We would like to thank all funders who supported this research through their contributions to the CGIAR Trust Fund (www.cgiar.org/funders).

We extend our gratitude to Mr. Sunil Kumar Yadav of Work Plan Nepal for his support in coordinating data collection and in facilitating field activities. We also extend our sincere thanks to Ms. Kalpana Katuwal, Mayor of Barahathawa Municipality, for her cooperation, collaboration, and support in conducting the research. We are also grateful to the citizen scientists who supported IWMI in groundwater data collection.

Lastly, we would like to thank all community participants, officials, and elected representatives from Barahathawa Municipality and Madhesh Province, as well as other stakeholders who actively engaged in the borehole inventory, interviews, co-design, validation, and dissemination workshops. Their feedback has greatly enriched this research.

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Citation

KC, Sumitra, Manohara Khadka, Anuj Mishra, and Anil Aryal. 2026. *Mapping the Invisible: Groundwater Use, Access, Equity, and Governance in Nepal's Southern Plains; Policy Pathways for Equitable and Sustainable Groundwater Use.* International Water Management Institute (IWMI).

Front cover photo: A Woman participating in groundwater game at Barahathawa Municipality, Sarlahi District, Nepal. (*photo:* Sumitra KC/IWMI)
Back cover photo: Groundwater being used in the field at Barahathawa Municipality, Sarlahi, Nepal (*photo:* Onion Films)

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Contents

Summary

Groundwater is a critical resource for meeting domestic, agricultural, industrial, and ecological water needs in Nepal's southern plains. In Madhesh Province, in the southern plain of Nepal, approximately 80% of households rely on groundwater for domestic water supply and about 37% of land with irrigation access is irrigated using groundwater. In Barahathawa Municipality, in Madhesh province of the Terai region, canal irrigation is limited and most farmers depend on private wells and pumps. This study mapped 1,136 boreholes and wells across all 18 wards of the municipality. Although groundwater levels are relatively stable compared to neighboring areas, water tables vary from 12 to 117 feet below the ground level, with deeper levels in the eastern part of the municipality and some artesian wells present.

Access to groundwater is also shaped by social and economic inequalities. Pump and borehole ownership is concentrated among certain groups, while others – such as Dalits, Muslims, and women-headed households, tenant farmers and other marginalized groups – face challenges linked to historic, social, linguistic, financial, and gender barriers. Informal groundwater markets fill irrigation gaps, but they also reinforce inequalities, as those without boreholes and pumps pay higher pump rental prices.

Subsidy benefits are skewed towards medium-scale farmers (who own land between 0.51–1.01 ha) and certain caste groups, leaving smallholders (who own less than 0.51 ha land), tenant farmers, Terai Dalits, Terai Janajatis, and other marginalized groups underserved. The absence of local policy on groundwater and fragmented institutional arrangements in groundwater management have resulted in limited attention to recharge, and to sustainable and equitable extraction.

The study recommends formulating and enforcing local policies along with stronger coordination across sectors and three tiers of government to improve groundwater access, equity, and sustainability. Priority actions should include targeted subsidies, participatory and multistakeholder groundwater management, investment in recharge and nature-based solutions, expansion of citizen science networks to strengthen local groundwater databases, improved access to credit, and stronger support for women, smallholders, tenant farmers and marginalized farmers.

Background

Groundwater is a critical resource for meeting domestic, agricultural, industrial, and ecological water needs in Nepal's southern plains known as the Terai,[1] with approximately 80% of households relying on groundwater to meet their domestic needs (MoWSS, 2016). Over the past decade, groundwater abstraction for irrigation has increased markedly, rising from 29.8% in 2011 to 41.7% in 2021 across the country, including the Terai (NSO, 2023). Out of the total 1.1 million ha of land with irrigation access, 37% (441,887 ha) is irrigated by groundwater in the Terai (DoWRI, 2019). The Terai region is estimated to have a substantial groundwater recharge potential, with an annual storage capacity of 8.8 billion cubic meters (Shrestha et al., 2018).

Despite the extensive groundwater reserves, the Terai – often regarded as Nepal's breadbasket – faces significant challenges. These include declining groundwater levels in the unconfined aquifer and unsustainable extraction practices, driven by rising agriculture demand, slow and unreliable expansion of surface irrigation, and increasing urbanization. The recharge of groundwater in the Terai is primarily influenced by seasonal monsoon rains, which replenish unconfined reservoirs and serve as the primary source of groundwater renewal. However, erratic rainfall patterns, climate change, and degradation of the Chure region have severely disrupted the recharge mechanisms in the Terai region.

The projected change in temperature in the Terai is between 2016–2045 is by 0.93˚C under Representative Concentration Pathway (RCP) 4.5 and 1.11 ˚C under RCP 8.5. The projected change in precipitation is by 2.1% under RCP 4.5 and 5.4 % under RCP 8.5 (MoFE, 2019). The region is increasingly experiencing water scarcity during dry seasons due to delayed monsoon in the past few years (Yadav, 2018).

Rationale

Recognizing the growing concerns over unsustainable groundwater use and drying of handpumps and wells in the dry season in Nepal's southern plains, International Water Management Institute (IWMI) Nepal conducted a scoping visit to Barahathawa Municipality in Sarlahi District, Madhesh Province in the Terai region, at the request of the municipal mayor. From the scoping visit, it was clear that groundwater has been the lifeline for both agriculture and domestic needs, yet evidence on its status, extraction trends, and governance arrangements remains limited.

To fill this knowledge gap, IWMI Nepal, in collaboration with the municipality, initiated a detailed inventory of groundwater borewells. The assessment was designed to generate a comprehensive profile of groundwater availability, use patterns, and governance structures.

Data and Methodology

This study was conducted in Barahathawa Municipality to establish a comprehensive baseline for the municipality's groundwater profile. It involved a detailed inventory of wells and boreholes (Figure 1), monitoring groundwater levels through measurements of borehole and well depths, and mapping of the policies and institutions governing groundwater management within the municipality.

Barahathawa has a total population of 81,120 (50.4% men and 49.6% women). This study mapped 1,136 boreholes and wells primarily for irrigation purposes.

To capture the complexity of groundwater use and governance, the study adopted a mixed-methods design, integrating both quantitative and qualitative approaches to provide a holistic understanding of the biophysical and institutional dimensions of groundwater resources in the municipality.

As part of the quantitative approach, a well and pump inventory was conducted across all 18 wards of the municipality (Figure 1). Data were collected on functionality, depth, ownership, pumping technology (diesel, electric, or solar), access to subsidies, landholding size, and participation in renting and lending of pumps and wells (informal water markets). The survey was administered through the mobile-based KoBo platform, which enabled systematic geo-referencing and real-time data entry. Further, statistical analyses, including cross-tabulations and chi-square tests, were used to explore relationships between landholding size, pump/well ownership, ethnicity, and subsidy access.

To complement the quantitative analysis, a qualitative approach involved key informant interviews, in-depth interviews, and focus group discussions. These were conducted with 32 diverse groundwater stakeholders (22 men and 10 women), including farmers; pump drillers; municipal officials; representatives from the Nepal Electricity Authority, Groundwater Division, and Agriculture Knowledge Center; and elected representatives.

[1] Nepal is divided into three ecological regions: Mountain (High Himalayas), Hills (middle mountains), Terai (southern plains).

Federal, provincial, and local policies were reviewed and analyzed to identify gaps, overlaps, and opportunities for sustainable use of groundwater, and to understand how policy and institutional arrangements support groundwater management. Such policies include the Constitution of Nepal 2015, the draft Water Resources Bill 2025, the National Water Resources Policy 2020, the Local Governance Operation Act 2017, the National Irrigation Policy 2023, Irrigation Master Plan 2019 (updated 2024), the National Water Supply and Sanitation Act 2022, and the National WASH Policy 2023.

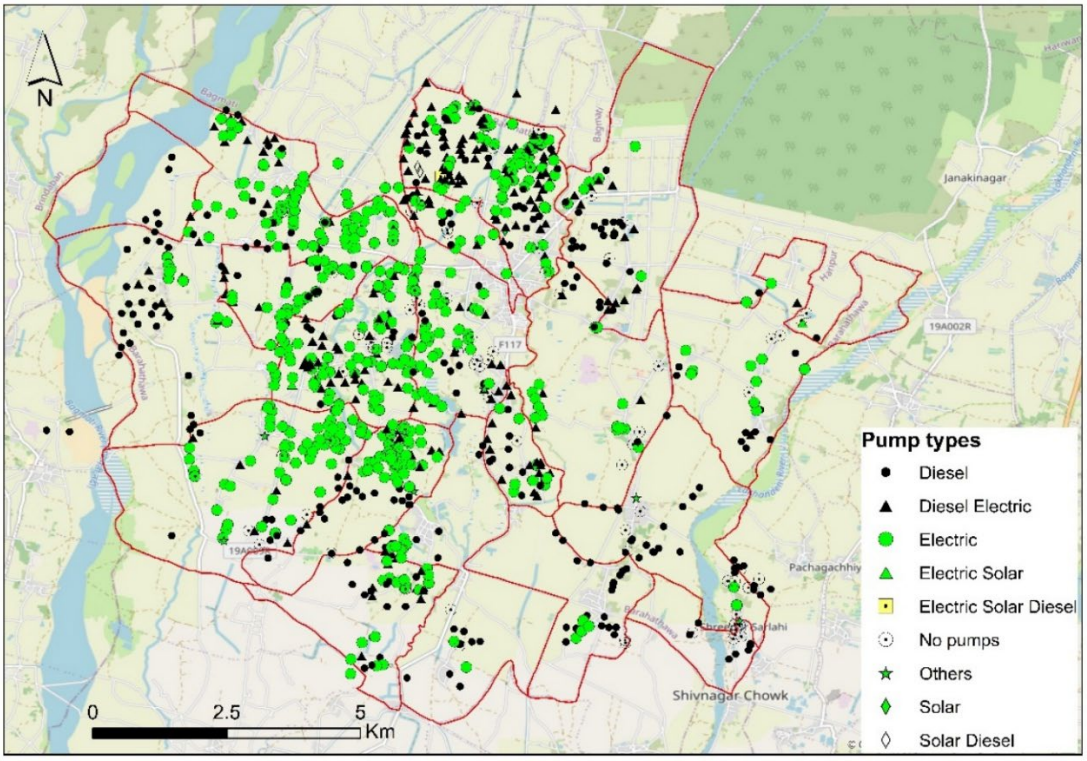

Figure 1. Spatial distribution of distinct types of pumps across the municipality (*Source:* author's creation)

Current Groundwater Situation in Barahathawa Municipality

The inventory of the surveyed boreholes and wells in Barahathawa shows 1,136 boreholes and wells in the municipality, of which 95% are functional and 84% are privately owned. The majority of the borehole or well owners (75.3%) also own their own pump sets.

- More than half of borehole and well owners use electric pumps (Figure 2), reflecting the municipality's strong commitment to agricultural electrification in its annual plans and budgets. In fiscal year 2024/25, the municipality allocated dedicated funds to expand electricity access to farmers' fields across 11 of its 18 wards, demonstrating a sustained effort to promote clean energy-based irrigation and reduce reliance on diesel pumps.
- One-quarter of the borehole and well owners do not have pumps and rely on rented pumps.

In the municipality, canal irrigation from the Bagmati Irrigation Project has failed to meet the irrigation demand of farmers in approximately 50% of the arable land that has canal infrastructure. Five out of 18 wards have no canal infrastructure. **Therefore, farmers rely heavily on groundwater for irrigation.**

> *"The Bagmati Irrigation Project releases water in the canal on the day of Chhath Puja only to ensure people don't get upset, but the rest of the year, it does not release water. That's why everyone in this locality owns well or shares water from neighboring wells".* – From an in-depth interview with a male farmer from ward 6 on 21 January 2024.

For drinking water, households rely on individual and community-managed private boreholes, hand pumps, and wells. The municipality has only one municipal drinking water system, but it is not operational as of 2025, and another is under construction. While there have been reports of arsenic contamination, no laboratory testing has been conducted at the municipal level. Bio sand filters were distributed to the families of the pregnant women some years back; since then, there has been no intervention on water quality at the municipal level. There are no official records of water quality tests and they exist only in the memory of the people and municipal officers.

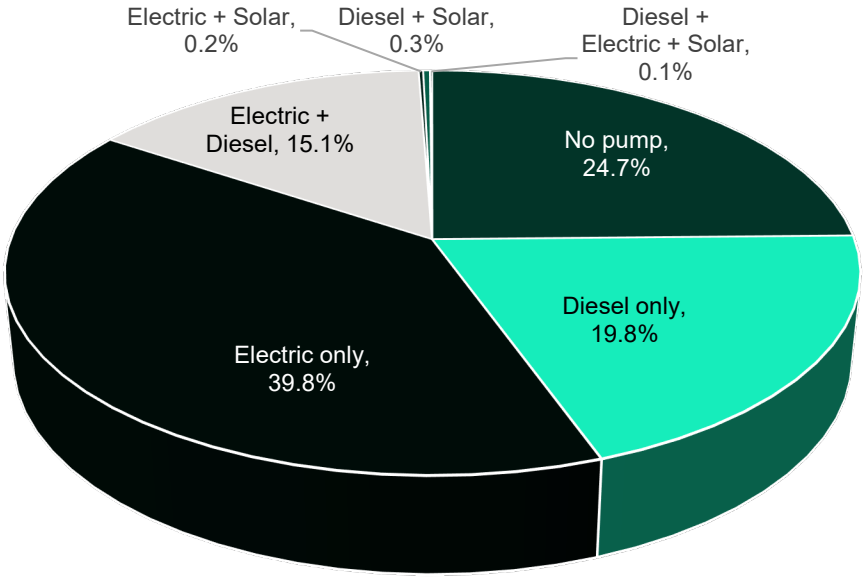

Figure 2. Types of pumps owned by borehole and well owners in Barahathawa Municipality, surveyed as of 2024 (*Source:* authors'creation)

The observed data show that Barahathawa has experienced a spatial decline in groundwater level spatially, as validated during the focus group discussions and key informant interviews. Figure 3 shows that the eastern wards have been experiencing low groundwater levels (~120 feet below ground level), while the groundwater levels in the western wards are less depleted. However, growing groundwater demand for agriculture, coupled with minimal efforts to recharge sustainably, is exacerbating pressure on the aquifer. In the present context of rapid urbanization of the municipality and climate change, there is a rising concern that the municipality may face a severe water crisis soon.

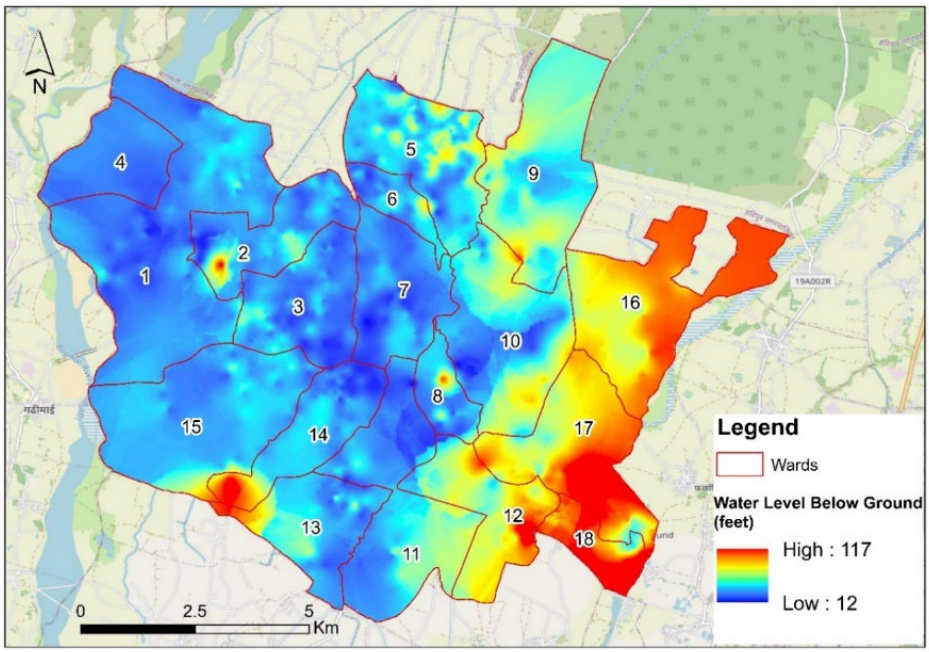

Figure 3. Water level below the ground level (the higher the number, the lower the depth) across Barahathawa Municipality, measured in feet. Numbers on the map represent the ward number of the municipality. (*Source:* authors'creation)

Equity in Groundwater Access, Informal Water Markets

People in the Madheshi Other Caste[2] and Hill BCN[3] groups dominate borehole and pump ownership, holding significantly more than their demographic share (Figure 4). People in the Madheshi Other Caste group account for up to 54% of the population, who own 70% of the total boreholes and 71% of the total pumps. Likewise, Hill BCN people make up around 10% of the population and own 16% of the boreholes and wells and 14% of the pumps. In contrast, Hill Dalits[4] and Terai Dalits form 16% of the population but own less than 1.5% of the boreholes and 1.2% of the pumps. Ownership of boreholes/wells and pumps among both Hill Dalits and Terai Dalits is therefore shown to be less compared to other castes. Figure 4 shows the overrepresentation of Madhesi Other Caste and Hill BCN, with the relative index being greater than 1. In contrast, there is an underrepresentation of Terai Dalits, Hill Dalits, Muslims, Hill Janajati[5], and Terai Janajati in borehole well and pump ownership with respect to their population size in the municipality, shown by a relative index less than 1.

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[2] "Tarai/Madheshi Other Castes" refers to non-Dalit, non-Janajati, and non-Brahmin Madheshi caste in the Tarai/Madhesh. The term replaces earlier "Terai Middle Caste" to avoid implying a hierarchical ranking among castes. Bennett, L, Dahal, D. R. and Govindasamy, G. 2008. Caste, Ethnic and Regional Identity in Nepal: Further Analysis of the 2006 Nepal Demographic and Health Survey. Calverton, Maryland, USA: Macro International Inc.

[3] "Hill BCN" refers to the Bahun, Chhetri, and Newar communities of Nepal, often described as the high-caste Hindu groups originating from the country's middle hills.

[4] According to National Dalit Commission, Dalit is a term used to refer to lower-caste communities who face caste-based discrimination, and are socially, economically, politically, and religiously excluded and deprived of social justice. https://giwmscdnone.gov.np/media/pdf_upload/signed_original_avd0ejk.pdf

[5] Janajatis are the Indigenous, ethnic communities who have their own mother tongue and traditional customs, different cultural identity, and distinct social structure. https://www.ifad.org/documents/d/new-ifad.org/nepal_ctn-pdf

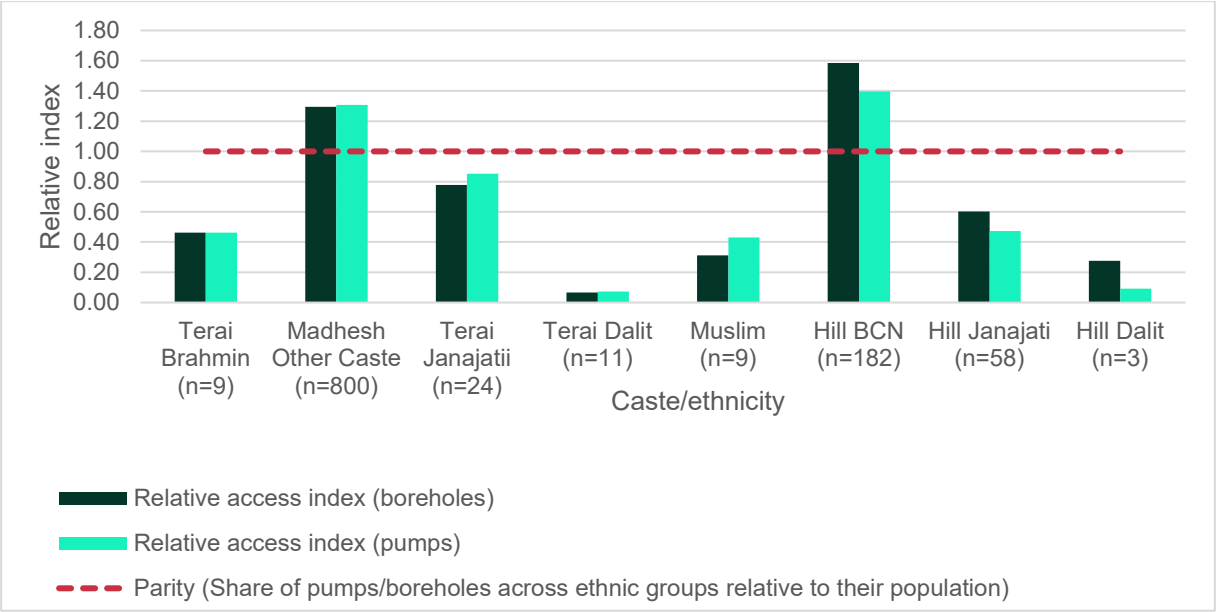

Figure 4. Relative index: borehole and pump ownership by ethnicity and caste in comparison to respective population size (*Source:* authors'creation)

Survey data also show that out of 1,136 borehole owners in the municipality, 20.8% own multiple pumps. While descriptive patterns show that the proportion of borehole and well owners with more than one pump increases from smallholder farmers (less than 20 Katha[6,7]) to larger farmers (more than 100 Katha), these differences are not statistically significant (Pearson $\chi^2 = 3.42$, $p = 0.33$). This indicates that decisions to invest in multiple pumps are driven by multiple factors and not only landholding size. Qualitative data indicate that many larger landholders do not engage in agriculture directly and instead lease out to tenants. Many large landholders grow sugarcane, which is not labor-intensive. According to local farmers, unlike maize and other crops, sugarcane farmers rarely apply scheduled irrigation from private borings to sugarcane and are mostly rainfall dependent. Irrigation is needed only during prolonged dry spells. A study conducted by Sugden (2014) also found that larger landholders in other parts of the Terai do not engage in agriculture and instead prefer to give their land on tenancy due to the increasing cost of agricultural inputs, inadequate irrigation access, and untimely rainfall due to the impacts of climate change.

Qualitative data support this pattern. Pump ownership is determined by several factors, such as land size, land fragmentation, land ownership, tenancy type, crop choices, irrigation intensity, access to credit, and access to canal irrigation. Farmers who grow vegetables and maize, farmers with scattered land plots, and farmers with investment capacity, such as through remittances, usually have more than one pump. The study also shows that the tenant, sharecroppers, or leasehold farmers are less likely to invest in wells and pumps due to uncertainty in their tenancy or contractual period with landowners and a lack of investment capacity. A study conducted in Dhanusa District, Madhesh Province, and Rupandehi District, Lumbini Province, also showed that farmers owning and cultivating small plots (less than 0.5 ha) have fewer boreholes and pumps (Sugden, 2014).

The absence or failure of public irrigation infrastructure, such as canals and community tubewells, has pushed farmers to use private groundwater solutions; a shift that reinforces existing inequalities. Tenant farmers, smallholders, Dalits, and women without secure land rights or access to capital are unable to invest in boreholes and are left to rely on either the costly informal water market or rainfed agriculture alone. A study conducted by Bhandari and Pandey (2006) also showed that factors such as farm size, land fragmentation, education, age, crop choices, access to electricity, and access to credit are the major factors influencing farmers' decisions to own a borewell.

[6] There is no formal definition of small, medium, and large landholders in Nepal; however, the following figures reference the national census of agriculture conducted by the National Statistics Office. Land less than 1 *Bigha* (0.51 ha) as a small landholder, 1–3 *Bigha* (0.51–1.01 ha) as a medium landholder, and more than 3 *Bigha* (1.01 ha) as a large landholder. https://giwmscdnone.gov.np/media/app/public/36/posts/1715839697_14.pdf

[7] 1 *Katha* = 0.0338 ha

A farmer from Murtiya has 3 Bigha of land and two pumps. He mentions that he installed a borehole in 2015 at his own expense, as the canal water was not dependable. He grows maize and paddy in one half of his land and sugarcane in the other half. He mentions maize is profitable, but it needs a lot of water and requires irrigation 3–5 times per season. – From an interview with a male farmer from ward 9 on 27 September, 2023.

An inventory also shows that renting and lending pumps are widespread across all wards and all types of landholders and ethnic groups. Statistically, no significant association between landholding size and renting and lending patterns (informal water market) is observed, but there is a strong spatial difference across wards. The informal water market is widespread across the municipality but concentrated more in wards 1,10, 8, 9, and 11.

Wards 8, 9, 10, and 11 have lower borehole density and no or limited access to surface irrigation. Although wards 8 and 11 have canal infrastructure, there is an insufficient water supply through the canals. As a result, farmers in these areas depend heavily on pump renting and lending to secure irrigation. These are also among the wards with comparatively higher use of diesel pumps.

Households with boreholes and wells but without their own pump are overwhelmingly dependent on renting. More than 80% of farmers without their own pumps rent on an hourly basis from their neighboring fields for irrigation, as rainfall and irrigation water in the canal are not dependable. Around 8% of those who own their own pumps still have to rent additional diesel or electric pumps due to fragmented land plots and unreliable electricity, due to voltage fluctuation.

Renting and lending of pumps has created informal water markets, which are also coping strategies for farmers where surface irrigation is inaccessible, inadequate, and unreliable , and personal investment is costly.

Informal water markets: The survey shows that in the informal water market the cost of renting pumps varies widely. For diesel pumps, including equipment, water, and fuel, the price ranges from NPR 100 to NPR 600 per hour (USD 1 = NPR 140.38),[8] while for electric pumps, the range is NPR 100 to NPR 250 per hour. Qualitative data further highlight that these **prices fluctuate across locations and depend on the availability of other rentals, relationships with pump and borewell owners, and bargaining power**. Similar localized and personalized groundwater markets have been documented elsewhere in South Asia, serving as coping mechanisms for irrigation access but also reproducing social and economic hierarchies (Palanisami, 2008; Hasanain et al., 2012;). These findings underscore how Nepal's historical land tenure system continues to shape irrigation inequities. Dalits and other marginalized groups, often land-poor or landless, traditionally worked as tenants or sharecroppers under landowners with high caste/ethnicity identity. This legacy limits their participation in groundwater economies today, reinforcing caste- and class-based social relations and exclusion in irrigation access (Aryal & Holden, 2013).

Gendered Dimension of Groundwater

Among the 803 men-headed households with boreholes and wells, 24% (196) do not own a pump. In contrast, nearly half of the women-headed households (21 out of 43; 48%) lack their own pumps. This shows that women-headed households are twice as likely to be without pumps, keeping them under water stress conditions. Spatially, these women-headed households are clustered in wards 12, 14, 15, 16, and 17. These are also areas where electrification is limited, and canal irrigation is either absent or does not provide enough water in the canal. Wards 14 and 15 have canal infrastructures but have had no water supply for years. In such areas, limited expansion of field electrification has further increased reliance on diesel pumps.

Barriers to women in pump access: While inadequate or no access to irrigation impacts all farmers, it disproportionately impacts single, Dalit, poor, and smallholder women farmers. Several factors determine women's ability to own, rent, and operate pumps. Diesel pumps are heavy and difficult to transport, making them less preferable and less practical for households with fewer human resources, such as migrant workers or children. Also, it is found that women have less engagement in the informal water market, either renting a pump or a well, than men. There are social norms that often prevent women, more specifically Terai women, from negotiating with pump owners if they are men, further reducing their bargaining power on rental rates. Also, information regarding pump subsidies frequently does not reach women, and even if it does, they are unable to tap into opportunities. This is because women are often unable to navigate the process of filling out forms. Notices are either published on websites or pasted on notice boards of municipal and ward offices. Given high gaps in literacy in the region[9], many women are illiterate or have a lower level of digital literacy and education

[8] USD 1 = NPR 140.38 (October 25, 2025).

[9] As per the municipality demographic profile, 32% of women are literate or above, compared with 45% of men.

overall. In addition, women do not regularly visit municipal and ward offices and have weaker social networks. This makes it difficult for women to access information, fill out forms, and obtain recommendations from wards.

> *One woman farmer, whose husband is a migrant worker in West Asia, mentioned that she has a borehole which was installed with support from an organization, but she is not aware of which one, and she is not able to buy a pump. When asked why, she explained that she believed only men can operate diesel pumps, and her children are small. She also lives in an area that has no field electrification. She does not rent any pumps from the neighbor and relies solely on rainwater.* – From an in-depth interview with a woman farmer from ward 10 on 22 January, 2024.

Women-headed households in wards with limited electrification face compounded disadvantages – lower rates of pump ownership, minimal or no participation in informal water markets, and when engaged, exposure to higher irrigation rental costs.

These factors make women farmers more vulnerable to high water prices and have less control over groundwater. At the same time, evidence from Nepal also shows that many women are increasingly stepping into irrigation management, particularly in farmer-managed irrigation systems, where they are helping to sustain local institutions and challenge the idea that irrigation is solely men's work (Leder et al., 2024). While some women are becoming more willing and able to join water user groups and participate in irrigation governance, this also brings added responsibility. As Shrestha et al. (2023) suggest, some women are more constrained than others by care work, limited mobility, and weak social networks. Similarly, Suhardiman et al. (2023) suggest that women's agency extends beyond labor contribution and includes negotiating institutional spaces, mobilizing social and financial resources, and redefining gender norms. In the context of groundwater management, this means that women's roles as both beneficiaries and decision-makers regarding groundwater is shaped by wider social, economic, and cultural factors that influence their access and control over it.

Subsidy Distribution

Many governmental organizations (Local Government, Agriculture Knowledge Center, Prime Minister Agriculture Modernization Project), development agencies, and non-governmental organizations provide full or partial subsidies on shallow tubewells for both individuals and the community. Likewise, the Alternative Energy Promotion Centre provides a 60% subsidy on solar irrigation pumps. These agencies have their own criteria for selecting beneficiaries, and most require a recommendation from the ward or municipality to be eligible for a subsidy. While exploring who receives subsidies, the statistical tests indicate a strong association between landholding size and subsidy receipt indicating access to subsidies varies by landholding category (Pearson $\chi^2 = 27.413$, df = 10, $p = 0.002$). Medium-scale farmers have mostly benefited from the subsidies, while the smallholders struggle to access support. A study conducted by Kafle et al. (2022) also shows inequitable distribution of subsidized solar irrigation pumps, where smallholder farmers, tenants, women farmers, and ethnic minorities were either unaware of subsidies or lacked social networks and political connections and had small land sizes. This study also found that large landholders have not accessed subsidies. This is mainly because many large landholders are not directly engaged in agriculture themselves. According to Shrestha et al. (2023), women farmers – especially single, smallholder, Dalit, and marginalized women farmers – remain excluded from irrigation subsidy programs due to weak outreach and other eligibility criteria (such as land ownership). Often, there is a tokenistic inclusion of women in subsidy programs.

Madhesi Other Caste and Hill BCN are the dominant beneficiary groups receiving subsidies for pumps and wells for groundwater extraction compared to their population size, while Terai Dalits, Terai Janajatis, and Muslims are significantly underrepresented (Figure 5).

Qualitative data also support this pattern: subsidy programs mostly benefit farmers who can co-finance investments and meet technical requirements, which are mostly medium-sized landholders. Among these groups, those with political connections and information access mostly capture the benefits. The most marginalized farmers – those disadvantaged by caste, language barriers, low income, small landholdings, or those cultivating others' land under different formal or informal contracts, such as sharecropping (*battaiya*) or lease – are unable to tap the opportunities. Further, the digital divide, language barriers, and lack of outreach prevent information from reaching these groups.

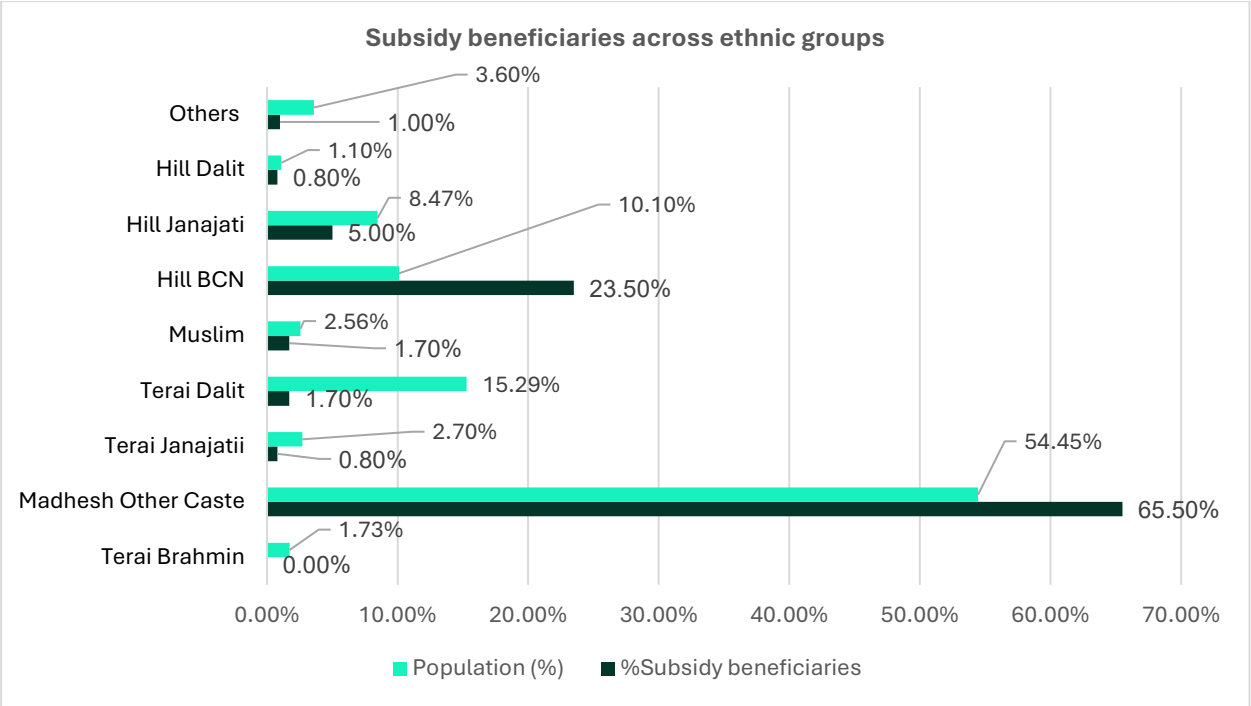

Figure 5. Relative access to subsidy for groundwater extraction by caste and ethnicity (*Source:* authors'creation)

Policy and Institutional Landscape

Nepal currently lacks a standalone policy and dedicated government agency on groundwater. While some federal sectoral policies on WASH, climate change, agriculture, wetland, and irrigation, such as the National Climate Change Policy 2019, Water Supply and Sanitation Act 2022, National Irrigation Policy 2023, National Water Resources Policy 2020 include some provisions related to groundwater, they remain incoherent, and do not clearly define the responsibilities, recharge obligations, and enforcement procedures of the multiple agencies involved in both abstraction and recharge.

Both the National Assembly and the House of Representatives endorsed the draft Federal Water Resources Bill 2025. For the first time, the bill included a dedicated chapter on groundwater, marking a significant milestone in Nepal's water governance. The bill was in the final approval process in the House of Representatives before it was due to go to the presidential certification. However, following the "Gen Z" civic movement and the subsequent dissolution of Parliament in September 2025, the bill became inactive, creating uncertainty over the formation and implementation of a new water law.

Many Province and local governments are yet to formulate their own water policies, laws, and bylaws in many areas that fall under shared responsibilities across the three tiers of government. The delay in enacting the federal law has further delayed this process, as subnational laws cannot contradict federal laws. At present, neither Madhesh Province nor Barahathawa Municipality has policies or bylaws to guide sustainable groundwater management. Existing interventions are mostly focused on extraction, with little attention to recharge. As per the Local Governance Operation Act 2017, local governments can formulate and implement their policies for local water supply, irrigation management, and watershed management (GoN, 2017).

Institutional responsibilities for groundwater management are also fragmented in Nepal. Using information from the key informant interviews and review of policies, annual plans, and progress documents, this study found that there are multiple government and non-government agencies involved in groundwater extraction projects, providing technical and financial support. Agencies such as the Groundwater Division office under the Ministry of Energy, Water Resources and Drinking Water (Madhesh Province) installs deep borewells; the Agriculture Knowledge Center under the Ministry of Land Management, Agriculture and Cooperatives of Madhesh Province installs shallow tubewells; and the Alternative Energy Promotion Center under the Ministry of Energy, Water resources and Irrigation (Federal Government) provides subsidies for installation of solar irrigation pumps. Likewise, the Prime Minister Agriculture Modernization Project also provides subsidies to install shallow tube wells (PMAP, 2024). Apart from irrigation, drinking water projects under the municipality, province, and federal government also install deep tubewells for drinking water supply. In the fiscal year 2024/25, a deep-boring project for drinking water funded by Madhesh Province started in the municipality. Yet, no mechanism exists to coordinate or monitor the number of boreholes or wells installed, where they are located, or at what depth they extract groundwater. The emphasis and budgets remain on extraction only, while recharge receives minimal or no attention and support. President Chure–Terai, Madhesh Conservation Area Program Board, and the Division Forest Office in Madhesh Province have made investments in groundwater recharge through the construction of small ponds (recharge ponds), the rejuvenation of old ponds, and the conservation of wetlands. But these efforts are isolated and lack an integrated approach (*Group discussion in dissemination workshop held in Barahathawa Municipality, 14 November 2024*).

The government's electricity subsidy for irrigation of NPR 2.25 (USD 0.02) per unit has incentivized a shift from diesel to electric pumps (NEA, n.d) .While this reduces farmers' irrigation costs, improves productivity, and lowers carbon emissions, without parallel policies on recharge and monitoring, the shift risks accelerating groundwater depletion, delivering short-term economic benefits at the expense of long-term sustainability.

Current water policies do not adequately address the needs of women, smallholders, tenants, and marginalized groups who remain excluded from the benefits and decision-making (Clement et al., 2012; Khadka et al., 2021). Although policies acknowledge gender equality, social inclusion, and equity concerns, they fall short of addressing deeper structural barriers such as entrenched gender norms and social norms, and unequal power dynamics that continue to limit women and marginalized groups' access to resources, technologies, and benefits (Khadka et al., 2024). A study conducted by KC et al. (2025) which applies a stakeholder-driven groundwater governance framework across technical, operational, legal, institutional, and cross-sector policy coordination in Barahathawa shows that the transitional governance system is constrained by weak technical capacity, legal ambiguity, and fragmented coordination in groundwater governance.

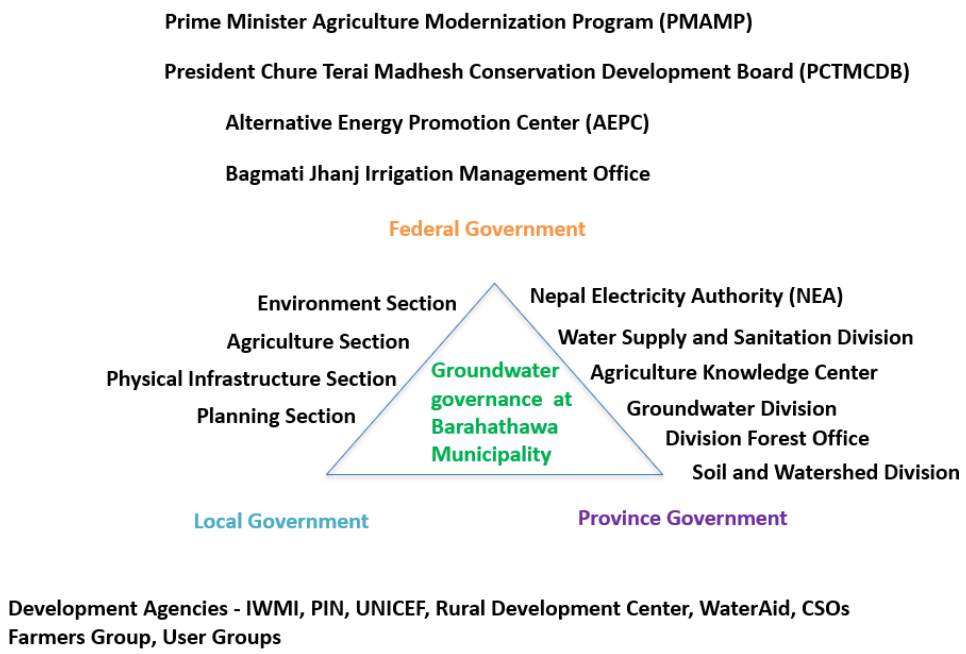

Figure 6. Institutional mapping of agencies concerned with groundwater use and recharge in Barahathwa Municipality, Sarlahi District (*Source:* authors'creation)

Conclusion

Barahathawa Municipality stands at a critical juncture in its groundwater governance journey. While electrification and pump subsidies have expanded irrigation access, they have also deepened social and gender inequities. The lack of coherent policies, fragmented institutional roles, and minimal recharge efforts pose risks to long-term water security. Addressing these challenges requires a shift from only abstraction-focused interventions to sustainable, inclusive, participatory, and collaborative groundwater governance. The study conducted by KC et al. (2025) in the municipality also underscores that groundwater sustainability hinges on bridging existing silos in governance, centering community agency, and aligning sectoral priorities through a nexus lens. By empowering marginalized groups, institutionalizing multistakeholder platforms, and investing in recharge and data systems, Barahathawa can lead the way in transforming groundwater management in Nepal's Terai region.

Recommendations

The following are some recommendations from the research:

- **Formulate local policies and bylaws.** The municipality needs to establish clear, enforceable local policies for sustainable groundwater extraction and recharge. Moreover, local governments hold primary responsibility and are at the frontline for watershed management, directly managing local drinking water and irrigation as mandated by the Constitution of Nepal 2015. The federal and provincial governments should provide policy and technical guidance to strengthen the capacities of local governments in fulfilling these mandates (Khadka et al., 2021).
- **Strengthen multistakeholder platforms as a governance mechanism for integrated decision-making in groundwater management.** Municipality-led multistakeholder platforms can bridge groundwater governance gaps by convening diverse stakeholders for integrated planning and inclusive decision-making across the agriculture, energy, ecosystem, and water sectors. Institutionalizing and operationalizing the existing multistakeholder platform is essential to strengthen coordination, cooperation, transparency, and integrated planning with dedicated resources for groundwater recharge and sustainable extraction (KC et al., 2025).
- **Ensure participatory groundwater management.** Experience from many countries shows that there is no single solution, and top-down state control or formal laws and formal institutions are not enough for effective groundwater management (Meinzen-Dick & Bruns, 2024). There should also be participatory groundwater management models where local people, users, and community-based organizations are also actively engaged in planning and decision-making along with government institutions and private sector actors.

- **Strengthen citizen science and local database.** A citizen science network, where trained local youths collect and report groundwater data, can enhance monitoring, and empower communities with knowledge. The municipality should expand the existing citizen scientist network and institutionalize a local groundwater database for storing, visualizing, and using real-time data in planning. A centralized digital database, maintained collaboratively by local, provincial, and federal agencies, would facilitate evidence-based decision-making and adaptive management.

- **Target subsidies for unreached population.** Current subsidy schemes reinforce social hierarchies. Therefore, local government should ensure a one-door policy in beneficiary selection and ensure those who need or are targeted get the subsidy. Subsidy programs should also acknowledge that women are a heterogeneous group with diverse socio-economic backgrounds influencing their access, participation, and decision-making. Local government should therefore critically assess which farmers, and which women, actually receive and benefit from these subsidies. Currently, province and federal government subsidy programs require recommendations from the local government, but this is not enough. Province and federal programs should also engage with local government in beneficiary selection, not only in providing recommendations. Municipalities need to ensure adequate outreach and a simplified application process and help desks to assist with the application process.

- **Advance leadership and technical capacity of women and marginalized groups.** Quotas alone are insufficient to ensure meaningful participation of women as well as marginalized communities. Local policies should invest in capacity building and mentorship, recognizing and strengthening existing social networks to enhance technical skills and leadership (Suhardiman et al., 2023; Khadka et al., 2023). Recognizing and strengthening women's informal networks can help amplify their voices in decision-making spaces. Embedding gender equality and social inclusion principles across planning, budgeting, and monitoring can transform governance from tokenistic inclusion to substantive participation in natural resources management.

- **Provide access to credit.** Subsidies are limited and often inaccessible to the poorest, women, and other marginalized groups. Women, smallholders, and marginalized farmers cannot invest in groundwater as they are unable to make an upfront investment. Therefore, local governments should coordinate with cooperatives, microfinance institutions, and banks to create accessible credit schemes for these groups. Small loans or revolving funds for construction, pump purchase, or recharge structures can promote groundwater equity and sustainability. Experiences from African countries such as Ethiopia show how public–private partnership models can help to adopt irrigation technologies and expand irrigation when supported by enabling policies, blended financing, and risk mitigation mechanisms (Seyoum et al., 2025).

- **Promote conjunctive use.** Integrating surface and groundwater use can reduce over-extraction pressures and promote sustainable use. The municipality, in coordination with irrigation agencies, should promote conjunctive use. This approach not only optimizes resource utilization but also supports climate resilience by balancing recharge and withdrawal cycles.

Invest in recharge and nature-based solutions. Recharge initiatives should be mainstreamed into municipal development plans. Investments in ponds, percolation pits, and restoration of wetlands and traditional water bodies can enhance aquifer replenishment while offering ecosystem co-benefits. Partnerships with local communities, schools, public health centers, and farmer cooperatives can ensure long-term maintenance and sustainability. Integrating recharge programs with land-use planning will also prevent further encroachment on natural recharge zones.

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