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Groundwater Resources Exploitation in Nepal: Challenges, Opportunities and Technological Interventions

Surendra Raj Shrestha[1]* and Churna Bahadur Wali[2]

[1]Groundwater Resources and Irrigation Development Division, Kavre, Bagmati Province
[2]Ministry of Energy, Water Resources and Irrigation, Lumbini Province
**Corresponding author's e-mail: shree.surendraraj@gmail.com*

ABSTRACT

In Nepal, the overall groundwater potential is considerable, particularly in the Terai region. There is also significant scope for expanding groundwater utilization in the river valleys of the hilly and mountainous areas. Artificial groundwater recharge has not yet been implemented in Nepal. If introduced, it could play a vital role in replenishing the depleting aquifers, thereby contributing to the sustainable management and long-term utilization of this critical resource. The technical innovations in groundwater extraction have increased resource utilization. Nevertheless, numerous challenges persist in ensuring the sustainable management of this vital resource. Some of the major challenges include unregulated extraction, lack of a regulating governing authority, overlapping institutional responsibilities, and the adverse effects of climate change. Recent government higher investment and support provide a path forward to overcoming these challenges. This paper highlights the challenges, opportunities and technological interventions required for sustainable groundwater management in Nepal.

Keywords: *Groundwater; recharge; monitoring; sustainable management; challenges*

INTRODUCTION

Nepal's water supply system is highly dependent on groundwater resources to meet the demands of agriculture, domestic consumption, and industrial activities (Pathak 2017). It is reported that total renewable groundwater resource is approximately 13,215 Mm^3 (DWRI 2024). The Terai area which is said to food basket of the country possesses huge groundwater reserve. Groundwater is the primary source of water for communities in this region. However, rapid urban development, increasing agricultural demand, and industrial expansion have led to uncontrolled and unmonitored groundwater extraction. Consequently, declining water tables are posing serious threats to the long-term sustainability of this vital resource. This is even more true in the Kathmandu Valley where groundwater reserve is reduced significantly due to overextraction (Gautam and Prajapati 2014). It has created doubt about its long-term availability and viability of the resource. Moreover, climate change is impacting natural recharge, resulting in reduced availability of dependable groundwater particularly in shallow aquifer even in monsoon. The absence of dedicated national groundwater authority and regulatory structures intensify these issues, resulting in disjointed management and suboptimal use of groundwater resources

CHALLENGES OF GROUNDWATER EXPLOITATION IN NEPAL

At the moment in the country, groundwater is being withdrawn unregulated, particularly in Kathmandu Valley, where the demand exceeds the natural recharge (Pandey et al. 2010; Gautam and Prajapati 2014) . Excessive extraction of groundwater has led to falling water tables and higher pumping cost. Nepal does not have an extensive licensing and metering system, allowing private tubewells, industries and agricultural users to extract groundwater without consideration of its adverse impacts. The Department of Water Resources and Irrigation, Water Supply and Sanitation Department, provincial and local governments share overlapping duties, resulting in ineffective coordination and implementation of groundwater development projects. The absence of a legal framework specifically for groundwater leads to poor management and depletion of resources. Climate change is modifying monsoon patterns with unpredictable rainfall which have caused increasing dependence on groundwater (Kaini et al. 2022). In the hilly areas, the hydrogeology poses significant challenges. Lifting water from river valleys is difficul because the distribution network becomes long and the energy requirement is also relatively high. Furthermore, Nepal lacks a unified groundwater monitoring system, complicating efforts to monitor depletion rates, quantity extraction and recharge efficien . Ultimately, Nepal is experiencing a significant decline in its valuable groundwater resources as a result of ineffective and inefficient utilizati

OPPORTUNITIES FOR GROUNDWATER DEVELOPMENT IN NEPAL

Despite these challenges, Nepal retains substantial unexploited groundwater resources, particularly in the Terai region and inter-mountain valleys. The Irrigation Master Plan has estimated USD 997 million to increase irrigated land by 318,000 hectares using groundwater (DWRI 2024). Likewise, the document mentions that each extra hectare irrigated with groundwater in Terai could boost the district's production value by USD 2,044. The aquifers systems of Nepal can sustain groundwater driven

agriculture which will decrease dependence on precipitation. Metering systems, and advanced irrigation technologies are essential tools for sustainable groundwater management of Groundwater. The involvement of Water User Associations and cooperatives in groundwater can play a significant role in groundwater conservation and equitable distribution at the community level. So far, Nepal has lacked effective conjunctive use of surface water and groundwater in irrigation. Conjunctive use can provide a reliable year-round irrigation and makes agriculture resilient to climate change by minimizes the effect of droughts and unpredictable rainfall. In Terai, one of the main reasons for the defunct groundwater irrigation systems is the high cost of pumping. Conjunctive use can reduce the annual irrigation cost by lowering energy consumption and pumping cost by using surface water available during the wet season.

TECHNOLOGICAL INTERVENTIONS FOR SUSTAINABLE GROUNDWATER USE

In order to increase sustainable groundwater management a proper extraction, recharge and monitoring techniques must be implemented. The focus should be on increasing the recharge of groundwater for which managed aquifer recharge like recharge wells, percolation ponds, and check dams should be applied. So far in the country artificial recharge of aquifer is nonexistence. In the river valleys of the hilly region, Riverbank Filtration systems provide a cost-effective solution for water extraction. Solar energy is a viable alternative of energy for lifting groundwater in the areas where electricity supply is erratic or absent. Modern irrigation methods, such as drip irrigation combined with soil moisture sensors and automated water meters, can help curb excessive groundwater use in agriculture. Additionally, hydraulic ram pumps, which utilize the natural kinetic energy of flowing water to lift groundwater without electricity, offer a practical alternative for farming communities in hilly regions.

POLICY RECOMMENDATIONS AND CONCLUSIONS

Adaptation of robust policy frameworks, technological advancements, and community driven conservation approaches is the need of time for the sustainable management of groundwater resources. A national level groundwater monitoring and management institution is necessary for overseeing groundwater extraction, implementing licensing and metering systems, and facilitating coordination among various government bodies. A separate Groundwater Act must be formulated for proper management and also to establish groundwater ownership, impose extraction restrictions, and control industrial pollution. Compulsory metering of groundwater uses must be implemented for all users to avoid over-extraction and wasteful usage. Groundwater recharge projects should be carried with no delay anymore which will help in maintaining and recovering water level in aquifers. For equitable and sustainable utilization of groundwater resources community-based groundwater management systems involving local cooperatives and Water User Associations should be adopted. Installation of modern groundwater monitoring systems, hydrogeological studies, and experimental initiatives on sustainable groundwater extraction should be carried more intensively which in turn will yield improved information for decision-making and long-term resource management.

In conclusion, there are considerable difficultie in sustainable management of groundwater. At the same time there is ample opportunities for achieving water security through use of groundwater due to the technological advancements, policy reforms, and proper investment. Groundwater utilization can be optimized, and its resilience to climate change and potential future water shortages can be enhanced through the incorporation of modern monitoring technologies, the strengthening of governance frameworks, and the promotion of efficien water use. A harmonized multi-sector strategy that includes government agencies, local communities, and private sector is need of the time. Scientific planning, regulatory body, and involvement of community in conservation efforts will be crucial for sustainable uses and safeguarding of groundwater resources.

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