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Research Article

Assessing Groundwater Conservation Barriers for Farmers Through Quantitative Ranking Methods

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Abstract

Despite having large freshwater reserves, India is experiencing a serious and worsening water problem, especially in the agricultural sector, which uses around 85% of the country's water resources. This study methodically looks into the obstacles that farmers face while implementing groundwater conservation techniques. Data were collected from 180 farmers in water-intensive areas utilizing a mixed-methods approach that included key informant interviews, focus groups, and structured surveys. The respondents' perceptions of the restrictions were ranked using two analytical tools: the Rank-Based Quotient (RBQ) approach and Garrett's Ranking Technique. The study identified important issues in five areas: economic limits, ecological and resource constraints, technical accessibility, governance support, and demographic and livelihood-related considerations. Intergenerational knowledge gaps (RBQ 93.19), reliance on conventional irrigation techniques (Garrett score 71.50), market volatility (Garrett score 68.50), unpredictable weather patterns, and a lack of regulatory incentives (RBQ 91.60) were among the main obstacles. In order to assist sustainable groundwater management in Indian agriculture, the results highlight the critical need for comprehensive policy reforms, improved agricultural extension services, and farmer-centric support networks.

1. Introduction

Water, a fundamental resource for life, sustains ecosystems, economies, and human health. In agriculture, it plays a vital role, consuming nearly 70% of global freshwater withdrawals (FAO, 2020). Yet, freshwater constitutes only 2.5% of Earth's water resources, with the majority locked in glaciers and groundwater (USGS, 2021). India, home to 1.4 billion people, faces acute water stress despite an extensive river basin system. Although the country's average annual water availability is around 1,999.20 billion cubic meters (BCM), only 1,123 BCM is utilizable due to geographic and temporal variability (CWC, 2021). Alarmingly, per capita water availability has fallen from 5,178 cubic meter per year in 1951 to just 1,441 cubic meter per year in 2015, with projections of 1,140 cubic meter per year by 2050 (NITI Aayog, 2018). Concurrently, water demand is expected to rise to 1,447 BCM by 2050 (NITI Aayog, 2018). Another report projects that by 2050, total water demand could range from 973 BCM in a low-demand scenario to 1,180 BCM in a high-demand scenario (NCIWRD, 2019).

Agriculture, India's largest water-consuming sector, is also the largest user of groundwater. States like Punjab and Haryana extract groundwater at over 100% of recharge levels, exacerbating aquifer depletion (CGWB, 2017– 2018). Contributing factors include subsidized electricity (Singh, 2012; Baweja et al., 2017; Dubash and Navroz, 2007), inefficient irrigation systems (Chaudhuri et al., 2021; Kalli et al., 2024)), and limited awareness (Shah et al., 2008; Rodell et al., 2009). This study investigates the major constraints hindering the adoption of sustainable groundwater conservation practices among farmers, providing evidence-based recommendations for policy and practice.

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2. Materials And Methods

Sampling Procedure

The study was conducted in Jaipur district, Rajasthan, with a specific focus on over exploited groundwater blocks characterized by intensive agricultural activity and high dependence on groundwater resources. To ensure representative coverage, six villages were purposively selected from these overexploited blocks based on groundwater dependency, cropping intensity, and irrigation practices. From each selected village, a sample of 30 farmers was randomly chosen, resulting in a total sample size of 180 respondents. The sample population comprised farmers who primarily rely on tube wells and canal irrigation for agricultural operations. Data were collected using a mixed-method approach, including structured questionnaires, focus group discussions (FGDs), and key informant interviews to capture both quantitative and qualitative insights into the constraints faced in adopting groundwater conservation practices.

Analytical Methods

Garrett's ranking technique

To analyze the constraints faced by farmers for groundwater conservation measures, Garrett's Ranking Technique was employed. This technique is very a popular method in research to rank constraints/factors based on respondent's preference. A set of farmers were asked to rank a set of indicators related to irrigation constraints. These rankings were converted into scores using the formula

$$Percent\ position = R_i - 0.5/N \times 100$$

Where; R_i = Rank assigned by the respondents N = Total number of constraints ranked.

Rank-based quotient (RBQ)

For this paper, respondents were asked to rank the constraints they encountered in adopting groundwater conservation practices. In parallel, they were also requested to rank suggested measures that could potentially enhance groundwater resource management. The Rank- Based Quotient (RBQ) values were then computed for each constraint and suggested measure, with higher RBQ values reflecting greater perceived severity or priority. This quantitative ranking allowed for a systematic, data-driven prioritization of the most critical barriers and actionable solutions as perceived by the farming community. The RBQ was calculated using the following

$$RBQ = \frac{F_i \times (N + 1 - R_i)}{N \times F_i} \times 100$$

where Fi = Frequency of respondents assigning a particular rank to a constraint, Ri = Rank assigned to the constraint, N = Total number of ranks.

3. Results And Discussion

Demographic and Livelihood Cons- traints

Among all constraints, generational knowledge gaps ranked highest (Garrett Score: 73.20; RBQ: 93.19), highlighting a disconnect between traditional wisdom and modern practices. Younger generations are increasingly disengaged from farming, leading to a decline in indigenous groundwater knowledge. Similarly fragmented landholdings (Garrett Rank: II) complicate the implementation of collective water-saving technologies and irrigation systems.

Migration and labor shortages further compound the issue. The data showed limited family support and shortage of skilled labor were notable constraints, especially in regions where youth migrate to urban areas. This demographic shift reduces the availability of active farm labor and increases reliance on costly alternatives.

Technology and Accessibility Cons- traints

A key insight from this category is the over- reliance on traditional irrigation methods (Garrett Score: 71.50; RBQ: 82.50). Many farmers are skeptical or unaware of modern conservation technologies, and this hesitance stifles innovation. Lack of awareness and limited access to advanced equipment followed closely, pointing to significant extension and education gaps in agricultural outreach programs.

Interestingly, insufficient hands-on training and inadequate customization of technologies were rated lower, but they remain critical barriers to long-term adoption. These findings suggest that while some infrastructure exists, it is underutilized due to knowledge and capacity issues.

Ecological and Resource-Based Constraints

Ecological stressors were among the most urgent. Unpredictable weather patterns ranked highest (Garrett: 74.50; RBQ: 91.60), reflecting the real-time impact of climate change on farming operations. Farmers cited erratic rainfall, extended dry spells, and increasing temperatures as major disruptors. Closely related was groundwater depletion (Rank II), which signals the urgent need for aquifer recharge efforts and regulated extraction. Soil degradation and land fragmentation were also significant, reinforcing the need for integrated land and water management policies.

Economic Constraints

Economic factors emerged as powerful disincentives. Market instability and low profitability ranked as the most pressing constraint (Garrett Score: 68.50; RBQ: 78.64).
Farmers hesitate to invest in conservation methods when returns are uncertain or delayed. High initial costs and lack of incentives are further deterrents. While many farmers recognize the long-term benefits of water conservation, the absence of short-term financial relief prevents them from making such investments. Limited access to credit and loans, though ranked lower, still poses challenges for marginal and smallholder farmers.

Governance and Support System Constraints

The most significant constraint identified was the absence of rewards for water conservation, with the highest Garrett Score (75.60) and RBQ Score (81.64), highlighting the critical need for incentives to promote sustainable practices. Cumbersome subsidy application processes ranked second (with Garrett Scores 65.42 and RBQ value 72.00), reflecting the challenges farmers face in accessing financial support.

4. Conclusion

A comparative analysis across all five dimensions; demographic, technological, ecological, economic and government support reveals that knowledge gaps, ecological uncertainty, economic insecurity, and institutional inefficiencies collectively form a complex web of constraints hindering groundwater conservation among farmers. The alignment between RBQ values and Garrett's rankings further reinforces the reliability of the identified priorities, providing a robust basis for strategic planning. These insights offer a clear roadmap for targeted interventions: strengthening capacity building and farmer training programs to bridge knowledge deficits; implementing incentive-based schemes to alleviate economic constraints; developing climate-adaptive policies to buffer ecological risks; and promoting integrated governance frameworks to enhance institutional coordination and streamline support mechanisms.

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