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GROUNDWATER DEPLETION AND SUSTAINABLE MANAGEMENT STRATEGIES IN THE SEMI-ARID SIKAR DISTRICT OF RAJASTHAN

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Abstract

Groundwater is severely strained by the climate and hydrology of Sikar district in the semi-arid Shekhawati region of northeastern Rajasthan. Although the area receives an average of 500–560 mm of rain per year, the majority of which falls during the southwest monsoon, high evaporation rates, frequent droughts, and erratic rainfall patterns severely restrict natural groundwater recharging. Because surface water is scarce in the region, groundwater is necessary for residential, agricultural, and drinking purposes. A growing imbalance between recharge and demand has resulted from this increased dependency and over-extraction, endangering ecological stability and livelihoods. To solve these problems and ensure long-term water security, sustainable and integrated water management strategies are crucial. Rainwater collection, aquifer recharge programs, efficient irrigation systems, and community-based water governance are crucial strategies to boost resilience against recurring water scarcity. (Dhetarwal, Dhyani, & Singh, 2013; Singh & Rathore, 2015).

Introduction

The semi-arid Shekhawati region, which includes the northeastern Rajasthani district of Sikar, is especially susceptible to groundwater stress. The majority of the district's 500–560 mm of annual rainfall occurs during the southwest monsoon season, which runs from June to September.

However, natural recharging is severely limited by high rates of evaporation, frequent droughts, and erratic rainfall. Groundwater is required for residential, agricultural, and drinking purposes due to the scarcity of surface water supplies. In recent decades, groundwater supplies have been severely strained by the growth of agricultural supported by tube well irrigation. Improved mechanization and the use of high-yielding agricultural varieties have led to an increase in water consumption. During the rabi season, farmers typically produce water-intensive crops like wheat and mustard in addition to cash crops like vegetables, which require a lot more groundwater than traditional millets and pulses. (CGWB, 2024; Indian Streams Research Journal, 2013).

This over-reliance has detrimental effects. Deeper drilling and higher pumping costs are a result of the several-meter drop in groundwater levels. The quality of the water has decreased due to high amounts of salt, nitrate, and fluoride that are harmful to human health and limit the acceptability of groundwater for drinking. Irrigation stress further reduces agricultural productivity and farmer livelihoods in addition to ecological imbalances such reduced soil moisture, vegetation loss, and weakened ecosystem resilience. Singh and Sharma (2017).

Groundwater depletion in the Sikar district is therefore a social and environmental issue. The integrated and localized solutions required to solve this issue include rainwater collecting, artificial recharge structures, crop diversification, promotion of micro-irrigation technologies, stricter regulatory frameworks, and active community involvement. Together, these initiatives can help the district manage its groundwater in a sustainable and resilient manner. (Dhetarwal and others, 2013).

Study Area – Sikar

Sikar district is located in the semi-arid Shekhawati region, which is extremely susceptible to water stress, in northeastern Rajasthan, India. Alluvial deposits, aeolian sands, and worn or fractured hard rock formations like schist and gneiss define the district's geological makeup. The hydrogeological processes of the area are greatly influenced by this geological framework. Although there is considerable possibility for aquifer growth in alluvial tracts, overall recharge is still severely limited because of high evapotranspiration rates and little rainfall. CGWB (2017).

The topography of Sikar is mostly composed of level plains with isolated hillocks and sand dunes. With hot summers, cold winters, and wildly fluctuating monsoon rainfall that averages 500–560 mm annually, the area has a semi-arid climate. Rainfall variability, recurrent droughts, and a scarcity of surface water resources all lead to issues with groundwater recharge and water retention, which makes aquifers more necessary for home and agricultural uses.(Singh &Rathore, 2015).

The bulk of the workforce in Sikar is employed in agriculture, which is the foundation of the city's economy. Cluster beans (guar), mustard, wheat, barley, green gram (moong), pearl millet (bajra), and other crops are common. Farmers rely nearly entirely on groundwater drawn by tube wells and drilled wells to maintain agricultural production because of the semi-arid climate and lack of canal or surface water irrigation. Because of this, groundwater is currently the district's main irrigation source. (Indian Streams Research Journal, 2013).

However, the widespread use of groundwater for both traditional and automated irrigation methods has raised serious concerns about the sustainability of aquifers. Nearly every block in Sikar is classified as "over-exploited," which means that extraction consistently exceeds natural recharge, according to hydrogeological assessments carried out by the Central Ground Water Board (CGWB). Groundwater tables have significantly dropped and water quality has deteriorated as a result of excessive levels of fluoride, nitrate, and salinity endangering both agricultural production and drinking water security. (Dhetarwal et al., 2013; CGWB, 2024).

According to earlier research, the district's groundwater levels have been continuously dropping, primarily as a result of unsustainable irrigation practices. These findings underscore the vital need for comprehensive groundwater management strategies that employ rainfall collection, artificial recharge techniques, micro-irrigation systems, and crop diversity.

Community-based water budgeting, hydrogeological modeling, and ongoing monitoring are essential for capturing the dynamic nature of groundwater systems, notwithstanding the useful information provided by current research. This study attempts to ensure the sustainable management of groundwater resources in the Sikar region of Rajasthan by integrating field-level observations, synthesizing secondary data, and proposing context-specific strategies. (Dhetarwal, Singh, and Dhyani, 2013).

Causes of Groundwater Depletion in Sikar

Over-extraction for Irrigation

One of the primary reasons of groundwater depletion in Sikar is excessive pumping for agricultural irrigation. Groundwater is the main source of irrigation because rainfall is erratic. Due to their widespread use of drilled and tube wells, farmers often extract more water than the natural recharge capacity. Water levels sharply decline as a result of increased demand brought on by the widespread usage of wheat, mustard, and cash crops. Almost all of the blocks are overused, and excessive pumping has contaminated them with fluoride and nitrate, which is harmful to human health and agriculture.

Geological Factors

The Sikar district's geology is primarily composed of aeolian sands, alluvial deposits, and hard rock formations including schist and gneiss. The low to moderate water-holding and recharge characteristics of these layers limit aquifer replenishment. Shallow aquifers can dry up rapidly, but deeper aquifers are contaminated by nitrate, fluoride, and salt. Because of the geological context, the district's groundwater resources are therefore scarce and vulnerable.

Agricultural Practices

Agriculture is mostly dependent on groundwater due to the scarcity of surface water. Farmers mostly use tube wells and dug wells to irrigate crops like wheat, mustard, bajra, moong, and guar. Due to the shift to water-intensive crops including wheat, mustard, and vegetables as well as traditional flood irrigation methods, groundwater use has exceeded its natural recharge. Because of this over-reliance, water levels have been continuously dropping, and problems with water quality, such as fluoride and nitrate toxicity, have emerged. Sustainable practices like crop diversification and micro irrigation are needed to reduce the pressure on groundwater.

Climate Change and Groundwater Recharge

Due to changes in rainfall and recharging patterns brought on by climate change, groundwater depletion has gotten worse. Rising temperatures, erratic monsoons, and intermittent droughts have decreased the district's ability to effectively recharge aquifers, even though it receives 500–560 mm of rainfall annually. While heavy, short rains promote runoff rather than percolation, prolonged dry spells increase the significance of groundwater. Water tables continue to decline because natural recharging cannot keep up with the increased exploitation.

Land Use Changes and Groundwater Levels

Changes in land use have been one of the primary drivers of groundwater depletion. Traditional water features including johads, ponds, and baoris have been neglected, encroached upon, or silenced, which has reduced the district's capacity for natural recharge. Concurrently, the rapid growth of cities and built-up areas has created impermeable surfaces, such as housing colonies and roads, which increase runoff and prevent rainfall from penetrating the ground. In terms of agriculture, the expansion of irrigation and the transition from traditional low-water crops like millets and pulses to water-intensive crops like wheat, mustard, and vegetables have led to excessive groundwater extraction. The proliferation of tube wells and flood irrigation have accelerated the depletion of aquifers.

When taken as a whole, these land use changes have decreased groundwater levels and deteriorated water quality, causing an increase in fluoride, nitrate, and salinity pollution issues throughout the area.

Technological Factors and Groundwater Depletion

Technological developments have had a major impact on groundwater depletion. Farmers could now readily access deeper aquifers thanks to the development of deep tube wells, submersible pumps, and mechanized drilling. In the past, irrigation relied on traditional ponds, wells, and rainwater collection systems, which ensured limited extraction. Over-extraction over the natural recharge capacity is promoted since large-scale pumping is now more accessible and affordable thanks to the widespread usage of electric and diesel-powered pumps. Aquifers are currently under unsustainable strain even though agricultural productivity has increased as a result. Additionally, because water-efficient technologies like drip and sprinkler irrigation are being adopted slowly, traditional flood irrigation wastes a significant amount of extracted water. Inadequate groundwater level monitoring and loose drilling depth and pumping capacity limits have exacerbated the problem. Therefore, rather than encouraging sustainable management, technology has accelerated groundwater depletion and quality degradation in the Sikar area.

Consequences of Groundwater Depletion in Sikar

Lowering of Water Tables

Due to our excessive reliance on groundwater for both residential and agricultural purposes, the Central Ground Water Board (CGWB) has designated most of the district's blocks as over-exploited, which means that extraction greatly exceeds natural recharge. Farmers' heavy reliance on tube wells and submersible pumps, which draw water from deeper aquifers, is causing groundwater levels to gradually decline, forcing them to build deeper bore wells and spend more money on pumping. The situation is made worse by decreasing rainfall, unpredictable monsoons, and a lack of recharging structures.In addition to decreasing groundwater availability, this irresponsible withdrawal raises the possibility of aquifer drying, increasing the district's vulnerability in terms of agriculture and drinking water supplies.

Agricultural Impacts

Agriculture is the main source of groundwater depletion since farmers almost exclusively use tube wells for irrigation. Conventional flood irrigation and the shift to water-intensive crops including wheat, mustard, and vegetables have led to over-extraction. This careless usage of groundwater lowers the water table every year and leads to quality issues like fluoride and nitrate pollution, endangering the safety of farming and drinking water.

Socioeconomic Consequences

Socioeconomic repercussions that impact the general well-being of the community as well as rural livelihoods. Farmers' financial burden is increased as a result of having to make significant investments in powerful submersible pumps and deeper bore wells due to the ongoing fall in water tables. Due to inadequate irrigation, small and marginal farmers frequently have crop failures, which lowers agricultural output, lowers household incomes, and increases debt. Lack of drinking water has also become a major problem, forcing families especially those with women and children to spend a lot of time getting water from far-off sources, which takes away from time spent on constructive activities like schooling.

Due to these circumstances, a large number of rural households experience financial hardship and are compelled to migrate to cities in pursuit of employment. Groundwater depletion is not only an environmental problem but also a significant socioeconomic burden for the district, since it has exacerbated poverty, social inequality, and rural-to-urban migration over time.

Sustainable Management Strategies for Groundwater in Sikar

Water Conservation Practices

Water conservation has always been crucial to daily living in the Sikar district due to its semi-arid climate and low rainfall. In the past, groundwater was replenished and rainfall was stored in check dams, ponds, kunds, baoris, and johads. These structures were required to keep the balance between recharge and water use. In response to the increasing groundwater depletion in recent years, local communities and government agencies have promoted rainfall collection structures, rooftop harvesting, recharge wells, and farm ponds to raise groundwater levels. As part of watershed and rural development initiatives, check dams and percolation tanks are being constructed to enhance recharging. To increase irrigation efficiency and save water, some farmers have also begun to use sprinkler and drip irrigation systems. Despite these initiatives, the advantages of conservation efforts are typically outweighed by population pressure, excessive water extraction for agriculture, and growing water demand.

Localized Policy

Because of the region's distinctive agricultural, geological, and meteorological characteristics, localized approaches are crucial. District-specific problems like excessive extraction, inadequate recharge, and problems with water quality like fluoride pollution are occasionally overlooked by typical state or federal standards. Limiting bore well digging, encouraging crop diversification toward less water-intensive crops, and providing incentives for micro-irrigation methods like drip and sprinkler irrigation should be the main objectives of a Sikar-specific policy.

Community-based water management organizations may be given the power to oversee groundwater extraction and maintain traditional recharge infrastructure such as ponds, baoris, and johads. Additionally, policies should encourage rainwater collection on farms and in homes, link farmer subsidies to the implementation of water-efficient practices, and support watershed development programs. A well-thought-out localized strategy can help restore equilibrium between water supply and demand and guarantee the district's long-term groundwater sustainability by fusing traditional knowledge with contemporary management techniques.

Community Engagement

Community engagement is one of the finest approaches for proper groundwater management in the Sikar district. Through traditional systems like johads, baoris, and ponds, people have historically managed water jointly, ensuring water supply and recharging groundwater. As water stress increases, community involvement is now required in rainwater collecting, recharge structure maintenance, and watershed development. Farmers' associations can play a significant role in promoting crop diversity and micro irrigation methods to reduce groundwater use.

Self-help groups and local organizations can keep an eye on bore well usage and encourage conservation. Local action can be strengthened by including women and young people in water committees and awareness campaigns. When individuals take responsibility and get government support, groundwater management in the Sikar district becomes more practical, inclusive, and sustainable for future generations.

Technological Solutions

Technological solutions have the potential to greatly enhance sustainable groundwater management in the Sikar district. Micro-irrigation techniques like drip and sprinkler irrigation can significantly minimize water wastage in agriculture, which uses the most groundwater. Soil moisture sensors, GIS-based monitoring, and water meters can all help monitor water consumption more efficiently and prevent over-extraction.

By constructing recharge wells, percolation tanks, and check dams utilizing modern techniques, rainwater percolation and groundwater recharge can be enhanced. Solar-powered pumps and smart controllers can control pumping hours and minimize needless extraction. Policymakers and farmers can gain a better understanding of groundwater levels and trends by combining satellite data with remote sensing. By combining these modern technologies with traditional techniques, the Sikar district can develop a more efficient and sustainable groundwater management system. By combining these modern technologies with traditional techniques, the Sikar district can develop a more efficient and sustainable groundwater management system.

Conclusion

The Sikar district example highlights the serious problems with water security in semi-arid areas like Shekhawati. The very seasonal and erratic nature of precipitation, significant evaporation losses, and sporadic droughts impede the effective recharge of groundwater aquifers, despite the region receiving 500–560 mm of rainfall annually. The demand for groundwater for residential, agricultural, and drinking uses is increased by insufficient surface water sources, which speeds up extraction beyond acceptable bounds. The district is facing extreme groundwater stress as a result of this widening gap between natural recharge and demand, endangering ecological stability and livelihoods.

Integrated and sustainable water management strategies, including as community-based water governance, efficient irrigation techniques, aquifer recharge programs, and rainwater collection, are required to tackle this challenge and ensure the region's long-term resilience against water scarcity.

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