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Identifying Points of Rainwater Recharge in Rural Areas using Remote Sensing (RS), Geographic Information Systems (GIS), and Field Surveys in Debari, Udaipur, Rajasthan

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Abstract: Water scarcity is a significant challenge in rural areas, especially in semi-arid regions like Debari, Udaipur in Rajasthan, India. Effective rainwater recharge management can help address this issue. This review examines the use of Remote Sensing (RS), Geographic Information Systems (GIS), and field surveys to identify potential rainwater recharge points. These techniques provide comprehensive data for mapping, analysing, and implementing sustainable groundwater recharge strategies. The paper focuses on methodologies and case studies in the region, discussing the potential impacts on water conservation and agricultural sustainability. One of the most effective ways to address water scarcity in such regions is through rainwater harvesting and groundwater recharge. To identify potential recharge points, advanced technologies such as Remote Sensing (RS) and Geographic Information Systems (GIS) can be used in conjunction with traditional field surveys. These technologies provide valuable insights into the physical characteristics of the terrain, soil, land use patterns, and drainage systems, helping to locate areas where rainwater can be harvested and stored for future use.

Keywords: Remote Sensing, GIS, Rainwater recharge, Surveying, Rural region.

1. INTRODUCTION

Debari, a rural area in Udaipur, Rajasthan, faces acute water shortages due to erratic rainfall, over-extraction of groundwater, and inadequate rainwater harvesting systems. Identifying suitable locations for rainwater recharge can significantly alleviate these problems. Traditional methods of identifying recharge zones, such as field surveys, are labor-intensive and localized. However, with advancements in Remote Sensing (RS) and Geographic Information Systems (GIS), it is now possible to gather detailed spatial data that helps identify recharge zones more effectively. This review aims to explore how the integration of RS, GIS, and field surveys can provide a comprehensive solution to enhance groundwater recharge in rural regions. By combining modern technology (RS, GIS) with field surveys, community involvement, and sustainable water practices, the village can ensure the long-term sustainability of its rainwater harvesting system. Regular monitoring, proper maintenance, and adapting to changes in climate or land use will maintain the effectiveness of recharge points and help secure the village's water future (1, 2). Future sustainability can be maintained through construction of mix of recharge structures, including smaller, decentralized systems like farm ponds, to maximize groundwater recharge and reduce dependency on a few large structures and Implementation of policies that promote water conservation in agriculture, such as drip irrigation or rain-fed crop choices.

2. STUDY AREA: DEBARI, UDAIPUR

Debari is a rural area located on the eastern side of Udaipur city in the Aravalli hills. This region is characterized by semi-arid conditions, seasonal rainfall, and a dependency on agriculture (3). The undulating terrain, shallow soil depth, and rocky substratum pose significant challenges for natural rainwater percolation. Over-extraction of groundwater has led to a decline in the water table, necessitating the urgent identification of suitable recharge zones.

3. METHODOLOGY FOR IDENTIFYING RAINWATER RECHARGE POINTS

3.1 Remote Sensing (RS): Remote sensing is the science of obtaining information about objects or areas from a distance, typically from satellites or aircraft. In the context of rainwater recharge, RS techniques can help in:

- Land Use and Land Cover (LULC) Mapping: RS data can be used to classify different land use patterns, which is crucial for identifying impermeable areas (e.g., urban areas) and permeable areas (e.g., forests, agricultural land) that facilitate rainwater recharge.
- Soil Moisture Content Estimation: Satellite sensors can measure soil moisture, which indicates the area's potential for groundwater recharge. Higher moisture content suggests better infiltration rates (4).
- Rainfall Data Acquisition: Satellite-based rainfall estimates provide insights into the temporal distribution of precipitation, which is critical for identifying high-rainfall areas suitable for recharge.

3.2 Geographic Information Systems (GIS): GIS is a powerful tool that integrates and analyzes spatial data to visualize and model the potential rainwater recharge areas. The process includes:

- Hydrological Modeling: GIS-based models can simulate surface runoff and subsurface water flow. These models help in identifying low-lying areas where rainwater can accumulate and percolate into the ground.
- Slope and Elevation Analysis: The topography of Debari can be analyzed using Digital Elevation Models (DEMs). Flat or gently sloping areas with low elevation are typically better suited for recharge structures like percolation ponds or check dams.
- Soil and Geology Mapping: GIS helps in mapping soil types and geological formations, which are crucial for understanding the permeability and porosity of the region, influencing rainwater recharge potential.

3.3 Field Surveys: While RS and GIS offer significant insights, field surveys remain essential for ground-truthing and validating the data. The surveys include:

- Soil Testing: On-site soil tests determine the infiltration capacity of the soil, ensuring that areas identified through RS and GIS are suitable for rainwater recharge (5, 6).
- Hydrogeological Surveys: These surveys assess the existing groundwater levels, aquifer characteristics, and the current state of groundwater resources in Debari.
- Community Input: Engaging local farmers and residents can provide valuable insights into traditional water recharge practices and areas with historical water scarcity or abundance.

4. APPLICATIONS OF RS, GIS, AND FIELD SURVEYS IN RAINWATER RECHARGE

The integration of these technologies has already proven effective in several case studies:

Rainwater Harvesting in the Aravalli Hills, Rajasthan: This study used RS and GIS to identify potential locations for check dams and percolation tanks. The data revealed areas where rainwater accumulation could be maximized, leading to an increase in groundwater levels over three years.

Groundwater Recharge Zones in Gujarat: In Gujarat, a combination of RS, GIS, and field surveys helped identify areas for artificial recharge structures, which improved irrigation potential and reduced dependence on external water sources. Both case studies underscore the benefits of using RS and GIS for large-scale spatial analysis while relying on field surveys for localized verification.

5. CHALLENGES AND LIMITATIONS

While RS and GIS technologies offer numerous advantages, there are several challenges to consider:

- Data Availability and Resolution: High-resolution satellite data may not always be available for rural areas like Debari. In addition, real-time monitoring is often limited by cloud cover, sensor malfunctions, or satellite revisit times.
- Cost and Technical Expertise: Implementing GIS and RS requires significant financial investment and technical expertise (7, 8). Rural areas may face challenges in accessing and analysing this data due to resource constraints.
- Field Survey Limitations: Field surveys can be time-consuming and prone to human error. They require consistent maintenance and validation, which can be difficult in rural settings.

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6. RECOMMENDATIONS

To effectively address water scarcity in Debari, it is essential to adopt a holistic approach that combines technology with community engagement (9). Recommendations include:

Capacity Building for Local Authorities: Training local communities and authorities in using RS and GIS technologies can empower them to manage water resources independently.

Government and NGO Involvement: Collaborative efforts between the government, non-governmental organizations (NGOs), and local stakeholders can facilitate the implementation of rainwater recharge projects.

Continuous Monitoring and Maintenance: Once recharge structures are established, continuous monitoring through field surveys and RS data is crucial to ensure their long-term effectiveness.

7. IMPACT ON VILLAGE

The development of rainwater harvesting systems, particularly through the identification of recharge points in a village, can have significant impacts and benefits, including:

- Increased Water Availability: Harvesting rainwater helps capture and store rainwater, making it available for use during dry periods.
- Reduction of Surface Runoff: Effective rainwater harvesting reduces surface runoff, allowing more water to infiltrate the ground.
- Enhanced Groundwater Levels: Identifying recharge points helps facilitate groundwater replenishment, improving the water table (10) and ensuring a sustainable supply of groundwater.
- Prevention of Over-Exploitation: By enhancing recharge, communities can reduce reliance on deep bore wells and other sources of groundwater that may be over-exploited.
- Irrigation Support: Stored rainwater can be used for irrigation, improving agricultural productivity and food security.
- Drought Mitigation: Farmers can rely on harvested rainwater during drought conditions, minimizing crop failure risks.
- Ecosystem Protection: Recharge points can improve local ecosystems by maintaining water levels in wetlands and supporting local flora and fauna.
- Soil Quality Improvement: Rainwater harvesting can prevent soil erosion and promote soil health by maintaining moisture levels.
- Increased Awareness: Developing a rainwater harvesting system raises community awareness about water conservation and sustainable practices.
- Local Participation: Involving the community in identifying recharge points encourages local participation and ownership, fostering a sense of responsibility towards water resources.
- Cost Savings: Reduced reliance on external water sources can lead to lower costs for water procurement and treatment.
- Enhanced Livelihoods: Improved water availability supports various livelihoods, from agriculture to small-scale industries.
- Flood Mitigation: Proper rainwater harvesting can help manage excess rainwater during storms, reducing flooding risks in the village.
- Resilience to Climate Change: Communities can become more resilient to climate variability and extreme weather events through improved water management practices.
- Improved Water Quality: Rainwater harvesting systems can provide clean water, reducing waterborne diseases associated with contaminated sources (11).
- Increased Sanitation: Access to stored rainwater can enhance sanitation practices, contributing to better overall public health.

The development of rainwater harvesting systems, guided by the identification of recharge points, is a sustainable approach that can greatly benefit villages. It supports water security, enhances agricultural productivity, and fosters community development, all while contributing to environmental sustainability.

8. CONCLUSION

The integration of Remote Sensing, GIS, and field surveys presents a promising solution for identifying rainwater recharge points in rural areas like Debari, Udaipur. These technologies provide accurate and cost-effective methods

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for mapping potential recharge zones, aiding in sustainable water management. Future research and policies should focus on further improving data accuracy, reducing costs, and engaging local communities to maximize the benefits of these technologies. Water scarcity is a pressing issue in India, particularly in rural areas. Rajasthan, a semi-arid state, faces chronic water shortages due to low and erratic rainfall, high evapotranspiration rates, and excessive groundwater extraction. The village of Debari, located in the Udaipur district of Rajasthan, is not immune to these challenges. The growing demand for water, both for agricultural and domestic purposes, has led to a significant depletion of groundwater levels in this area, making sustainable water management a necessity.

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