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Water Resources Management in Simrawal River Sub-Basin, Central India

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ABSTRACT:
Water management is a serious issue in the Simrawal area of Satna district, which plays a vital role in maintaining the economic, social, and environmental balance of the region. Both the availability and quality of water in the region are continuously declining. The aim of this study is to analyze the current status of water management in Simrawal and propose measures to improve its water resources. Techniques such as artificial recharge and geomorphology analysis have been used. Increasing population, growing agricultural demand, and expansion of industrial activities in the Simrawal area are putting great pressure on its water resources. Declining water levels and deterioration in water quality are the major challenges of the region, which are further aggravated due to inadequate water management and pollution. The study includes an analysis of streams in the region, an assessment of the catchment area, river system analysis, and the calculation of various geomorphological parameters. The findings indicate that artificial recharge techniques can significantly improve the water level. Geomorphology analysis has provided valuable insights into the catchment area, which will help in making water management strategies more effective. Water conservation and recharge structures like ponds, wells, and reservoirs to store rainwater have shown positive results. This provides new directions for water management in the study area. Urgent and effective action is needed to improve the water situation in the study area, which should focus on enhancing, conserving, and managing water resources. Achieving water security and sustainable development in the region is possible only through combined efforts of community participation and government support. Implementation of concrete strategies and policies in this direction is essential for the future of the region.
Key Words: Simrawal river, Satna district, water management, artificial recharge.

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I. INTRODUCTION:

Water resources management plays a crucial role in ensuring sustainable development, especially in regions experiencing increasing pressure on freshwater availability due to climate change, population growth, and industrial expansion. Water exists primarily as surface and groundwater resources, which are interdependent and require careful management for sustainable development. Surface water is limited, making groundwater the primary alternative source. India, with only 4% of the world's water resources but nearly 20% of the global population, faces severe water scarcity. In this context, the Simrawal watershed in Satna District, Madhya Pradesh, Central India, is a significant hydrological unit that contributes to the regional water supply. However, challenges such as declining groundwater levels, contamination, and inefficient water management practices necessitate a comprehensive study of water resource dynamics in the region. While previous studies have examined aspects of its hydrology, the hydrogeological characteristics remain insufficiently explored.

The study of water resources management in river basins has been a focus of numerous researchers. The morphometric evaluation of watersheds provides critical insights into the hydrological behaviour and geomorphic evolution of river systems (Banerjee et al., 2017; Kaushik and Ghosh, 2015). Morphometric analysis, using remote sensing and GIS techniques, helps in prioritising sub-watersheds for conservation planning and water resource management (Chandniha and Kansal, 2017; Kudnar and Rajasekhar, 2020). Groundwater recharge and vulnerability assessment are also essential aspects of water resources management. Artificial groundwater recharge has been extensively studied as a strategy to augment water availability, particularly in regions facing water stress (Bhattacharya, 2010; Manal Abd El Moneam, 2023). The identification of suitable recharge sites through hydrogeological modelling has been explored in different watersheds, emphasising the role of integrated geospatial and hydrogeological approaches (Kadam et al., 2023). Studies have also highlighted the risks associated with groundwater contamination due to the presence of toxic elements, which necessitate periodic assessment and management strategies (Vinnarasi et al., 2021; Malik and Shukla, 2019).

Large-scale hydrological assessments have revealed the extent to which human activities modify natural flow regimes, leading to changes in sediment transport, water quality, and aquatic ecosystems (Peñas and Barquín, 2019). Freshwater availability is a global challenge, and the management of water resources at a watershed level is crucial for addressing this issue (Dubey and Pandey, 2014). Studies on water level fluctuations and groundwater suitability in different regions of Central India have provided valuable data for resource planning (Tiwari et al., 2016). The assessment of hydrological models for streamflow prediction and water balance analysis has further aided in developing reliable water management frameworks (Kumari et al., 2021). Recent studies have emphasized the use of geospatial techniques for delineating groundwater potential zones and identifying suitable sites for water conservation structures (Tiwari and Kushwaha, 2018; Tiwari et al., 2024). This study integrates remote sensing, GIS, and hydrological modeling to develop sustainable water management strategies for the Simrawal River sub-basin, ensuring long-term water security and resource optimization.

This research aims to fill this gap by conducting an in-depth study of the hydrogeology of the Simrawal watershed. The region suffers from water scarcity and declining groundwater quality, making it a critical area for study. Hydrogeology focuses on the occurrence, distribution, movement, and chemical properties of groundwater. Understanding these aspects will contribute to improved water management strategies, ensuring a sustainable supply for the local population and ecosystems. By addressing these key challenges, this research will support long-term water conservation and development efforts in the Simrawal watershed and surrounding areas.

Study Area

The total area is about 600 sq. km. Falling in the survey of India Toposheet no. 63H/1, 63H/2, 63D/13, and 63D/14, it lies between approximately latitude 24°37' to 24°47'N and longitude 80°45' to 81°07'E. The research area is drained by the Simrawal River and by its tributaries. Simrawal River is a tributary of Tons River. The climate of the study area is tropical type. In the proposed work, the groundwater resources and natural recharge conditions in the area would be evaluated. Artificial recharge and groundwater management will also form part of this work.

Climate

Satna district experiences a hot summer and a dry climate except during the south-west monsoon. The year is divided into four seasons: a cold season (December–February), a hot season (March–mid-June), the monsoon season (mid-June–September), and a post-monsoon period (October–November). The district receives an annual rainfall of around 1092 mm, with approximately 87% occurring during the monsoon. Rainfall is the primary source of groundwater recharge. The highest recorded rainfall is 1106.5 mm at Satna, while Maihar records the lowest at 1056.1 mm. The temperature ranges from 41.9ºC in May to 8.7ºC in January, with an annual mean maximum of 32.2ºC and a minimum of 19ºC.

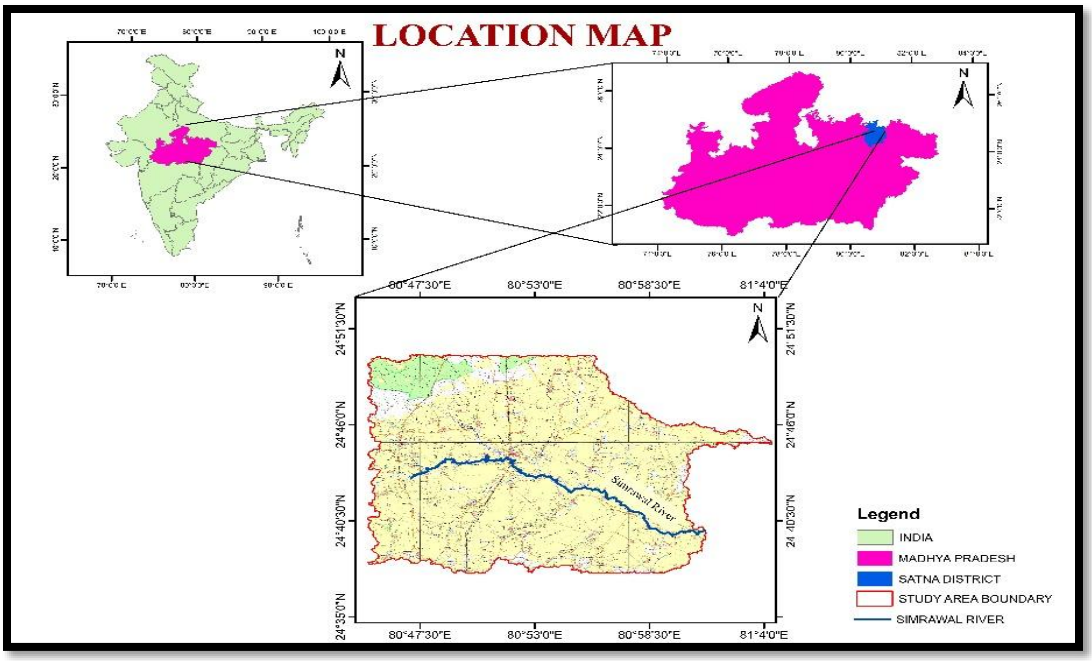

Fig. 1: Location map of the study area

WATER RESOURCE MANAGEMENT

Effective water resource management is crucial for ensuring sustainability, especially in regions like the Simrawal River Sub-Basin in Central India, where groundwater serves as a vital resource for agriculture and domestic use. Remote sensing and GIS-based techniques have been widely applied to assess groundwater potential and watershed management strategies (Jhriya et al., 2016; Javed et al., 2011). Multi-Criteria Decision Analysis (MCDA) methods have proven effective in delineating groundwater potential zones and recharge areas (Tiwari et al., 2022).

Groundwater depletion is a growing concern due to increased irrigation demands, as observed in the Barind area of NW Bangladesh, where meteorological parameters and groundwater fluctuation trends were analysed to assess the impact of irrigation (Jahan et al., 2010). Sustainable water management requires an integrated approach considering climate change and anthropogenic influences (Jain, 2012). Challenges such as over-extraction and uneven distribution necessitate improved policy frameworks and conservation strategies (Jain, 2019). Understanding aquifer characteristics and groundwater recharge mechanisms is essential for long-term resource planning (Tiwari, 2017).

CURRENT STATUS OF WATER RESOURCES IN THE SUB-BASIN

The Simrawal River Sub-Basin encompasses parts of Majhgawan, Rampur-Baghelan, and Sohawal. The total geographical area of the sub-basin is 329,468 hectares (ha), out of which 294,698 ha are categorised as recharge-worthy areas, while 34,770 ha comprise hilly terrain (Table 1). The recharge-worthy area includes both command and non-command areas, with Rampur-Baghelan contributing 77,594 ha, Sohawal 77,192 ha, and Majhgawan the largest at 139,912 ha.

Table 1: Assessment unit wise area Details Dynamic

Asessment Unit	Total Geographical Area (ha)				
	Recharge Worthy Area (ha)			Hilly Area	Total
	Total Command Area	Non-Command Area	Total		
MAJHGAWAN	0	139912	139912	24970	164882
RAMPUR-BAGHELAN	31250	46344	77594	9800	87394
SOHAWAL	10442	66750	77192	0	77192
TOTAL	41692	253006	294698	34770	329468

(Groundwater Resources of Madhya pradesh As On 2022 by CGWB)

Groundwater recharge is primarily influenced by rainfall, other water sources, and conservation structures. The total annual groundwater recharge in the sub-basin is estimated at 32,928.4 hectare-meters (Ham), with Majhgawan contributing the highest recharge of 13,309.5 Ham, followed by Sohawal at 10,288.1 Ham and Rampur-Baghelan at 9,330.75 Ham (Table 2).

Table 2: Assessment unit wise Ground Water Recharge Scenario

Assessment Unit	Recharge from Rainfall Monsoon Season (Ham)	Recharge from Other Sources Monsoon Season (Ham)	Recharge from Rainfall Non-Monsoon Season (Ham)	Recharge from Other Sources Non-Monsoon Season (Ham)	Total Annual Ground Water Recharge (Ham	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)
MAJHGAWAN	11921.9	254.84	277.62	855.2	13309.5	665.48	12644
RAMPUR-BAGHELAN	5630.26	417.12	114.99	3168.38	9330.75	933.08	8397.68
SOHAWAL	7798.47	490.51	143.89	1855.21	10288.1	1028.8	9259.28
TOTAL	25350.6	1162.47	536.5	5878.79	32928.4	2627.36	30301

(Groundwater Resources of Madhya pradesh As On 2022 by CGWB)

The sub-basin's groundwater recharge is significantly supported by other sources such as irrigation, tanks, ponds, and water conservation structures. Recharge from groundwater irrigation is the highest contributor at 4,333.56 Ham, followed by surface water irrigation at 1,881.86 Ham and recharge from canals at 539.26 Ham. Additionally, water conservation structures add 229.44 Ham to the groundwater reserves (Table 3).

Table 3: Assessment unit wise Recharge from Other Sources

Assessment Unit Name	Recharge from Canals (in Ham)	Recharge from Surface Water Irrigation (in Ham)	Recharge from Ground Water Irrigation (in Ham)	Recharge due to Tanks and Ponds (in Ham)	Recharge due to Water Conservation Structures (in Ham)	Recharge due to Pipelines (in Ham)	Total Recharge from Other Sources (in Ham)
MAJHGAWAN	0	0	1040.17	46.29	23.58	0	1110.04
RAMPUR-BAGHELAN	334.91	1496.39	1715.77	10.71	27.72	0	3585.5
SOHAWAL	204.35	385.47	1577.62	0.14	178.14	0	2345.72
TOTAL	539.26	1881.86	4333.56	57.14	229.44	0	7041.26

(Groundwater Resources of Madhya pradesh As On 2022 by CGWB)

Water utilisation in the sub-basin is predominantly for irrigation, followed by domestic and industrial needs. Groundwater extraction for irrigation is the highest in Rampur-Baghelan (6,863.08 Ham), followed by Sohawal (6,310.48 Ham) and Majhgawan (4,160.7 Ham). Industrial water usage is negligible, with only 14.6 Ham recorded in Majhgawan. Domestic use is relatively lower compared to irrigation, with a total extraction of 1,868.82 Ham across all three assessment units (Table 4).

Table 4: Ground Water Extraction Scenario

Assessment Unit	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization
MAJHGAWAN	4160.7	14.6	624.06	4799.36	675.17	7793.57	37.96	safe
RAMPUR-BAGHELAN	6863.08	0	674.54	7537.63	729.8	2889.86	89.76	semi critical
SOHAWAL	6310.48	0	570.22	6880.71	616.93	2331.86	74.31	semi critical
TOTAL	17334.26	14.6	1868.82	19217.7	2021.9	13015.29	202.03	0

(Groundwater Resources of Madhya pradesh As On 2022 by CGWB)

The net groundwater availability for future use is estimated at 13,015.29 Ham, with Majhgawan having the highest at 7,793.57 Ham, followed by Rampur-Baghelan (2,889.86 Ham) and Sohawal (2,331.86 Ham). The stage of groundwater extraction varies significantly across the sub-basin, with Rampur-Baghelan categorised as semi-critical (89.76%), Sohawal also semi-critical (74.31%), and Majhgawan categorised as safe (37.96%).

The increasing dependence on groundwater, coupled with growing agricultural activities, poses a potential risk of water quality deterioration. The presence of excess fertilisers, pesticides, and other agrochemicals in the soil can lead to contamination of groundwater. Additionally, recharge sources such as ponds and tanks can be prone to surface pollution due to inadequate waste management practices in the region. Climate change poses a serious challenge to water availability in the Simrawal River Sub-Basin. Variability in monsoon patterns significantly influences groundwater recharge, with a substantial amount of recharge occurring during the monsoon season (25,350.6 Ham). Extended dry spells during non-monsoon periods result in limited recharge (536.5 Ham), making the region vulnerable to seasonal water stress. Rising temperatures and erratic rainfall patterns are expected to further impact groundwater recharge and availability, necessitating adaptive water management strategies to ensure long-term sustainability.

CHALLENGES IN WATER RESOURCES MANAGEMENT

The Simrawal River Sub-Basin, located in Central India within the Vindhyan Supergroup, faces several challenges in water resources management due to its geological and hydrogeological characteristics. The region is primarily composed of Ganurgarh shale and Nagod limestone, with shale covering a significant portion of the area. Shale formations typically have low permeability, leading to limited groundwater recharge and reduced aquifer storage, which affects water availability, especially during dry seasons.

The region, being an inter-stream area between the Tons and Satna Rivers, is vulnerable to surface water fluctuations. Erratic rainfall patterns and seasonal variations further exacerbate water scarcity, impacting agriculture, drinking water supply, and ecosystem sustainability. Additionally, unregulated groundwater extraction and inefficient water conservation practices contribute to declining water tables.

Soil erosion and sedimentation, influenced by the geological composition and land use patterns, degrade water quality and reduce reservoir capacities. Industrial and agricultural activities pose pollution threats, leading to contamination of both surface and groundwater sources. Lack of proper water governance, infrastructure, and community participation further hampers sustainable water management efforts. Addressing these challenges requires integrated watershed management, improved conservation techniques, and policy interventions to ensure long-term water security in the Simrawal River Sub-Basin.

STRATEGIES FOR SUSTAINABLE WATER MANAGEMENT

Sustainable water management in the Simrawal River Sub-Basin requires an integrated approach to balance water availability, demand, and conservation. Key strategies include:

- Implementing recharge structures such as nala bunds, check dams, percolation tanks, and farm ponds can significantly improve groundwater levels. These structures help in rainwater retention, reducing runoff and increasing infiltration.
- Promoting drip and sprinkler irrigation can reduce groundwater extraction for agriculture. Additionally, on-farm water conservation techniques like contour bunding and mulching can enhance soil moisture retention.
- Restoring and maintaining traditional tanks, ponds, and wetlands will improve surface water storage and support ecological balance.
- Enforcing sustainable groundwater withdrawal limits, especially in semi-critical zones like Rampur-Baghelan and Sohawal, will help prevent over-extraction.
- Encouraging water user associations (WUAs) and local governance involvement in water conservation programs will ensure long-term success.
- Adoption of rainwater harvesting and climate-adaptive cropping patterns can mitigate the impact of changing rainfall patterns.

Implementing these strategies will ensure water security and sustainability in the sub-basin.

II. CONCLUSION

The Simrawal River Sub-Basin in Central India faces multiple challenges in water resource management due to increasing water demand, groundwater depletion, and climate variability. The study highlights that while the sub-basin has a total geographical area of 329,468 hectares, only 294,698 hectares are recharge-worthy, making efficient water conservation and management strategies essential. Groundwater recharge is primarily dependent on monsoon rainfall, contributing 25,350.6 Ham, while non-monsoon recharge remains significantly lower at 536.5 Ham. Given the reliance on groundwater for irrigation and domestic use, unsustainable extraction poses a growing concern. The assessment of groundwater extraction indicates that Rampur-Baghelan and Sohawal fall under semi-critical zones, with extraction levels at 89.76% and 74.31%, respectively, while Majhgawan remains safe at 37.96%. The total annual groundwater recharge of 32,928.4 Ham is supported by additional sources such as canals, tanks, ponds, and irrigation activities, contributing 7,041.26 Ham. However, the net groundwater availability for future use is only 13,015.29 Ham, with Rampur-Baghelan and Sohawal having limited reserves.

The major challenges include erratic rainfall patterns, geological constraints of low-permeability shale formations, unregulated extraction, and increasing pollution risks from agricultural and domestic activities. Climate change further exacerbates water stress by altering rainfall patterns and reducing natural recharge.

To address these issues, sustainable water management strategies must be implemented. Artificial recharge structures such as nala bunds, check dams, and percolation tanks should be prioritized to enhance groundwater levels. Additionally, efficient irrigation techniques like drip and sprinkler systems can reduce agricultural water demand. Restoring traditional water bodies and enforcing groundwater regulation policies are essential for long-term sustainability. By integrating scientific assessment methods such as GIS-based mapping, Multi-Criteria Decision Analysis (MCDA), and hydrogeological studies, policymakers and local communities can develop effective water conservation frameworks. Strengthening community participation and local governance will be key to ensuring equitable water distribution and long-term resilience in the Simrawal River Sub-Basin.

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