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Integrated Water Resource Management in Banka District, Bihar

[1]Devashish Pushkar, [2]Dr. Ayush Bharti [3]Prof. Sharat Chandra

[1,2]Research Scholar, [2]Former Head of the Department (Retired)

University Department of Geography, T.M. Bhagalpur University, Bhagalpur (Bihar)

ABSTRACT: Integrated Water Resource Management (IWRM) has emerged as a crucial approach for addressing water scarcity, quality degradation, and sectoral competition in agrarian regions of India. The present study examines the status, challenges, and prospects of integrated water resource management in Banka District, Bihar, with special emphasis on surface and groundwater utilization, institutional arrangements, and sector-wise water demand. The study is based on secondary hydrological data, water supply records, agricultural statistics, and primary field observations. Temporal variations in rainfall, groundwater levels, and irrigation dependency have been analysed using statistical techniques. The findings reveal increasing pressure on groundwater resources due to agriculture-dominated water demand, uneven access to drinking water, and limited recharge interventions. Seasonal variability of rainfall and inefficient water-use practices further intensify local water stress. The study argues that fragmented management approaches need to be replaced by an integrated framework focusing on demand management, conservation, institutional coordination, and community participation. The paper highlights the relevance of IWRM as a policy-oriented and sustainable pathway for ensuring long-term water security in district-level planning.

Keywords: Integrated water resource management; groundwater; irrigation; water sustainability; Banka district

INTRODUCTION

Water is a critical natural resource that underpins agricultural productivity, public health, and socio-economic development, particularly in agrarian regions of India. Despite being home to nearly 18 per cent of the world's population, India possesses only about 4 per cent of global freshwater resources, leading to increasing pressure on both surface and groundwater systems (FAO, 2011; World Bank, 2020). Rapid population growth, expansion of irrigated agriculture, and climate variability have significantly intensified water stress, especially at the sub-national and district levels where planning and implementation gaps are more pronounced.

Bihar is among the most water-dependent agrarian states of India, where agriculture employs more than 60 per cent of the workforce and irrigation relies heavily on monsoonal rainfall and groundwater extraction (Government of Bihar, 2021). Although the state is traversed by major river systems, spatial and seasonal variability of rainfall often results in localized water scarcity during the pre-monsoon period. According to Central Ground Water Board estimates, groundwater accounts for more than 70 per cent of

irrigation and nearly 85 per cent of rural drinking water supply in Bihar, indicating high dependency and growing vulnerability (CGWB, 2020).

Banka District represents a typical agrarian district of southern Bihar where water resource availability is closely linked with rainfall variability and groundwater extraction. The district receives an average annual rainfall of around 1,100–1,200 mm, nearly 80 per cent of which is concentrated during the southwest monsoon months (June–September). However, uneven temporal distribution of rainfall often leads to short-term water surplus followed by prolonged dry spells, adversely affecting crop productivity and drinking water availability (District Statistical Handbook, Banka, 2022). Agriculture remains the dominant water-consuming sector, with paddy and wheat cultivation exerting significant pressure on groundwater resources, particularly during the rabi season.

Recent observations indicate a gradual decline in pre-monsoon groundwater levels in several blocks of the district, attributed to increased use of tube wells, limited surface water storage, and inadequate recharge mechanisms (CGWB, 2019). Simultaneously, traditional water bodies such as ponds and tanks—once integral to local water management—have experienced reduced storage capacity due to siltation, encroachment, and lack of maintenance. These challenges reflect a fragmented approach to water management, where irrigation, drinking water supply, and conservation initiatives operate in isolation.

In this context, Integrated Water Resource Management (IWRM) provides a comprehensive framework that emphasizes coordinated development and management of water, land, and related resources to maximize social and economic welfare without compromising ecological sustainability (GWP, 2000). At the district level, IWRM is particularly relevant as it promotes sectoral integration, demand management, institutional coordination, and community participation. The present study applies the principles of IWRM to assess water resource use, emerging challenges, and management prospects in Banka District, with the objective of contributing to sustainable and decentralized water governance in Bihar.

CONCEPTUAL FRAMEWORK OF INTEGRATED WATER RESOURCE MANAGEMENT (IWRM)

Integrated Water Resource Management (IWRM) is a holistic and participatory approach that seeks to manage water resources in a coordinated manner across sectors, scales, and stakeholders. The concept gained global recognition with the Dublin Principles (1992) and was further formalized by the Global Water Partnership, which defines IWRM as “a process that promotes the coordinated development and management of water, land, and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (GWP, 2000).

At its core, the conceptual framework of IWRM rests on the understanding that water resources are finite, interconnected, and multi-sectoral in nature. Surface water and groundwater are not independent systems; rather, they interact dynamically through recharge, base flow, and extraction processes. Similarly, water availability and use are closely linked with land use patterns, agricultural practices, population dynamics, and institutional arrangements. Therefore, fragmented and sector-specific water management approaches often lead to inefficiencies, resource degradation, and inequitable access.

The IWRM framework integrates three fundamental pillars—economic efficiency, social equity, and environmental sustainability—often referred to as the “triple bottom line” of water governance (Biswas, 2004). Economic efficiency emphasizes optimal allocation and use of water to maximize productivity, particularly in agriculture, which is the largest water-consuming sector in rural districts. Social equity focuses on fair and inclusive access to water for all sections of society, especially marginalized and water-insecure communities. Environmental sustainability underscores the need to maintain ecological flows, groundwater balance, and water quality to ensure long-term resource availability.

At the operational level, IWRM promotes horizontal integration across sectors such as agriculture, drinking water supply, sanitation, and ecosystem management, as well as vertical integration across governance levels—from local institutions and district administrations to state-level agencies. This integration is particularly significant at the district scale, where water-related decisions directly influence livelihoods, food security, and public health. Effective coordination among departments responsible for irrigation, rural water supply, agriculture, and local governance is therefore a central component of the IWRM framework.

Another critical dimension of IWRM is demand-side management, which shifts the focus from merely augmenting water supply to improving water-use efficiency and conservation. This includes promoting water-saving irrigation techniques, crop diversification, reduction of conveyance losses, and rational pricing or regulation of groundwater extraction. Demand management is complemented by supply-side interventions such as rainwater harvesting, recharge structures, revival of traditional water bodies, and protection of catchment areas.

The conceptual framework also highlights the role of institutions and stakeholders in water governance. Local communities, farmers, Panchayati Raj Institutions, and user groups are viewed not as passive beneficiaries but as active participants in planning, implementation, and monitoring. Participatory decision-making enhances accountability, local ownership, and long-term sustainability of water management initiatives (Meinzen-Dick, 2007). In rural districts, community-based management of ponds, wells, and minor irrigation systems forms a practical foundation for implementing IWRM principles.

Furthermore, IWRM recognizes the importance of adaptive management, particularly in the context of climate variability and uncertainty. Variations in rainfall patterns, frequency of droughts, and extreme weather events necessitate flexible and learning-based management strategies. Continuous monitoring, feedback mechanisms, and periodic policy adjustments are therefore integral to the IWRM framework.

In the context of district-level planning, the conceptual framework of IWRM serves as an analytical lens to assess existing water use patterns, identify institutional gaps, and design integrated strategies that align water availability with sectoral demand. By emphasizing coordination, participation, efficiency, and sustainability, IWRM provides a robust theoretical and practical foundation for addressing water resource challenges in agrarian regions.

LITERATURE REVIEW

Previous studies on water resource management in India broadly emphasize the growing stress on freshwater resources due to population pressure, agricultural intensification, and climate variability, highlighting the limitations of sector-wise and supply-oriented approaches (Biswas, 2004; World Bank, 2010). The concept of Integrated Water Resource Management (IWRM) emerged as a response to these challenges, advocating coordinated management of surface water, groundwater, land, and institutional systems to achieve economic efficiency, social equity, and environmental sustainability (Global Water Partnership, 2000). Several scholars have examined the application of IWRM in developing countries and noted that while the framework is theoretically robust, its implementation at local and district levels often faces institutional fragmentation, weak governance, and limited stakeholder participation (Molle, 2008; Meinzen-Dick, 2007). In the Indian context, studies have shown that agrarian regions are increasingly dependent on groundwater for irrigation and drinking water, leading to declining water tables and quality deterioration, particularly in eastern India (Shah, 2009; CGWB, 2019). Research focusing on Bihar indicates that despite relatively high annual rainfall, seasonal variability, inadequate surface storage, and unregulated groundwater extraction have resulted in localized water stress and growing demand–supply gaps (Government of Bihar, 2021). However, most existing studies remain either state-level or thematic, with limited emphasis on district-scale integrated assessments that combine resource availability, sectoral demand, and institutional dimensions. This highlights a clear research gap for micro-level studies, such as in Banka District, where applying the IWRM perspective can provide context-specific insights for sustainable and decentralized water governance.

Objectives of the Study

1. To assess the availability and utilization of surface and groundwater resources in Banka District.
2. To analyse rainfall variability and groundwater dependency in relation to agricultural and domestic water demand.
3. To suggest integrated and sustainable water management strategies for improving water security in the district.

DATA SOURCES AND METHODOLOGY

The study is based exclusively on secondary data obtained from government publications and official records. Rainfall and climatic data were collected from the India Meteorological Department and the District Statistical Handbook of Banka District. Groundwater-related information was sourced from reports of the Central Ground Water Board and the State Ground Water Directorate, Bihar. Data on irrigation, water use, and drinking water supply were taken from relevant departments of the Government of Bihar and Census of India publications.

The methodology involves descriptive and trend-based analysis of compiled datasets to examine water availability, groundwater dependency, and sector-wise water use. The analysis is guided by the principles of Integrated Water Resource Management to understand existing challenges and management prospects at the district level.

STUDY AREA — BANKA DISTRICT, BIHAR

Banka District lies in southern Bihar (approx. 24°30′–25°08′ N, 86°30′–87°12′ E) and covers about 3,020 sq. km (≈3,020 km²). According to the 2011 Census the district had a population of 2,034,763 (rural population ≈ 96.5%), a population density of ~670 persons km^{-2}, and a literacy rate near 58.2%; scheduled castes and tribes form notable minority shares in the social structure. Administratively Banka comprises 11 blocks and roughly ~2,000 villages (major towns and block headquarters include Banka, Belhar, Amarpur, Katoriya etc.). Agriculture is the dominant livelihood — major crops include paddy, wheat and pulses — which makes water demand sectorally concentrated in rural areas.

Climatically Banka is monsoon-dominated with an average annual rainfall ~1,100–1,200 mm, most of it received during June–September; temperatures range roughly 15°C–45°C across the year. Surface water is mostly seasonal — small rivers, streams and numerous traditional ponds/tanks — while groundwater is the principal source for irrigation and rural drinking water. Recent technical assessments and CGWB notes report localized pre-monsoon groundwater declines and indicate the need for targeted recharge and contamination monitoring in parts of the district. These hydro-climatic and socio-economic characteristics — high rural population, agriculture-centric water use, seasonal rainfall, limited surface storage, and rising groundwater dependence — make Banka a representative district for a micro-level IWRM study

STATUS OF WATER RESOURCES IN BANKA DISTRICT

1. Surface Water Resources

Surface water resources in Banka District are limited in scale and highly seasonal in nature. The district does not have any perennial major river system; instead, its surface water system is dominated by small seasonal streams, local drainage channels, ponds, tanks, and traditional water harvesting structures. These water bodies are primarily rain-fed and become functional during the monsoon months (June–September), when nearly four-fifths of the annual rainfall is received. Historically, ponds and tanks played a crucial role in supporting domestic water needs, livestock, supplementary irrigation, and groundwater recharge.

However, in recent decades, the effectiveness of surface water resources has declined considerably. Field observations and district-level reports indicate that many ponds and tanks have experienced siltation, reduction in storage capacity, encroachment for agriculture or settlement, and lack of regular maintenance. As a result, their contribution to irrigation and drinking water supply has diminished, increasing dependence on groundwater sources. Moreover, the absence of systematic desilting and rejuvenation programmes has reduced the role of surface water bodies as recharge structures, thereby weakening the overall water balance of the district.

2. Groundwater Resources

Groundwater constitutes the primary and most reliable source of water for both irrigation and drinking purposes in Banka District. The majority of rural households depend on hand pumps and tube wells for drinking water, while agriculture relies extensively on shallow and medium tube wells, particularly during the rabi season. Due to limited surface water availability and absence of canal irrigation, groundwater extraction has increased steadily over the years.

Secondary data from groundwater assessment reports suggest that pre-monsoon groundwater levels show a declining trend in several blocks, reflecting localized stress conditions. This situation is largely attributed to unregulated extraction through privately owned tube wells, expansion of water-intensive crops, and inadequate artificial recharge mechanisms. The stress becomes more pronounced during the pre-monsoon months, when water demand peaks and recharge from rainfall is minimal. In addition, systematic monitoring of groundwater abstraction and quality remains limited, further complicating sustainable management.

Despite the district receiving moderate annual rainfall, the lack of surface storage and poor recharge conditions have resulted in an increasing imbalance between groundwater withdrawal and replenishment. These trends underline the urgency of adopting integrated and demand-oriented groundwater management practices at the district level.

The combined assessment of surface and groundwater resources reveals a highly groundwater-dependent water system in Banka District. The declining functionality of traditional surface water bodies has intensified pressure on groundwater, leading to localized stress conditions. This imbalance highlights the need for integrated management measures focusing on surface water rejuvenation, groundwater regulation, and recharge enhancement in line with Integrated Water Resource Management principles.

WATER USE PATTERN AND SECTORAL DEMAND IN BANKA DISTRICT

Water use in Banka District is strongly shaped by its agrarian economy, rural settlement pattern, and limited surface water infrastructure. The overall water demand is dominated by agriculture, followed by domestic use, while industrial and commercial demand remains negligible. The heavy reliance of all major sectors on groundwater has created an imbalanced and stress-prone water-use system, particularly during the dry pre-monsoon months.

Table: Sector-wise Water Use Pattern in Banka District

Sector	Main Water Source	Share of Total Water Use (%)	Seasonal Demand Pattern
Irrigation	Groundwater (tube wells)	75–80	High during rabi season
Domestic (drinking & household)	Groundwater (hand pumps, tube wells)	15–20	Uniform throughout the year
Livestock & allied activities	Ponds, groundwater	3–5	Moderate, seasonal
Industrial / commercial	Minimal	<2	Insignificant

Source: CGWB Reports; District Statistical Handbook, Banka; Government of Bihar (compiled)

Irrigation constitutes the largest share of water demand in Banka District, accounting for nearly four-fifths of total water use. The dominance of paddy cultivation, along with traditional flood irrigation practices, results in inefficient water use and high seasonal extraction of groundwater. During the rabi season, when rainfall contribution is absent, dependence on tube wells intensifies, leading to localized groundwater stress.

Domestic water demand, although smaller in volume, holds higher social priority, as rural households depend almost entirely on groundwater for drinking and household needs. Any decline in groundwater availability or quality directly affects public health and daily livelihoods. Livestock-related water use plays a supplementary role, often relying on ponds and shallow groundwater sources.

The near absence of industrial water demand indicates low industrialization; however, it also means that inter-sectoral competition for water is primarily between irrigation and domestic sectors. This overlap in water sources increases vulnerability during drought years and dry seasons.

From an Integrated Water Resource Management perspective, the existing water-use pattern highlights the urgent need for demand management in agriculture, protection of drinking water sources, and revival of surface water bodies to reduce excessive pressure on groundwater resources.

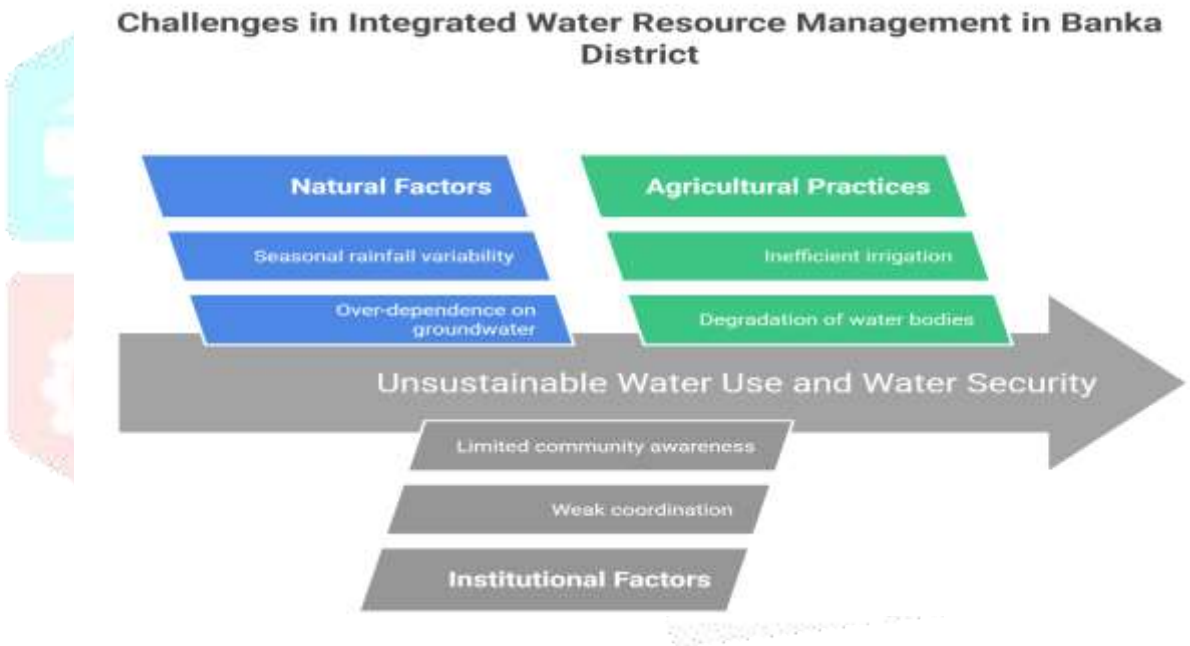
CHALLENGES IN INTEGRATED WATER RESOURCE MANAGEMENT IN BANKA DISTRICT

Integrated Water Resource Management in Banka District faces multiple interlinked challenges that stem from both natural and institutional factors. These challenges collectively constrain sustainable water use and long-term water security.

1. **Over-dependence on groundwater resources** is the most critical challenge, as both irrigation and domestic water requirements rely predominantly on tube wells and hand pumps. The absence of perennial surface water sources and limited storage infrastructure has intensified groundwater extraction, leading to localized stress, particularly during the pre-monsoon period.
2. **Seasonal rainfall variability and drought-like conditions** further aggravate water scarcity. Although the district receives moderate annual rainfall, its uneven temporal distribution results in short periods

of water surplus followed by extended dry spells. This variability reduces effective recharge and increases vulnerability during years of delayed or deficient monsoon.

3. **Inefficient irrigation practices** contribute significantly to excessive water withdrawal. Traditional flood irrigation methods, especially for paddy cultivation, lead to high conveyance losses and low water-use efficiency. The limited adoption of micro-irrigation technologies has restricted opportunities for demand-side water conservation.
4. **Degradation of traditional water bodies** such as ponds and tanks has weakened local water storage and recharge mechanisms. Siltation, encroachment, and lack of maintenance have reduced their capacity to support irrigation, livestock needs, and groundwater replenishment.
5. **Weak institutional coordination among water-related departments** poses a major governance challenge. Responsibilities related to irrigation, drinking water supply, groundwater management, and rural development are distributed across multiple agencies, often operating with limited coordination. This fragmented approach undermines integrated planning and implementation.
6. **Limited community awareness and participation** further restrict effective water management. Local users often have minimal involvement in planning, monitoring, and maintenance of water resources, reducing accountability and sustainability. Strengthening community engagement is therefore essential for successful implementation of IWRM principles at the district level.



POLICY IMPLICATIONS AND MANAGEMENT STRATEGIES FOR INTEGRATED WATER RESOURCE MANAGEMENT

The assessment of water resources and use patterns in Banka District clearly indicates the need for a shift from fragmented, supply-oriented approaches to a coordinated and demand-sensitive framework of Integrated Water Resource Management. Effective policy interventions must recognize groundwater as a common-pool resource and prioritize sustainability, equity, and institutional coordination at the district level.

First, **groundwater regulation and monitoring** should be strengthened through district-level mechanisms. Registration of tube wells, periodic assessment of groundwater levels, and regulation of extraction during critical periods can help prevent over-exploitation. Integrating groundwater management with local governance institutions, particularly Panchayati Raj Institutions, would enhance accountability and compliance.

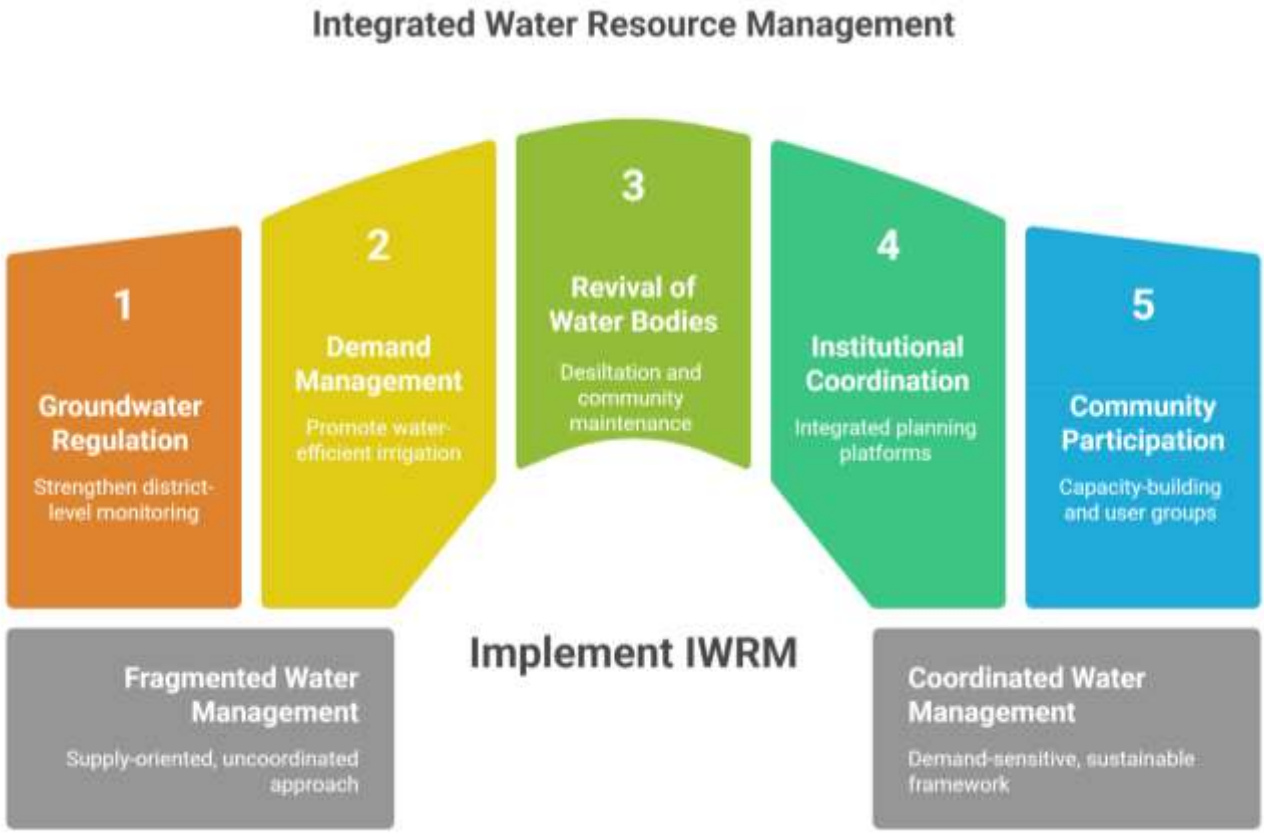
Second, **demand management in agriculture** must become a central policy focus. Promotion of water-efficient irrigation practices such as sprinkler and drip systems, along with incentives for crop

diversification away from water-intensive crops, can significantly reduce irrigation demand. Aligning agricultural support policies with water availability is essential for long-term sustainability.

Third, **revival and protection of traditional water bodies** should be prioritized as a cost-effective strategy for enhancing surface storage and groundwater recharge. Policies aimed at desiltation, prevention of encroachment, and community-based maintenance of ponds and tanks can restore their multifunctional role in irrigation, domestic use, and ecosystem support.

Fourth, **institutional coordination among water-related departments** needs to be improved through integrated planning platforms at the district level. Establishing a district water coordination committee involving departments responsible for irrigation, drinking water supply, agriculture, and rural development can facilitate data sharing and coherent decision-making.

Finally, **community participation and awareness** should be strengthened through capacity-building programmes and participatory water management initiatives. Encouraging the formation of water user groups and involving local communities in monitoring and maintenance can enhance ownership and sustainability of water resources.



CONCLUSION

The present study highlights that water resource management in Banka District is characterized by high dependence on groundwater, limited and declining surface water storage, and strong seasonal variability in water availability. Agriculture dominates water demand, while domestic water use, though smaller in volume, holds critical social importance. The combined pressure of inefficient irrigation practices, degradation of traditional water bodies, and unregulated groundwater extraction has resulted in localized water stress, particularly during the pre-monsoon period.

The findings underscore that existing sector-wise and fragmented management approaches are inadequate to address the complex and interlinked nature of water challenges at the district level. Integrated Water Resource Management offers a suitable and sustainable framework by emphasizing coordinated planning, demand management, institutional integration, and community participation. Strengthening

groundwater regulation, improving water-use efficiency in agriculture, revitalizing traditional surface water systems, and enhancing inter-departmental coordination emerge as key priorities.

Overall, the study concludes that adoption of IWRM principles in district-level planning is essential for ensuring long-term water security and resilience in Banka District. The insights generated by this research can support evidence-based policymaking and serve as a reference for similar agrarian districts of Bihar facing comparable water resource challenges.

Overall, adopting these policy measures within the IWRM framework can contribute significantly to improving water security and resilience in Banka District, while offering a replicable model for other agrarian districts of Bihar.

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