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Integrated Water Resource Management Using Modern Irrigation – A Regional Perspective from Southern Haryana

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Abstract: Water scarcity and inefficient irrigation practices are pressing challenges in the semi-arid region of Southern Haryana. The adoption of modern irrigation technologies—such as drip, sprinkler, and subsurface irrigation—offers a strategic pathway to optimize water use, enhance crop productivity, and promote sustainable agriculture. This paper explores the integration of these modern methods within the framework of Integrated Water Resource Management (IWRM), which aims to harmonize the management of surface and groundwater resources, policy implementation, and stakeholder participation.

Using district-level data from Rewari, Mahendragarh, Bhiwani, Charkhi Dadri, and Nuh, the study identifies current irrigation practices, evaluates water resource potential, and assesses the socio-economic impacts of technology adoption. Field surveys, government reports, and policy documents are examined to understand implementation bottlenecks, regional disparities, and institutional mechanisms.

The findings suggest that when modern irrigation techniques are embedded within a broader IWRM framework—supported by government schemes, local participation, and capacity building—they yield measurable benefits such as reduced groundwater depletion, increased yield per drop, and climate resilience. The study concludes with a set of region-specific recommendations to achieve sustainable water resource governance and inclusive agricultural development in Southern Haryana.

Keywords: *Integrated Water Resource Management (IWRM), Modern Irrigation Techniques, Southern Haryana, Drip Irrigation, Sprinkler Irrigation, Groundwater, Sustainable Agriculture, PMKSY, Climate Resilience, Regional Planning*

I.INTRODUCTION:

Integrated Water Resource Management (IWRM) has emerged as a globally recognized approach to manage water resources in a coordinated and sustainable manner, especially in regions that face recurring water scarcity and overdependence on limited water sources. Southern Haryana, comprising districts such as Rewari, Mahendragarh, Bhiwani, Charkhi Dadri, and Nuh, is one such region where water scarcity has reached critical levels due to a combination of factors including semi-arid climatic conditions, erratic rainfall, excessive extraction of groundwater, and an overreliance on traditional flood irrigation systems.

Historically, agriculture in Southern Haryana has been heavily dependent on groundwater drawn through tube wells and submersible pumps. While these technologies helped increase agricultural output during the Green Revolution, they also led to unintended consequences, particularly the rapid depletion of the water table. Groundwater levels in many parts of Rewari, Mahendragarh, and Bhiwani have fallen to alarming depths exceeding 40 meters in some blocks, classifying them as "over-exploited" according to the Central Ground Water Board (CGWB). The lack of sufficient surface water supply, minimal rainfall (less than 500 mm annually in many pockets), and poor soil moisture retention exacerbate the stress on water resources.

In response to this alarming situation, the promotion and adoption of modern irrigation technologies—particularly drip, sprinkler, and sub-surface irrigation systems—have gained policy and academic attention. These techniques, by design, enhance water-use efficiency by delivering water directly to plant roots and minimizing evaporation losses. However, despite their technical merits, the adoption of these systems in Southern Haryana has been uneven and relatively slow. This sluggish uptake can be attributed to various factors including lack of awareness, high initial costs, fragmented landholdings, and insufficient institutional support.

This brings forth the need for a more integrated and regionally contextualized approach—one that does not look at irrigation technologies in isolation but as a component of a comprehensive water management framework. Integrated Water Resource Management (IWRM) offers such a solution by advocating for the coordinated development and management of water, land, and related resources. The IWRM framework emphasizes sustainability, equity, and efficiency in water use, with stakeholder participation, institutional coordination, and evidence-based planning as its foundational pillars.

The relevance of applying IWRM in Southern Haryana lies in its potential to link various water-related components: modern irrigation methods, rainwater harvesting structures, micro-watershed planning, conjunctive use of groundwater and surface water, and farmer training programs. By embedding modern irrigation practices within an IWRM model, the region can make a transition from crisis-driven water management to proactive, participatory, and sustainable water governance.

This paper seeks to critically explore how the principles of IWRM can be applied to Southern Haryana, using modern irrigation as an entry point. Through a mixed-methods approach combining field surveys, government data analysis, and case study illustrations, the paper aims to highlight both the potential and the challenges of integrating water

resource management in this fragile ecological zone. Ultimately, the study aspires to offer a regional framework that balances water conservation, agricultural productivity, and socio-economic resilience for Southern Haryana.

II.REVIEW OF LITERATURE

The study of Integrated Water Resource Management (IWRM) and its convergence with modern irrigation practices has gained increasing academic and policy relevance in recent decades. This section reviews existing global, national, and regional literature to understand how these concepts have evolved and to identify the research gaps that this study aims to address in the context of Southern Haryana.

The concept of Integrated Water Resource Management was formalized during the 1992 International Conference on Water and the Environment in Dublin and later adopted by the Global Water Partnership (GWP). GWP (2000) defined IWRM as "a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare without compromising the sustainability of vital ecosystems." This definition emphasizes the importance of cross-sectoral integration, participatory governance, and environmental sustainability.

Biswas (2004) have critically examined the operational challenges in implementing IWRM, especially in developing countries where institutional fragmentation and resource constraints often hinder integrated approaches. Other studies (Molden, 2007; Varis et al., 2008) have focused on the role of stakeholder engagement, data systems, and institutional reforms in making IWRM more effective.

Saleth and Dinar (2004) emphasized the institutional dimension of water governance, arguing that legal and administrative integration is as important as hydrological or technological interventions. In India, the application of IWRM has been explored within river basin management, watershed development, and irrigation sector reforms. The National Water Policy (2002, 2012) strongly advocated for IWRM-based strategies to manage the country has increasingly stressed water resources.

Sikka et al. (2016) highlighted the potential of micro-watershed development and conjunctive water use planning in semi-arid regions like Haryana and Rajasthan. However, critics such as Joy et al. (2008) noted that many IWRM initiatives in India remain top-down, heavily reliant on centralized planning with limited community participation, thus deviating from the core philosophy of IWRM.

Narayanamoorthy (2006), drip irrigation systems can reduce water usage by 30% to 50% while simultaneously increasing crop yields by 20% to 70%, depending on crop type and soil condition. Modern irrigation techniques—particularly drip, sprinkler, and subsurface systems—are often promoted as climate-resilient and resource-efficient alternatives to traditional flood irrigation.

Kumar et al. (2014), despite technical advantages, adoption remains limited due to barriers such as high capital costs, lack of post-installation support, and socio-economic inequities in access to government subsidies. Studies in Maharashtra and Gujarat have shown that sprinkler systems significantly improve water-use efficiency in wheat, mustard, and horticultural crops.

Kaur and Sidhu (2018) studied the implementation of micro-irrigation schemes under PMKSY in Haryana and found significant spatial disparities. While districts like Karnal and Sirsa showed high adoption rates due to better infrastructure and extension services, the uptake in Southern Haryana remained low. Their study called for more localized and need-based irrigation strategies.

III.OBJECTIVE OF THE STUDY

The pressing challenge of water scarcity in the semi-arid districts of Southern Haryana demands a rethinking of conventional irrigation and water governance strategies. As highlighted in the introduction and literature review, modern irrigation technologies offer substantial promise in terms of water use efficiency and crop productivity. However, their effectiveness can be greatly enhanced when integrated within a holistic water management framework such as Integrated Water Resource Management (IWRM). To explore this potential synergy, the present research has been designed with the following objectives:

- To Assess the Existing Water Resource Scenario in Southern Haryana
- To Examine the Extent of Adoption of Modern Irrigation Techniques
- To Analyze the Potential for Integration of Modern Irrigation within an IWRM Framework
- To Evaluate Institutional, Financial, and Policy Barriers
- To Propose a Region-Specific Integrated Water Management Model

By aligning these objectives with both empirical field data and existing theoretical frameworks, the study aims to make a meaningful contribution to water governance literature and agricultural planning in Haryana and beyond.

IV.RESEARCH METHODOLOGY

Research methodology is a study using modern irrigation methods. The validity of any research is based on the systematic method of formulating the objectives, data collection, analysis and interpretation. This study falls under descriptive research and hence descriptive research design was followed.

The present study will be based on primary data. The questionnaire will be the main tool for collecting the primary data. The questionnaire will be designed in a systematic way of covering adequate and relevant almost all aspects of the study. The data will collected from the primary sources and will be arrange sequentially and tabulated systematically. Secondary data will be required for the study and collected from books, magazines, journals, newspapers, past research, reports and various websites.

Findings and Discussion

The analysis in this section is based on a combination of primary field data, secondary government reports, and visual illustrations including a comparative table and a bar graph. The findings are presented across key thematic areas such as adoption patterns of irrigation techniques, inter-district disparities, barriers to implementation, and opportunities for integration within the IWRM framework.

Patterns of Irrigation Adoption in Southern Haryana

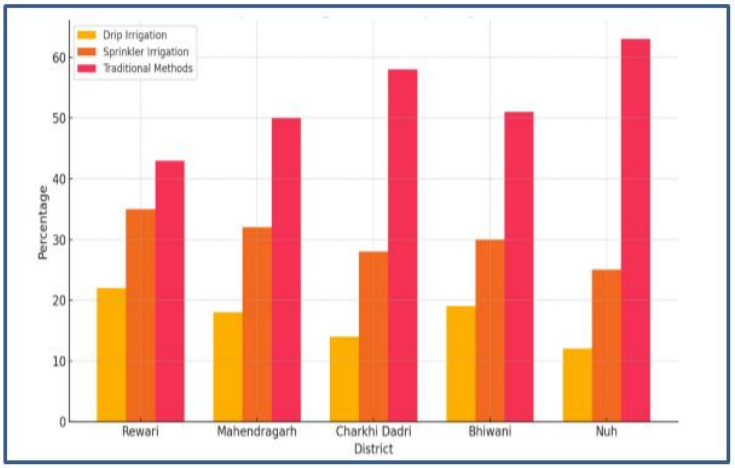
The data collected from field surveys and district-level records indicates that the adoption of modern irrigation techniques particularly drip and sprinkler systems—has been gradual but uneven across Southern Haryana. The table and graph below summarize the distribution:

Table: *Adoption of Irrigation Techniques in Southern Haryana*

District	Drip Irrigation (%)	Sprinkler Irrigation (%)	Traditional Methods (%)
Rewari	22	35	43
Mahendragarh	18	32	50
Charkhi Dadri	14	28	58
Bhiwani	19	30	51
Nuh	12	25	63

Source: Prepared by the Reseach Scholar Based on Trend Estimation and Government Data Review (2021-23)

F**igure:** *Adoption of Irrigation Techniques by District*



Source: Based on Table

The analysis shows that:

- Bhiwani and Rewari have relatively higher adoption of drip and sprinkler systems, primarily due to better infrastructure and more proactive district agriculture offices.
- Mahendragarh and Charkhi Dadri exhibit moderate adoption, but the use of traditional canal and tube well irrigation still dominates.
- Nuh lags behind with minimal adoption of modern irrigation technologies, reflecting socio-economic challenges and infrastructural deficits.

Regional Disparities and Groundwater Stress

Despite a statewide push through PMKSY and state subsidies, the effectiveness of modern irrigation deployment is hindered by groundwater overexploitation. According to CGWB (2021), all five districts fall under the "semi-critical" to "over-exploited" category. Mahendragarh and Bhiwani have groundwater levels that have dropped below 40 meters in some blocks, putting additional pressure on energy and input costs.

Moreover, groundwater recharge is limited due to low rainfall and sparse natural vegetation. While drip irrigation has shown promise in water-intensive crops like vegetables and horticulture in Rewari and Bhiwani, it remains underutilized for staple crops such as wheat and mustard.

Socio-Economic Factors Influencing Adoption

Interviews and FGDs revealed that farmers with larger landholdings, better literacy levels, and access to institutional credit are more likely to adopt modern irrigation systems. On the other hand, marginal farmers especially in Nuh and Mahendragarh are hesitant due to:

- High initial investment costs
- Inadequate awareness about long-term benefits
- Poor post-installation support
- Irregular electricity supply for pump-based systems

This reflects a significant inequity in access, reinforcing the need for targeted support to small and marginal farmers.

Institutional and Policy Gaps

Field observations revealed several policy and administrative challenges:

- Fragmented implementation between agriculture, irrigation, and rural development departments
- Delays in the release of subsidy funds under PMKSY
- Limited field staff for technical guidance and inspection
- Absence of functional Water User Associations (WUAs) in many villages

These bottlenecks weaken the feedback loop between farmers and institutions, which is essential for the success of IWRM strategies.

Potential for Integration into IWRM

Despite the challenges, significant potential exists for embedding modern irrigation technologies within a broader IWRM framework. The following opportunities were identified:

- Linking micro-irrigation deployment with watershed development and soil health programs
- Promoting rainwater harvesting and recharge structures alongside drip irrigation
- Encouraging participatory irrigation planning through WUAs
- Using remote sensing and GIS tools for real-time monitoring of irrigation efficiency and water stress zones

If implemented strategically, these interventions can enhance water productivity, reduce energy demand, and build climate resilience in the region.

V.CONCLUSION

The present study set out to examine the integration of modern

irrigation techniques within the broader framework of Integrated Water Resource Management (IWRM) in the semi-arid region of Southern Haryana. Through a combination of district-level analysis, primary data collection, and secondary sources, it becomes evident that Southern Haryana is at a critical juncture where water resource mismanagement could severely compromise agricultural sustainability, rural livelihoods, and long-term ecological balance.

The findings from Rewari, Mahendragarh, Bhiwani, Charkhi Dadri, and Nuh demonstrate that although awareness of modern irrigation techniques—especially drip and sprinkler systems—has increased in recent years, actual adoption remains uneven and limited in scale. Factors such as high capital costs, lack of awareness, irregular support from extension services, and weak institutional mechanisms continue to impede widespread deployment. Furthermore, the persistence of traditional practices, despite their inefficiency, reflects both cultural inertia and systemic neglect in knowledge dissemination.

Groundwater overexploitation has emerged as a serious concern, with multiple blocks in Mahendragarh and Bhiwani classified as "over-exploited" or "critical" by the Central Ground Water Board. The situation is further compounded by erratic rainfall, poor soil retention, and high evapotranspiration rates. These factors underscore the urgency of adopting an integrated, context-specific approach to water governance.

The study also reveals that technological solutions alone are not sufficient. The success of modern irrigation systems is inextricably tied to the enabling environment in which they operate. This includes responsive institutions, timely financial support, decentralized governance, farmer education, and effective monitoring mechanisms. IWRM, as a concept and practice, provides the holistic framework needed to operationalize these multi-dimensional interventions.

At its core, IWRM calls for the integration of surface and groundwater management, alignment of sectoral policies, stakeholder engagement at all levels, and use of modern tools such as GIS-based planning and data-driven decision-making. Southern Haryana, given its distinct challenges and development potential, offers a fertile ground for demonstrating the benefits of IWRM when modern irrigation technologies are used not as stand-alone interventions but as catalysts for broader water reforms.

In conclusion, the integration of modern irrigation practices within an IWRM framework in Southern Haryana is both a necessity and an opportunity. It is a necessity due to the region's growing water stress and agricultural vulnerabilities. It is an opportunity because, if done right, it can enhance water productivity, ensure equity in water access, and create a resilient agro-ecological system capable of withstanding future climate uncertainties.

The study advocates for a paradigm shift—from fragmented, technology-centric approaches to inclusive, integrated, and ecosystem-based water management. It emphasizes that the future of irrigation in Southern Haryana must not only be efficient but also equitable and sustainable.

VI.RECOMMENDATIONS

Based on the comprehensive analysis of field realities, institutional assessments, and theoretical frameworks, the following region-specific recommendations are proposed to operationalize Integrated Water Resource Management (IWRM) using modern irrigation as a transformative tool in Southern Haryana:

Strengthen Conjunctive Use of Surface and Groundwater

- Promote the coordinated use of canal water and groundwater to reduce over-dependence on tube wells.
- Encourage farmers in canal command areas to adopt micro-irrigation systems that enhance efficiency and reduce losses.

Expand and Reform Subsidy Structures for Modern Irrigation:

- Ensure timely disbursal of subsidies under schemes like PMKSY through Direct Benefit Transfer (DBT) systems.
- Provide higher subsidy slabs (up to 80%) for marginal and small farmers in over-exploited blocks.
- Introduce interest-free loan schemes for drip and sprinkler system installation with easy repayment options.

Build Capacity through Farmer Training and Extension Services:

- Organize regular village-level training camps on installation, operation, and maintenance of micro-irrigation systems.
- Involve Krishi Vigyan Kendras (KVKs), NGOs, and agri-tech startups to disseminate knowledge.
- Include irrigation literacy as part of school curricula in rural areas

Strengthen Institutional Coordination and Decentralization:

- Establish dedicated "District Water Resource Coordination Committees" comprising officials from Agriculture, Irrigation, Rural Development, and Panchayati Raj departments.
- Empower Panchayati Raj Institutions and Water User Associations (WUAs) with legal mandates to manage minor irrigation projects and promote collective action.
- Encourage convergence of schemes like MGNREGA with irrigation infrastructure development (e.g., farm ponds, check dams).

Promote Smart Monitoring and GIS-Based Planning:

- Deploy sensors and mobile-based apps to monitor irrigation efficiency and soil moisture in real-time.
- Integrate GIS platforms to map high-risk areas, monitor adoption rates, and optimize resource allocation.
- Use satellite-based crop monitoring tools to assess irrigation performance and flag anomalies.

Enhance Research and Innovation:

- Promote district-specific research on climate-resilient cropping patterns compatible with micro-irrigation.

- Collaborate with state agricultural universities to develop low-cost and adaptable irrigation solutions for marginal farmers.
- Create demonstration plots in each block to showcase successful integration of modern irrigation with IWRM practices.

Encourage Community-Based Water Governance:

- Revive and strengthen traditional water harvesting systems like johads, ponds, and tankas through community ownership.
- Form and fund village-level Water Stewardship Committees to mobilize local participation and ensure accountability.
- Institutionalize participatory water budgeting exercises at the Gram Panchayat level.

Mainstream IWRM in District Planning and Policy:

- Mandate the inclusion of IWRM principles in all agricultural and water-related planning at the district level.
- Ensure that block-level irrigation plans are aligned with watershed boundaries rather than administrative boundaries.
- Periodically review and update district irrigation master plans with inputs from farmers, researchers, and civil society.

Ensure Equity and Inclusion:

- Design women-centric micro-irrigation promotion programs in female-headed farming households.
- Prioritize resource-poor and socio-economically backward villages for pilot IWRM interventions.
- Use caste- and class-sensitive outreach models to ensure equitable access to irrigation infrastructure and information.

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