IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 18, Issue 9 Ser. 1 (September. 2025), PP 34-43
www.Iosrjournals.Org

Changing Irrigation Patterns And Policy Implications For Livelihoods And Agricultural Development In Kaushambi District, U. P.

Dr. Chandramauli,
Associate Professor

Arun Kumar,
Research Scholar
Department of Geography
Indira Gandhi National Tribal University, Amarkantak, M.P.

Abstract
Irrigation is essential for agricultural development in India; its distribution and significant use affect the sustainability of agriculture. Sustainable use of water plays a key role in enhancing agricultural production, income and environmental conditions. In Uttar Pradesh, a key farming state, irrigation has changed dramatically, reflecting a national trend shifting from surface water systems like canals, ponds, and dams to groundwater use. The present study is about Kaushambi district, located in the lower Ganga-Yamuna Doab, which is an essential case for studying these changes. This research examines block-level data on net and gross irrigated areas and irrigation sources for 2000, 2012, and 2024. The findings show an apparent decline in canal irrigation, with tube wells now providing more than 80 per cent of irrigation. Although this shift has led to higher cropping intensity and increased agricultural output, it raises serious concerns about groundwater depletion, unequal access to irrigation, and long-term water security. Blocks like Muratganj and Sirathu show significant growth in irrigated land, while blocks like Kada and Chail remain stagnant, highlighting resource imbalances. The study stresses the need for balanced water management strategies incorporating canal restoration, groundwater regulation, crop diversification, and community involvement. Policy suggestions aim to support sustainable agricultural growth in the Kaushambi district.
Keywords: *Irrigation patterns, irrigation system, net irrigation, spatial disparity, water management, agricultural sustainability, Livelihoods*

Date of Submission: 17-09-2025 Date of Acceptance: 27-09-2025

I.Introduction

Irrigation is crucial in shaping agriculture in India, where nearly two-thirds of the population relies on farming for their livelihood. The sustainability of agriculture, especially in semi-arid regions, depends mainly on the availability, accessibility, and effectiveness of irrigation systems (Sharma & Singh, 2017). In Uttar Pradesh, one of India's major agricultural states, irrigation development has historically supported agricultural growth (Government of Uttar Pradesh, 2022). However, changes in water use, population growth, and technological advances have significantly altered irrigation practices across the different districts (Verma, 2019). Kaushambi district reflects these changes clearly. Traditionally reliant on canal irrigation, it has gradually shifted to tube well use. Between 2000 and 2024, records show a notable decline in canal irrigation, while tube wells have become the primary source, providing over 80 percent of the irrigated area (District Statistical Handbook, 2024). This growing reliance on groundwater has increased cropping intensity and expanded farmland, but it has also raised concerns about sustainability, regional inequalities, and long-term water security (Shah, 2009). Studying the changing irrigation patterns in Kaushambi is vital to understanding the shifts in water use and their effects on agricultural sustainability. A block-level analysis shows that while areas like Muratganj and Sirathu have seen significant growth in irrigated land, others remain stagnant, highlighting resource inequalities (Singh & Prasad, 2020). The increasing pressure on groundwater in specific blocks and the declining role of canals stress the need to rethink irrigation strategies in the district. This study aims to examine the trends and variations in irrigation sources over time, analyse their impact on farming practices, and offer policy recommendations to encourage sustainable irrigation. This research seeks to contribute to the ongoing discussion about water management and agricultural sustainability in Uttar Pradesh by examining the quantitative changes and their social and economic implications.

II. Literature Review

Irrigation has consistently been recognised as a key component of Indian agriculture, affecting cropping patterns, productivity, and rural livelihoods. Since the Green Revolution, expanding irrigation facilities, especially groundwater use through tube wells, has transformed India's agricultural economy (Shah, 2009). Research shows that while irrigation expansion has improved food security, it has also resulted in significant sustainability challenges, notably groundwater depletion and regional inequalities (Mukherji et al., 2012). National studies indicate that India has gradually shifted from canal-based irrigation to groundwater systems since the 1970s (Sharma & Sharma, 2017). Uttar Pradesh exemplifies this transition, with groundwater providing more than 75% of its irrigation (Singh & Prasad, 2020). Government reports (Government of Uttar Pradesh, 2022) point out that although canal irrigation infrastructure exists, its efficiency and coverage have declined due to poor maintenance and silting. In the Ganga-Yamuna Doab, districts near canal networks initially benefited more, while peripheral areas have increasingly depended on tube wells (Verma, 2019). Block-level variations are significant, with some areas experiencing irrigation growth while others remain stagnant (Singh, 2014). These disparities affect cropping intensity, income levels, and agricultural sustainability; however, Groundwater development has been praised for providing reliable irrigation, especially during monsoon failures (Shah, 2009). However, over-extraction has sparked concerns about declining water tables, rising energy costs, and long-term feasibility (Mukherji et al., 2012). Studies in eastern Uttar Pradesh indicate that heavy reliance on tube wells has created economic benefits and environmental risks, making sustainable groundwater management a crucial policy priority (Singh & Prasad, 2020). Initiatives like the Pradhan Mantri Krishi Sinchai Yojana (PMKSY) and Atal Bhujal Yojana aim to enhance water-use efficiency and promote community-based management (Government of India, 2021). Scholars argue that restoring canal systems, encouraging micro-irrigation, and supporting crop diversification are key strategies for sustainable irrigation (Sharma & Sharma, 2017; Verma, 2019).

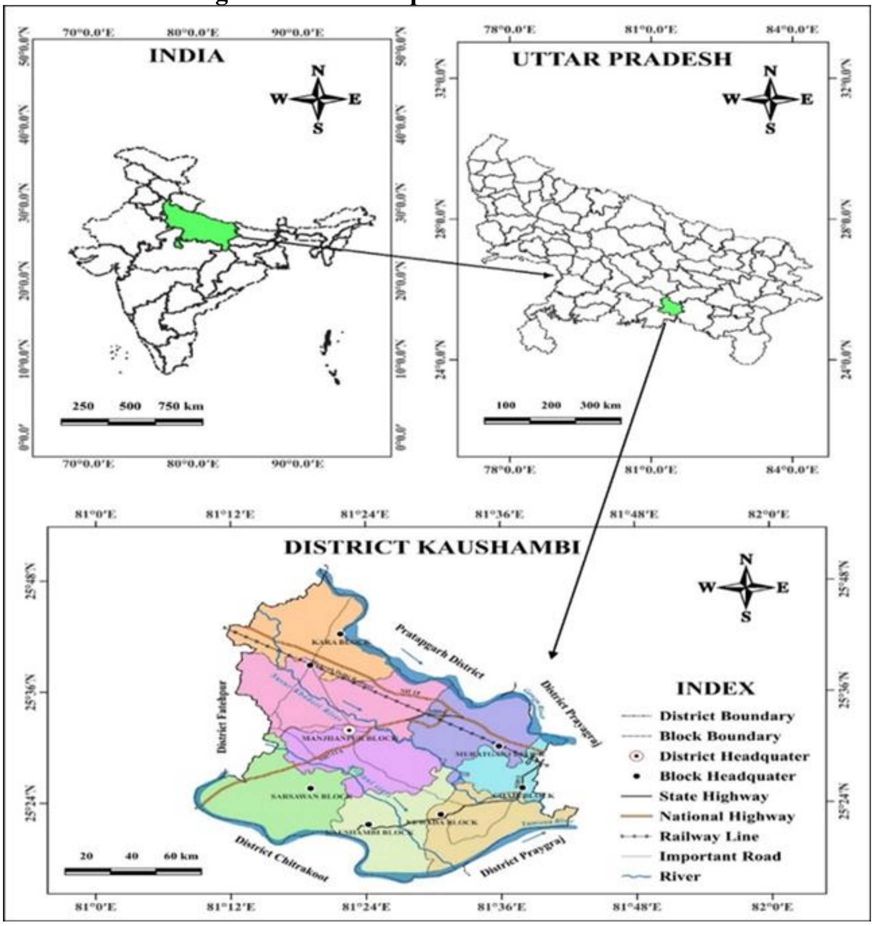
While many studies focus on irrigation at the state and regional levels, little research explicitly addresses the Kaushambi district, despite its unique position in the lower Ganga-Yamuna Doab. The district reflects broader trends-declining canal use and rising tube well reliance-but also displays block-level disparities that need further investigation. This study fills that gap by examining the temporal and spatial changes in irrigation patterns in Kaushambi and exploring policy implications for sustainable agriculture.

III. Study Area

District Kaushambi is a part of the Ganga-Yamuna Doab region located in the south-east of Uttar Pradesh. Its latitudinal extension is between 25° 15' north to 25° 47' north latitude, and longitudinal extension is between 81° 12' east to 81° 47' east longitude (Fig.1). District Kaushambi is surrounded by Prayagraj in the east, Fatehpur in the west, Pratapgarh in the north and Chitrakoot in the south and south-west. Administratively, Kaushambi district is divided into three tehsils, namely: Manjhanpur, Sirathu and Chail and eight development blocks, namely: Kara, Sirathu, Sarsawan, Manjhanpur, Kaushambi, Muratganj, Chail and Newada. The district headquarters is in Manjhanpur. District Kaushambi is one of the medium-sized districts of Uttar Pradesh whose total geographical area is about 1,779 square km. Fertile and highly agriculturally viable alluvial soil formed by the Ganga-Yamuna is found here, which is suitable for cultivating cereals and pulses.

The district has a subtropical monsoon climate characterised by extreme heat in summer and extreme cold in winter, while rainfall is normal. The average annual rainfall is about 900-1,000 mm, which occurs mainly during the monsoon season. Due to the irregular distribution of rainfall in the district, irrigation becomes an essential factor for agricultural sustainability. Groundwater levels vary in different blocks, and continuous exploitation through tube wells has led to local depletion of water levels in some areas.

Fig.1: Location Map of Kaushambi District



Source*: Survey of India & Census of India*

IV. Objectives

1. To analyse the notable and temporal changes in net and gross irrigated area in Kaushambi district between 2000 and 2024.
2. To examine spatial disparities in irrigation development across different blocks of the district.
3. To study the changing contribution of irrigation sources (canals, tube wells, and others) and their relative importance over time.
4. To identify policy gaps and recommend strategies for sustainable irrigation management in Kaushambi, focusing on groundwater regulation, canal revitalisation, crop diversification, and community-based water governance.

V. Database And Methodology

The present study is mainly based on secondary data collected from the District Statistical Handbook (2000, 2012 and 2024) of Kaushambi district. Additional data were collected from Statistical Abstracts of Uttar Pradesh, government reports of the Directorate of Economics and Statistics, and reviewed published works on irrigation development and water resources management. Various relevant research papers, books and policy documents have also been examined to provide theoretical and comparative insights. Block-wise comparisons were made to highlight the differences in irrigation development in the Kaushambi district. MS Office was used to show trends over time and to depict irrigation patterns.

VI. Results And Discussion

The results of this study present an in-depth analysis of the irrigation scenario in Kaushambi district, Uttar Pradesh, for the years **2000, 2012, and 2024**. By examining temporal shifts, spatial patterns, and source-wise irrigation dynamics, the study highlights the changing role of irrigation in shaping agricultural practices and its implications for sustainability.

Temporal Changes in Irrigation (2000–2024)

Net Irrigated Area (NIA)

The net irrigated area of Kaushambi district increased from 74,809 hectares in 2000 to 94,424 hectares in 2012, reflecting an expansion of about 26%. By 2024, however, the net irrigated area declined slightly to 92,390 hectares, indicating stagnation. The overall growth from 2000 to 2024 was 23.5% (Table 1).

This temporal change demonstrates two important trends. First, the early 21st century witnessed rapid irrigation expansion, driven by tube well development and government programs aimed at rural infrastructure improvement. Second, the recent decline reflects a saturation effect, where further expansion has been constrained by groundwater stress and declining canal use.

Gross Irrigated Area (GIA)

Gross irrigated area, which accounts for multiple cropping on the same land, showed a more pronounced rise. It increased from 93,062 hectares in 2000 to 123,157 hectares in 2012 and 1,72,146 hectares in 2024 (Table 2). This represents an impressive growth of 84.98% over the study period.

The increase in gross irrigated area relative to net irrigated area suggests a substantial rise in cropping intensity, made possible by reliable tube well irrigation. Farmers increasingly cultivated two or three crops annually, especially wheat, paddy, and pulses. While net irrigated expansion slowed after 2012, gross irrigation continued to rise due to intensification, not expansion. This indicates a shift from area expansion to crop intensification, an essential marker of agricultural transformation in Kaushambi.

Spatial Patterns: Block-Wise Variations

Block-level analysis reveals stark disparities in irrigation development:

- **High-Performing Blocks**:
  - *Muratganj*: Net irrigation rose from 6,050 (2000) to 9,224 ha (2024), and gross irrigation skyrocketed from 7,484 to 22,694 ha (+203%).
  - *Manjhanpur*: Gross irrigation more than doubled (11,601 to 25,123 ha), reflecting intensive use of tube wells.
  - *Kaushambi block*: Gross irrigation grew by 83%, indicating steady intensification.

Table 1: Net Irrigated Area by blocks (2000–2024)

Year / Blocks	2000		2012		2024		Change (2000-2024)	
	ha	%	ha	%	ha	%	ha	%
Kada	11,514	76.15	15,868	89.07	19,972	137.53	8,458	73.46
Sirathu	16,506	75.71	24,695	101.48	23,485	121.70	6,979	42.28
Sarsawan	14,155	75.20	20,422	96.86	19,972	113.64	5,817	41.10
Manjhanpur	11,601	73.64	15,325	97.34	25,123	203.52	13,522	116.56
Kaushambi	12,277	72.26	14,659	86.85	22,581	184.41	10,304	83.93
Muratganj	7,484	54.55	12,563	87.55	22,694	196.54	15,210	203.23
Chail	8,537	53.07	6,563	99.45	19,972	122.94	11,435	133.95
Newada	10,988	57.28	13,062	82.11	18,347	192.07	7,359	66.97
Total	**93,062**	**67.69**	**123,157**	**92.80**	**172,146**	**151.90**	**79,084**	**84.98**

Source: *Calculated from the Statistical Handbook of Kaushambi District, U.P.* (2000, 2012, & 2024)

Table 2: Gross Irrigated Area by blocks (2000–2024)

Year / Blocks	2000		2012		2024		Change (2000-2024)	
	ha	%	ha	%	ha	%	ha	%
Kada	9,578	63.35	11,440	64.21	10,694	73.64	1,116	11.65
Sirathu	12,453	57.12	16,246	66.76	18,260	94.62	5,807	46.63
Sarsawan	11,137	59.17	15,766	74.78	14,393	81.89	3,256	29.24
Manjhanpur	9,787	62.12	9,989	63.45	9,295	75.30	-492	-5.03
Kaushambi	10,207	60.07	11,465	67.92	11,001	89.84	794	7.78
Muratganj	6,050	44.10	11,423	79.61	9,224	79.88	3,174	52.46
Chail	6,790	42.21	5,848	88.62	7,728	47.57	938	13.81
Newada	8,807	45.91	12,247	76.99	11,795	123.48	2,988	33.93
Total	**74,809**	**54.42**	**94,424**	**71.15**	**92,390**	**81.52**	**17,581**	**23.50**

Source: *Calculated from the Statistical Handbook of Kaushambi District, U.P.* (2000, 2012, & 2024)

- **Moderate-Performing Blocks**:
  - *Sirathu*: Net irrigated area increased significantly (12,453 to 18,260 ha, +47%), though growth slowed after 2012.
  - *Sarsawan*: Showed healthy growth initially, but later faced slight declines due to canal-tube well adjustments.
- **Low-Performing Blocks**:
  - *Kada*: Despite high initial reliance on tube wells, growth was modest, reflecting physical constraints.
  - *Chail*: Fluctuations in net irrigation, with slight expansion (6,790 to 7,728 ha, only +13.8%).
  - *Newada*: Net irrigation rose from 8,807 to 11,795 ha (+34%), but fluctuations in canals reduced reliability.

Irrigation growth is spatially uneven. Blocks like Muratganj and Manjhanpur benefited disproportionately, while Chail and Kada lagged, creating intra-district disparities in agricultural opportunities.

Source-Wise Analysis: Canals vs. Tube Wells vs. Others

Canal Irrigation

- Declined from 13,513 ha in 2000 (18.1%) to 12,790 ha in 2024 (13.8%) (Table 3).
- Strong only in the *Sarsawan* and *Kaushambi blocks*, but declining in both.
- Absent in Kada, Muratganj, and Chail.
- Peak in 2012 (15,921 ha) declined afterwards due to siltation, poor maintenance, and unreliable supply.

Table 3: Source-wise irrigation share (in hectares) by blocks

Year / Blocks	2000				2012				2024			
	Canal	Tube Well	Other	Total	Canal	Tube Well	Other	Total	Canal	Tube Well	Other	Total
Kada	0	9,516	62	9,578	0	11,440	0	11,440	0	12,017	21	12,038
Sirathu	35	12,078	340	12,453	0	16,246	0	16,246	2,344	15,224	114	17,682
Sarsawan	6,286	4,794	57	11,137	10341	5,415	10	15,766	3,411	10,004	0	13,415
Manjhanpur	287	9,500	0	9,787	530	9,453	6	9,989	2,348	7,369	0	9,717
Kaushambi	5,990	4,184	33	10,207	4813	6,589	63	11,465	3,373	8,040	0	11,413
Muratganj	0	6,050	0	6,050	0	11,423	0	11,423	0	10,043	0	10,043
Chail	0	6,790	0	6,790	0	5,848	0	5,848	0	8,050	0	8,050
Newada	915	7,892	0	8,807	237	12,010	0	12,247	1,314	9,040	41	10,395
Total	**13,513**	**60,804**	**492**	**74,809**	**15921**	**78,424**	**79**	**94,424**	**12,790**	**79,787**	**176**	**92,753**

Source: *Calculated from the Statistical Handbook of Kaushambi District, U.P.* (2000, 2012, & 2024)

Tube Well Irrigation

- Rose consistently: 60,804 ha in 2000 (81.3%) to 79,787 ha in 2024 (86.0%).
- Nearly exclusive in Kada, Muratganj, and Chail (100% dependence).
- Dominant in Sirathu and Newada, although 2024 saw minor declines due to local canal revival.

Other Sources (Ponds, Tanks, Wells)

- Negligible, declining from 492 ha (0.66%) in 2000 to just 176 ha (0.19%) in 2024.
- Traditional water sources have lost relevance, indicating erosion of community water systems.

Tube wells have replaced canals as the backbone of irrigation in Kaushambi. While beneficial for cropping intensity, this trend has raised alarms regarding groundwater depletion.

Emerging Trends in Irrigation

The irrigation landscape of Kaushambi district has undergone significant structural shifts between 2000 and 2024, reflecting both growth and challenges. Several emerging trends highlight the transformation in water use, agricultural practices, and sustainability.

Over-Reliance on Groundwater: Tube wells have become the backbone of irrigation in Kaushambi, now accounting for more than 85% of the irrigated area. While this expansion has reduced dependence on rainfall and improved cropping intensity, it has also created serious vulnerabilities. Blocks such as Muratganj and Sirathu exhibit particularly high tube well density, making them prone to rapid groundwater depletion. The unsustainable pace of extraction threatens the long-term viability of irrigation and agricultural productivity in the district.

Declining Role of Canals: Once a vital component of Kaushambi's irrigation system, canals have steadily declined in both use and importance. In regions like the Kaushambi block and Sarsawan, canals historically provided a reliable surface water supply. Today, their contribution has diminished due to poor maintenance, silt accumulation, and irregular flow. The neglect of canal systems undermines the balancing role of surface water in ensuring sustainability, leaving agriculture almost entirely dependent on groundwater.

Regional Disparities: Irrigation growth has been uneven across the district. Blocks such as Muratganj, Manjhanpur, and Sirathu have witnessed significant irrigation expansion, resulting in higher cropping intensity and improved productivity. In contrast, Kada and Chail continue to lag behind, reflecting persistent intra-district inequalities. These disparities reinforce differences in agricultural output and rural incomes, creating uneven development within the district.

Intensification Over Expansion: Another striking trend is the stagnation of net irrigated area after 2012. While gross irrigated area continued to increase, the gains came mainly from intensification of existing irrigated land rather than expansion into new areas. This indicates that farmers are cultivating multiple crops per year on the same fields, raising cropping intensity but also increasing stress on water resources, particularly groundwater.

Disappearance of Traditional Sources: Traditional water sources such as tanks, dug wells, and community-managed systems have nearly disappeared from Kaushambi's irrigation portfolio. These sources once provided supplementary irrigation and supported local resilience during drought years. Their decline has reduced the diversity of irrigation options, leaving farmers more vulnerable to groundwater scarcity and rainfall variability.

Sustainability Concerns: The emerging trends raise serious sustainability issues for the future of irrigation in Kaushambi. Over-extraction of groundwater risks a steady decline in water tables, while rising dependence on electric and diesel pumps increases costs and energy use. Equity concerns also emerge, as poorer farmers without access to private tube wells remain disadvantaged, particularly in low-performing blocks like Kada and Chail. Finally, heavy dependence on groundwater makes agriculture highly sensitive to climate variability, especially erratic monsoons, further reducing resilience in the district.

Kaushambi's irrigation trajectory reflects both achievements and challenges. While the district has expanded irrigation and intensified agriculture, this progress has been accompanied by deepening sustainability concerns, spatial disparities, and rising risks for the future. Addressing these issues will require integrated water management, canal revitalisation, and promotion of less water-intensive crops.

VII. Policy Implications

The analysis of irrigation patterns in the Kaushambi district from 2000 to 2024 reveals a significant change. Groundwater has become the main source of irrigation, while canal irrigation is now minimal. This shift has increased cropping intensity and agricultural productivity and led to long-term sustainability issues. Heavy reliance on tube wells has caused groundwater stress, higher energy use, and disparities among farmers. Less use of canals has made the irrigation system even less resilient. To tackle these problems, we need a comprehensive policy that balances surface and groundwater resources, promotes efficient water use, and ensures fair irrigation access.

This section outlines essential policy implications based on the findings. It focuses on groundwater regulation, canal revitalisation, crop diversification, integration with government programs, and community-based water management.

Groundwater Regulation and Recharge Measures

The findings of this study reveal that over 85% of irrigation in Kaushambi is dependent on tube wells. While groundwater expansion has supported agricultural growth and reduced vulnerability to erratic monsoon rainfall, such overwhelming reliance is unsustainable. Areas such as Muratganj, Sirathu, and Newada exhibit particularly high tube well density, which raises serious concerns about falling water tables. If unchecked, over-extraction will not only endanger agricultural productivity but also threaten drinking water supplies for rural communities. A comprehensive strategy for groundwater regulation and recharge is therefore essential.

Regulation of Tube Wells: Effective governance of groundwater begins with monitoring and controlling tube well expansion. A district-level licensing system should be introduced to regulate the construction of new wells and prevent indiscriminate drilling. Furthermore, policies must prioritise the development of **communal or shared tube wells** over private ones. Such measures would promote fairness by reducing inequalities between large farmers with greater resources and smallholders who are often excluded from access.

Groundwater Pricing and Energy Reform: Subsidised electricity and diesel for pumping currently encourage excessive and often wasteful use of groundwater. To counter this, energy subsidies should be gradually rationalised while offering incentives for adopting efficient irrigation methods such as drip or sprinkler systems. The introduction of **solar-powered pumps linked to grid buy-back schemes** presents an innovative solution: farmers can sell surplus energy to the grid, creating an incentive to avoid unnecessary water extraction. This not only conserves groundwater but also promotes renewable energy use.

Artificial Recharge Structures: Replenishing aquifers is critical for long-term sustainability. Investment in **check dams, farm ponds, percolation tanks, and recharge wells** can significantly enhance groundwater recharge. These structures can be developed through the **Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA)**, which provides rural employment while simultaneously building water security. Such convergence between employment and natural resource management offers both economic and ecological benefits.

Rainwater Harvesting: Rainwater harvesting is another important strategy to reduce pressure on groundwater resources. Village-level harvesting systems should be made mandatory in water-stressed blocks, ensuring that rainfall is captured and stored effectively. Additionally, **rooftop harvesting systems** in both rural households and public buildings can supplement domestic water needs, thereby reducing dependence on groundwater for drinking and household purposes.

Regulating groundwater extraction and enhancing recharge through artificial and natural means is central to Kaushambi's irrigation sustainability. These measures not only slow the decline of groundwater levels but also secure its long-term availability. Importantly, they align with the objectives of the **Atal Bhujal Yojana**, which emphasises community-based groundwater management. By combining regulatory frameworks with participatory approaches, Kaushambi can ensure that groundwater continues to support both agriculture and livelihoods in a sustainable manner.

Canal Revitalisation and Modernisation

Canal irrigation, once a lifeline for agricultural development in Kaushambi, has steadily declined in significance. In 2000, canals accounted for about 18% of the irrigated area, but by 2024 their share dropped to just 13.8%. This decline is attributed to factors such as poor maintenance, silt accumulation, leakage, and the irregularity of water supply, which discouraged farmers from depending on canals. Consequently, farmers increasingly shifted to tube wells as a more reliable alternative. However, canals remain a vital component of the irrigation system, not only as a surface water source but also as a means to balance groundwater use and improve long-term sustainability.

Rehabilitation of Canals: To restore their functionality, canals require systematic rehabilitation. Regular desilting, lining of canals, and repair of distributaries must be prioritised to reduce seepage and conveyance losses. The adoption of **modern technologies**, such as concrete lining, telemetry monitoring systems, and remote sensors, can enhance efficiency and improve water management practices. These interventions would ensure that the infrastructure is not only restored but also upgraded to meet present-day irrigation demands.

Assured Water Delivery: One of the main reasons farmers abandon canal irrigation is the uncertainty of water availability. Unreliable supply undermines crop planning and discourages investment in canal-dependent farming. Introducing **rotational water distribution schedules**—supported by community oversight—can enhance fairness and predictability. Such measures ensure that farmers know when and how much water they will receive, allowing them to plan cropping calendars more effectively.

Integration with Groundwater Recharge: Canal seepage, often perceived as a loss, can be strategically managed to recharge groundwater aquifers. By integrating canal networks with groundwater recharge mechanisms, Kaushambi can create a **synergy between surface and groundwater systems**. This dual benefit not only conserves water but also strengthens resilience against seasonal droughts, which are becoming more frequent due to climate variability.

Equitable Allocation: Equity in water distribution remains a significant challenge, as farmers at the head of canals often receive more water than those at the tail-end. To address this, **Water User Associations (WUAs)** should be empowered with decision-making authority to monitor and regulate distribution. Their involvement would help ensure that tail-end farmers also receive a fair share of water, reducing intra-district disparities and promoting social justice in irrigation access.

Canal revitalisation offers a pathway to reduce dependence on tube wells, enhance resilience against droughts, and provide farmers with a cheaper and more sustainable irrigation source. By rehabilitating infrastructure, ensuring reliable water delivery, integrating groundwater recharge, and promoting equitable distribution, Kaushambi can revitalise its canal system. This strategy is particularly crucial for underperforming blocks such as Kada and Chail, where tube wells dominate and sustainable alternatives are urgently needed.

Crop Diversification towards Less Water-Demanding Crops

Kaushambi's irrigation growth has encouraged farmers to expand the cultivation of water-intensive crops such as paddy and wheat. While these crops are profitable and contribute significantly to household incomes, their high-water requirements make them unsustainable under conditions of groundwater stress. To address this challenge, crop diversification emerges as a critical strategy, enabling farmers to shift towards less water-demanding crops that also offer nutritional and economic benefits. Diversification not only reduces irrigation pressure but also promotes resilience in farming systems.

Promotion of Pulses and Oilseeds: Pulses and oilseeds are ideally suited for Kaushambi's agro-climatic conditions and require far less irrigation than paddy or wheat. By providing a higher Minimum Support Price (MSP) and assured procurement, these crops can be made more competitive with traditional staples. Additionally, block-specific diversification plans based on soil conditions would help farmers select the most suitable crops, ensuring both productivity and sustainability.

Millet Revival: Millets are climate-resilient, nutrient-rich, and water-efficient, making them a valuable alternative for sustainable farming in Kaushambi. Policies promoting seed subsidies, input support, and their inclusion in the Public Distribution System (PDS) can encourage wider adoption. Integrating millets into food security schemes also enhances dietary diversity and addresses rural malnutrition.

Incentives for Mixed Cropping: Intercropping systems, such as combining pulses with wheat or maize, can optimise land and water use while diversifying income sources. Providing incentives under the Pradhan Mantri Krishi Sinchai Yojana (PMKSY) for mixed cropping would encourage farmers to experiment with more sustainable practices. Demonstration plots and farmer training programs can showcase successful models, building confidence in these approaches.

Market Linkages: A critical constraint for diversification is the lack of reliable markets for alternative crops. Strengthening Farmer-Producer Organisations (FPOs) can help aggregate produce and improve bargaining power. Moreover, the establishment of local agro-processing units would create demand for oilseeds, pulses, and millets, ensuring farmers receive fair prices. By linking production to processing and marketing, diversification becomes both viable and profitable.

Crop diversification towards pulses, oilseeds, and millets offers multiple benefits—lower irrigation demand, improved soil fertility through nitrogen fixation, and enhanced nutritional outcomes. By reducing dependence on water-intensive crops, farmers not only lower risks associated with groundwater depletion but also secure more stable and sustainable livelihoods.

Nutrition-Sensitive Farming under Limited Irrigation

Ensuring food security in Kaushambi requires strategies that integrate water conservation with nutritional improvement. Given the rising stress on groundwater and declining canal irrigation, policies must promote nutrition-sensitive crops such as pulses, oilseeds, and millets that thrive under limited irrigation. These crops not only conserve water but also supply protein, essential fats, and micronutrients critical for rural diets. Government support in the form of higher MSPs, assured procurement, and inclusion in public distribution systems (PDS) can motivate adoption. Extension services should focus on training farmers in moisture-retention practices, mulching, and intercropping to maximise output. Such measures will reduce irrigation demand while improving nutritional outcomes and advancing sustainable agriculture.

VIII. Livelihoods And Agricultural Development

Agriculture remains the backbone of livelihoods in Kaushambi district, where a majority of households depend directly or indirectly on farming. Irrigation plays a pivotal role in shaping both agricultural development and rural livelihoods, influencing crop choices, productivity, and income stability. The district's transition from canal-based irrigation to heavy reliance on groundwater has brought mixed outcomes for farmers. On one hand, the expansion of tube well irrigation has ensured greater cropping intensity and reduced dependence on erratic monsoons. On the other hand, it has increased costs for marginal farmers, created inequities in access to water, and raised concerns about long-term sustainability.

The link between irrigation and livelihoods is particularly evident in the shift of cropping patterns. Farmers with assured tube well irrigation have increasingly adopted water-intensive crops such as paddy and wheat, which provide higher returns but require substantial water and energy inputs. These farmers enjoy relatively stable incomes and contribute to marketable surplus. In contrast, smallholders and landless labourers, who lack access to private irrigation, remain vulnerable to rainfall variability and often rely on less remunerative crops. This disparity highlights the dual impact of irrigation development: it enhances opportunities for some while widening inequalities for others.

The sustainability of rural livelihoods in Kaushambi is also tied to the rising cost of irrigation. Dependence on diesel or electric pumps has increased household expenditure, reducing net farm income. Farmers frequently report that electricity supply is irregular and diesel prices are volatile, further increasing financial risks. As a result, livelihood security is closely connected to the availability of irrigation water and the affordability and reliability of energy inputs.

Employment opportunities generated by irrigation development are another critical dimension. Expansion of irrigated agriculture has increased labour demand, particularly for transplanting, weeding, and harvesting in paddy and wheat cultivation. Seasonal migration, once common in the district, has decreased in irrigated villages where agricultural employment is available. At the same time, irrigation-induced agricultural growth has fostered ancillary activities such as dairy, fodder cultivation, and local Agro-processing, diversifying livelihood opportunities.

However, the long-term viability of these gains is uncertain. Over-reliance on groundwater is leading to declining water tables, which may threaten the very foundation of livelihood security in the district. Without effective groundwater management, the future livelihoods of smallholders will be at risk. Moreover, the decline of canal irrigation has reduced opportunities for community-based water management, traditionally ensuring a more equitable resource distribution.

For sustainable livelihoods, agricultural development in Kaushambi must integrate water conservation, energy efficiency, and crop diversification. Government initiatives like the *Pradhan Mantri Krishi Sinchai Yojana (PMKSY)* and *Atal Bhujal Yojana* can play a vital role by encouraging micro-irrigation, promoting pulses and oilseeds, and strengthening water user associations. Such interventions would reduce water stress and enhance resilience and equity in rural livelihoods.

In conclusion, livelihoods and agricultural development in Kaushambi are deeply intertwined with irrigation patterns. Ensuring a balance between productivity and sustainability will be crucial for securing rural livelihoods, reducing inequalities, and promoting long-term agricultural growth in the district.

IX. Conclusion

The current study looked at the irrigation situation in Kaushambi district from 2000 to 2024. It focused on changes over time, differences between areas, and concerns about sustainability. The findings show a clear shift in irrigation patterns. Canal irrigation has declined, while tube wells now dominate, accounting for over 80% of the irrigated area. This change has led to significant increases in irrigated land and cropping intensity but has also created new challenges. These include groundwater depletion, rising energy costs, and unequal access to irrigation. Spatial analysis showed that irrigation growth varies across blocks. For example, Muratganj, Manjhanpur, and Sirathu saw significant increases in irrigated area and cropping intensity, while blocks like Kada and Chail made little progress. This uneven growth highlights ongoing disparities in farming opportunities and access to resources within the district. The decline of traditional irrigation sources, such as tanks and wells, makes farmers more vulnerable as they increasingly depend on groundwater for reliable irrigation. The study emphasises the urgent need for balanced water management strategies that combine surface and groundwater resources. Revitalising canals, promoting groundwater recharge, and encouraging water-efficient technologies are crucial to alleviating pressure on aquifers. Market incentives and state procurement policies should support crop diversification toward plants that require less water. Community-based water governance through Water User Associations can improve fairness and accountability in irrigation distribution. Future research should examine the effects of climate change on irrigation demand, rainfall patterns, and water availability in Kaushambi.

Studying how farmers perceive and make irrigation decisions can also help design more inclusive policies. Evaluating irrigation efficiency at the farm level and using remote sensing and GIS-based monitoring can offer more insights into sustainable resource use. In summary, Kaushambi's irrigation development shows both advancements and challenges. The district has expanded its irrigated agriculture, but this has increased reliance on groundwater. To ensure sustainable agriculture in the future, a policy framework must balance efficiency, fairness, and environmental sustainability.

References

[1] District Statistical Handbook. (2024). Kaushambi District Statistical Handbook 2024. Directorate Of Economics And Statistics, Government Of Uttar Pradesh. Http://Updes.Up.Nic.In

[2] Government Of Uttar Pradesh. (2022). Statistical Abstract Of Uttar Pradesh 2022. Lucknow: Directorate Of Economics And Statistics. Http://Updes.Up.Nic.In

[3] Shah, T. (2009). Taming The Anarchy: Groundwater Governance in South Asia. Routledge. Https://Doi.Org/10.4324/9780203874520

[4] Sharma, R., & Singh, A. (2017). Irrigation Development and Its Impact on Agricultural Sustainability in India. Indian Journal of Agricultural Economics, 72(3), 321–334.
[5] Verma, S. (2019). Water Management Challenges in The Ganga-Yamuna Doab: A Regional Perspective. Economic And Political Weekly, 54(12), 45–53. Https://Www.Epw.In/Journal/2019/12
[6] Government Of India. (2021). Annual Report 2020–21: Ministry of Jal Shakti. New Delhi: Ministry Of Water Resources. Https://Jalshakti-Dowr.Gov.In
[7] Government Of Uttar Pradesh. (2022). Statistical Abstract Of Uttar Pradesh 2022. Directorate Of Economics and Statistics, Lucknow. Http://Updes.Up.Nic.In
[8] Mukherji, A., Shah, T., & Giordano, M. (2012). Managing Energy–Irrigation Nexus in India. Water Policy, 14(3), 489-505. Https://Doi.Org/10.2166/Wp.2012.126
[9] Shah, T. (2009). Taming The Anarchy: Groundwater Governance in South Asia. Routledge. Https://Doi.Org/10.4324/9780203874520
[10] Sharma, R., & Sharma, A. (2017). Changing Patterns of Irrigation in India: Implications for Sustainability. Indian Journal of Agricultural Economics, 72(3), 321–334. Https://Www.Indianjournals.Com/Ijor.Aspx?Target=Ijor:Ijae&Type=Home
[11] Singh, H. (2014). Regional Disparities in Irrigation Development In Uttar Pradesh. Geographical Review of India, 76(4), 421–435. Https://Www.Jstor.Org/Journal/Geogrevindia
[12] Singh, H., & Prasad, R. (2020). Groundwater Irrigation and Agricultural Disparities in Eastern Uttar Pradesh. Journal Of Rural Development, 39(4), 567–584. Https://Nirdprojms.In/Index.Php/Jrd
[13] Verma, S. (2019). Water Management Challenges in the Ganga-Yamuna Doab: A Regional Perspective. Economic And Political Weekly, 54(12), 45–53. Https://Www.Epw.In/Journal/2019/12
[14] Singh, H., & Prasad, R. (2020). Groundwater Irrigation and Agricultural Disparities in Eastern Uttar Pradesh. Journal Of Rural Development, 39(4), 567–584. Https://Nirdprojms.In/Index.Php/Jrd