International Organization of Research & Development (IORD)
ISSN: 2348-0831
Vol 13 Issue 02 | 2026

Impact of Peri-Urban Expansion on Groundwater Resources and Irrigation Practices in Hisar District, Haryana

[1]Mandeep (Ph. D Research Scholar), [2]Dr. Rohitash (Associate Professor)
[1,2]Department – Geography, Shri Jagdish Prasad Jhabarmal Tibrewala University, Chudela, Jhunjhunu

DOI: 10.5281/zenodo.22164522

ABSTRACT

Peri-urban growth changes more than the visible land surface; it also rearranges the way water is demanded, recharged, extracted and used in agriculture. This article examines that relationship in Hisar District, Haryana, with particular attention to the rapidly changing fringe of Hisar city. Instead of treating groundwater decline as a uniform outcome of urbanization, the paper combines evidence on urban expansion, rainfall variability, groundwater extraction, water-level change, water quality and irrigation demand. Published geospatial analysis shows that the built-up footprint of Hisar city and its peri-urban zone almost doubled between 2001 and 2021, while 41.62 per cent of new built-up land came from agricultural land. Groundwater data reveal a more differentiated water response. In 2024, Narnaund remained over-exploited, Agroha and Barwala were critical, and Hisar-I and Hisar-II were close to the 70 per cent threshold despite remaining in the safe category. Sectoral data for 2020 show that irrigation accounted for 480.06 MCM out of 486.02 MCM of groundwater extraction in the district, or about 98.77 per cent. At the same time, post-monsoon records for 2013-2023 indicate rising groundwater levels across about 67.43 per cent of the district area, demonstrating the influence of canal recharge, rainfall, artificial recharge and spatial variation in abstraction. Water quality further complicates irrigation choices: only 26.70 per cent of the district area falls in the fresh EC class, while marginal-fresh water dominates. The findings suggest that peri-urbanization in Hisar is producing a redistribution of groundwater stress rather than a simple district-wide decline, encouraging greater reliance on tubewells, conjunctive use, selective pumping and water-saving irrigation. Sustainable management therefore requires peri-urban land-use planning to be linked with aquifer management, canal-groundwater conjunctive use, recharge protection, micro-irrigation and crop adjustment.

Keywords: peri-urbanization; groundwater; irrigation practices; conjunctive use; water quality; Hisar; Haryana

1. INTRODUCTION

The outskirts of Indian cities are becoming increasingly important sites of water change. Housing colonies, educational campuses, industries, roads, warehouses and commercial uses appear within landscapes that may still be predominantly agricultural. The result is not a clean shift from rural to urban. Instead, farming, construction, municipal services and new private water demands coexist within the same space. This transition is especially important in semi-arid regions because changes in land use are superimposed on an already limited and variable water base.

Groundwater occupies a central place in this transition. It provides farmers with a flexible source of irrigation that can be used when rainfall is inadequate or canal deliveries do not coincide with crop requirements. The same aquifer, however, is also attractive to newly developing settlements, institutions and commercial establishments because groundwater can often be accessed faster than formal piped-water infrastructure can be extended. Peri-urban growth may therefore increase non-agricultural withdrawals even while agriculture continues to account for the largest share of total pumping. Simultaneously, conversion of open and agricultural land to impervious surfaces can alter local recharge conditions, while roads and drains redirect runoff. These processes make the relationship between urban expansion and groundwater less straightforward than a simple assumption that more built-up land always produces an equal fall in the water table.

The wider Indian evidence reinforces this complexity. Groundwater irrigation has supported agricultural intensification and rural income, yet persistent pumping has produced declining water levels in many intensively cultivated regions (Shah, 2012). Large-scale assessments of the Indo-Gangetic aquifer show that groundwater depletion is strongly localized and that water quality, particularly salinity, can constrain usable supplies even where aquifer storage remains substantial (MacDonald et al., 2016). Research on peri-urban India further shows that water access changes as new users enter the landscape and as farmers respond by deepening wells, changing crops, combining water sources or withdrawing from irrigation altogether (Butsch et al., 2021; Patil et al., 2019).

Hisar offers a useful setting for examining these processes. The district lies in western Haryana, where rainfall is relatively low and variable, agriculture remains extensive, and canal as well as groundwater irrigation are both important. At the same time, Hisar city has expanded rapidly. Rahul and Kaur (2024) estimated that the built-up area of Hisar city and its peri-urban zone increased from 4,965.12 ha in 2001 to 9,889.20 ha in 2021, a rise of 99.17 per cent. By 2021, 70 per cent of the built-up area in their study region lay outside the municipal boundary in the peri-urban belt. Agricultural land contributed 2,049.57 ha, or 41.62 per cent, of the total built-up gains. Thus, a substantial part of the changing urban footprint has developed directly within a formerly agricultural hydrological landscape.

The key question is what this transformation means for groundwater-dependent agriculture. A narrow approach would compare urban growth with a single groundwater-depth trend. Such a comparison can be misleading in Hisar because groundwater conditions vary sharply from one assessment unit to another and because canal seepage, irrigation return flow, rainfall and artificial recharge can locally offset pumping. This article therefore treats groundwater stress as a combined quantity-quality-access problem. It asks three linked questions: how has the peri-urban water-demand environment changed; where is groundwater extraction becoming more intensive; and how do these conditions reshape irrigation choices available to farmers? The analysis uses official water-resource statistics together with published geospatial evidence to develop a district-level interpretation with special relevance to the fringe of Hisar city.

2. PERI-URBAN WATER TRANSITION: AN ANALYTICAL PERSPECTIVE

Peri-urbanization alters the hydrological landscape through several pathways at the same time. The first is demand substitution. Agricultural land that is converted to residential, institutional or commercial use may no longer require irrigation, but the new land use creates domestic, service-sector or industrial demand. Whether total groundwater withdrawal increases or falls depends on the former irrigation intensity, the density of new development, the availability of piped surface water and the extent to which private borewells are used. In other words, land conversion does not automatically reduce groundwater demand simply because farming disappears from a plot.

The second pathway concerns recharge. Agricultural fields allow direct infiltration of rainfall and also receive irrigation water, a portion of which can percolate below the root zone. Urban development replaces some of these surfaces with roofs, paved yards and roads. Yet urban areas can also create new recharge through leaking supply lines, drains, wastewater and recharge structures. Research in semi-arid peri-urban Jaipur illustrates that urbanization can produce both declining levels through over-abstraction and localized recharge effects, depending on infrastructure and hydrogeological setting (Frommen et al., 2021). This is particularly relevant to alluvial settings such as Hisar, where groundwater behaviour reflects a large interconnected aquifer system rather than isolated shallow pockets.

The third pathway is institutional and economic. Water that was once used almost entirely as an agricultural input begins to serve households, institutions and urban businesses. Peri-urban water therefore becomes part of a changing 'hydrosocial' system in which access, technology and land-use decisions are interlinked (Butsch et al., 2021). Farmers with reliable tubewells can respond differently from those dependent on canal turns or shared wells. Water quality introduces another layer: saline or marginal groundwater may be usable only through mixing with canal water or by selecting salt-tolerant crops. Under such conditions, irrigation practice is shaped not merely by the depth of the water table but by the joint availability, quality, timing and cost of different sources.

This paper consequently evaluates peri-urban groundwater pressure through five indicators: urban expansion, rainfall variability, block-wise stage of groundwater extraction, sectoral composition of groundwater use, and groundwater quality. Irrigation practices are interpreted through their relationship with these indicators rather than through an assumed uniform response. The analytical pathway is summarized in Figure 1.

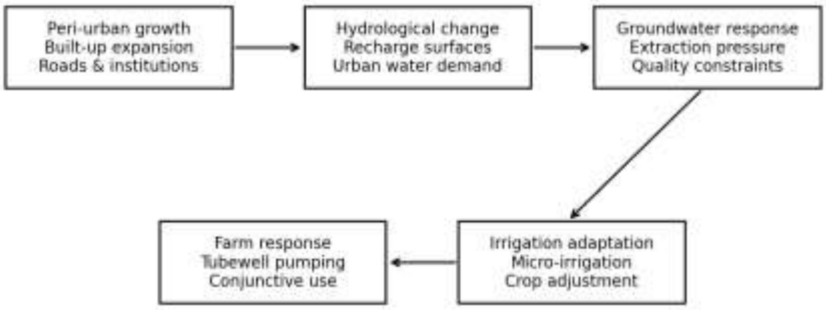

Figure 1. Analytical pathway linking peri-urban growth, groundwater stress and irrigation adaptation

3. HISAR AS A HYDRO-AGRICULTURAL SETTING

Hisar District occupies the western part of Haryana and forms part of the semi-arid alluvial plains of north-western India. The district is strongly agricultural but also contains one of western Haryana's most important urban centres. Hisar city functions as an administrative, educational, research, industrial and commercial node, and its road connections towards Delhi, Chandigarh and Rajasthan have encouraged outward development. The peri-urban landscape therefore includes cultivated fields, village settlements, residential sectors, educational campuses, industrial uses and transport-oriented development within a relatively narrow zone of transition.

The climate makes water management central to farming. Annual rainfall is low and highly variable. Haryana Water Resources Atlas data sourced from the India Meteorological Department show that Hisar received an average of about 315 mm annually between 2000 and 2023. The series ranged from only 129 mm in 2000 to 520 mm in 2008. The year 2023 recorded 171 mm. Such variability increases the value of assured irrigation because crop water requirements cannot be planned around rainfall alone.

The aquifer system is equally important. CGWB's aquifer mapping for Hisar identifies extensive alluvial aquifers and emphasizes groundwater management through recharge, irrigation-efficiency improvement, village ponds, drainage channels, underground pipeline systems and crop diversification (CGWB, 2017). The district also benefits from a developed canal network. Canal seepage and irrigation return flows can contribute to recharge, while canal supplies offer an alternative to poorer-quality groundwater. Consequently, the agricultural water system is best understood as conjunctive rather than exclusively groundwater-based.

The peri-urban fringe examined in this article is the zone surrounding Hisar city where agricultural land has experienced the strongest interaction with outward built-up growth. Settlements such as Gangwa, Satrod Kalan, Satrod Khas, Satrod Khurd, Mayyer and Dabra illustrate this transitional setting, although the groundwater statistics used for quantitative analysis are reported at district and assessment-unit scales. This distinction is important: the paper does not claim that a block-level extraction value represents every village within it. Instead, the block data provide the regional hydrogeological context within which peri-urban irrigation decisions are being made.

4. DATA AND ANALYTICAL PROCEDURE

The analysis is based on secondary but directly verifiable datasets. This design was chosen because the objective is to connect documented peri-urban expansion with official groundwater and irrigation evidence without inventing well-level or farmer-survey observations. Five data streams were integrated: land-use change, rainfall, dynamic groundwater resources, sectoral groundwater extraction and groundwater quality. Table 1 summarizes the evidence base.

Table 1. Evidence base used in the analysis

Dataset	Reference period	Source	Use in this paper
Peri-urban built-up expansion	2001-2021	Rahul & Kaur (2024)	Built-up growth, peri-urban share and agricultural land converted to built-up
Annual rainfall	2000-2023	Haryana Water Resources Atlas 2025 / IMD	Inter-annual rainfall variability and climatic pressure on irrigation
Stage of groundwater extraction	2023 and 2024	CGWB Dynamic Ground Water Resources, Haryana	Block/assessment-unit extraction stress and category
Sectoral groundwater extraction	2020	Integrated Water Resources Plan Haryana 2023-2026	Irrigation, industrial and domestic groundwater withdrawals
Post-monsoon water-level fluctuation	2013-2023	Haryana Water Resources Atlas 2025	Spatial extent of rising and declining groundwater levels
Groundwater quality by EC	2023	Haryana Water Resources Atlas 2025	Fresh, marginal-fresh, marginal and saline classes
Aquifer management recommendations	2017	CGWB Aquifer Mapping and Management Plan, Hisar	Recharge, irrigation efficiency and crop-diversification measures

The stage of groundwater extraction (SOGE) is used as the main pressure indicator. It expresses annual groundwater extraction as a percentage of annual extractable groundwater resources. Following CGWB classification, values up to 70 per cent are safe, values above 70 and up to 90 per cent are semi-critical, values above 90 and up to 100 per cent are critical, and values above 100 per cent are over-exploited. A two-year

International Organization of Research & Development (IORD)
ISSN: 2348-0831
Vol 13 Issue 02 | 2026

comparison is useful because movement across these thresholds can reveal rapidly worsening or improving conditions even when the long-term water-level trend appears stable.
Sectoral extraction data were summed for the nine Hisar assessment units reported in the 2020 water plan. The irrigation share was calculated as irrigation extraction divided by total extraction. Water-quality classes were converted from area in acres to percentage of the district total geographical area. For the decadal post-monsoon water-level assessment, all positive fluctuation classes were combined and compared with the three negative classes. These calculations are descriptive; they establish the structure of water pressure but do not imply that urban expansion alone caused every observed groundwater change.
The interpretation therefore uses triangulation. A finding is treated as stronger when independent datasets point in the same direction—for example, rapid peri-urban built-up growth, a rising stage of groundwater extraction near Hisar city, and overwhelming dominance of irrigation in total groundwater use. Where datasets appear contradictory, such as rising district-wide post-monsoon levels alongside critical or over-exploited blocks, the difference is retained and explained rather than averaged away. This is essential for understanding Hisar, where recharge and extraction vary substantially across space.

5. RESULTS: REWORKING WATER IN THE PERI-URBAN FRINGE

5.1 Urban expansion has changed the water-demand and recharge environment

The physical transformation of Hisar's fringe is substantial. Between 2001 and 2021, the built-up area within Hisar city and its delineated peri-urban zone increased from 4,965.12 ha to 9,889.20 ha. The increase of 4,924.08 ha represents 99.17 per cent growth in two decades. More important for the present analysis, the spatial balance of development shifted outward: the peri-urban zone accounted for 58 per cent of total built-up area in 2001 and 70 per cent in 2021 (Rahul & Kaur, 2024). This means that most new urban surfaces were being added where agricultural and rural water systems were already operating.
Agricultural land supplied 2,049.57 ha of the built-up gains, or 41.62 per cent of the total. The hydrological effect of this conversion is two-sided. On converted fields, crop irrigation demand disappears, potentially reducing agricultural pumping. At the same time, the new development produces year-round household and institutional water demand and may reduce direct rainfall infiltration where surfaces are paved. In fast-growing fringe areas, this shift also creates a timing change: irrigation is seasonal, whereas domestic and institutional demand is much less seasonal. Consequently, peri-urbanization can reduce one type of demand while making total water use more continuous.
The location of growth along transport corridors further matters because linear development fragments drainage and alters the direction in which runoff moves. Large institutions, warehouses and colonies can concentrate runoff that was previously distributed over fields. Unless storm-water harvesting and recharge structures are incorporated at the same pace as construction, part of the natural infiltration opportunity is lost. The effect cannot be measured from built-up statistics alone, but the land-use evidence confirms that the recharge-demand setting around Hisar has been substantially reorganized.

5.2 Rainfall variability keeps groundwater central to irrigation

Rainfall does not provide a stable substitute for irrigation in Hisar. Figure 2 shows strong year-to-year variation between 2000 and 2023. The mean for the period was about 315 mm, but several years fell well below 250 mm, while only a few crossed 450 mm. The contrast between 425 mm in 2022 and 171 mm in 2023 is particularly sharp. For farmers at the urban fringe, where land parcels may already be under conversion pressure, such variability makes access to an assured source of water economically important because a crop cannot depend on a predictable monsoon schedule.

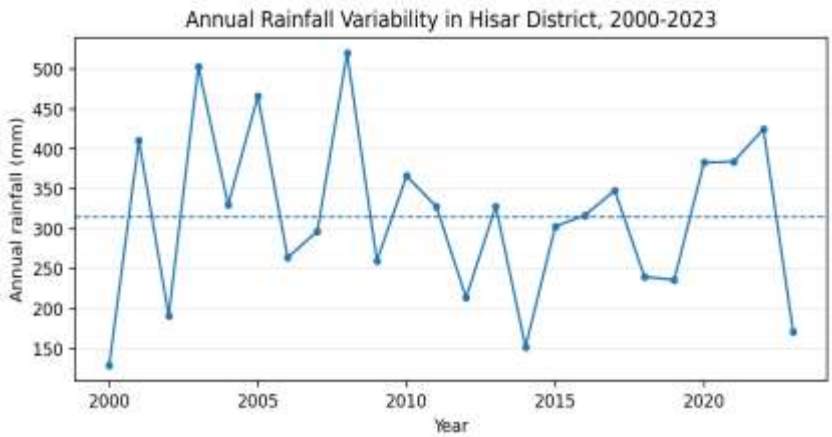

Figure 2. Annual rainfall variability in Hisar District, 2000-2023

Rainfall variability also complicates the interpretation of groundwater trends. A rise in water level after a wet year does not necessarily indicate reduced abstraction, just as a fall in a dry year does not prove an urbanization effect. Asoka et al. (2017) demonstrated at the Indian scale that monsoon precipitation and pumping interact in shaping groundwater-storage change. For Hisar, this means that peri-urban water analysis must consider demand pressure together with rainfall, canal recharge and management interventions.

5.3 Groundwater stress is spatially uneven and is intensifying in selected units

The most recent dynamic groundwater assessment presents a mixed picture across Hisar District. Table 2 compares the stage of groundwater extraction in 2023 and 2024. Narnaund remains clearly over-exploited, with extraction more than twice the annual extractable resource. Agroha and Barwala are critical in 2024. Barwala moved from 89.72 per cent in 2023 to 92.41 per cent in 2024, crossing from semi-critical to critical status. Hisar-I increased from 57.70 to 69.90 per cent in only one year and now lies just below the 70 per cent semi-critical threshold. Hisar-II is similarly close at 68.94 per cent. These two units are particularly relevant to the urban-fringe discussion because continued non-agricultural demand growth could push local groundwater stress across the category boundary even without a large change in agricultural pumping.

Table 2. Stage of groundwater extraction in Hisar District, 2023 and 2024

Assessment unit	2023 (%)	2024 (%)	Change (percentage points)	2024 category
Adampur	52.87	63.42	+10.55	Safe
Agroha	97.79	95.92	-1.87	Critical
Barwala	89.72	92.41	+2.69	Critical
Bass	63.77	64.62	+0.85	Safe
Hansi	60.65	62.87	+2.22	Safe
Hisar-I	57.70	69.90	+12.20	Safe
Hisar-II	68.44	68.94	+0.50	Safe
Narnaund	218.01	216.51	-1.50	Over-exploited
Uklana	37.10	36.99	-0.11	Safe

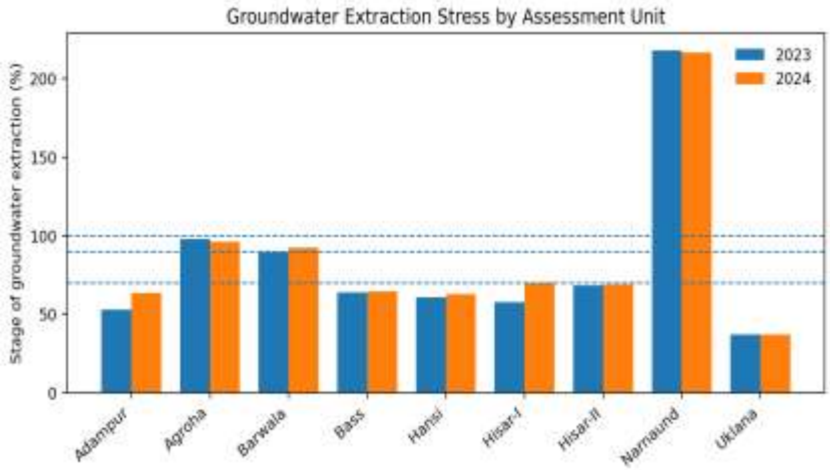

Figure 3. Change in stage of groundwater extraction by assessment unit, 2023-2024

The block pattern shows why district averages can be misleading. Uklana is only 36.99 per cent, while Narnaund is 216.51 per cent. A farmer's irrigation environment therefore depends strongly on location. Near a safe but rapidly worsening assessment unit, the issue is preventive management; in an over-exploited unit, the issue is immediate reduction of groundwater demand and expansion of alternative or conjunctive sources.

The one-year movement in Hisar-I is especially noteworthy. An increase of 12.20 percentage points does not establish a long-term trend by itself, but it signals that a formally 'safe' label should not be read as absence of pressure. Peri-urban development can introduce additional wells and year-round demand before groundwater categories are revised. Monitoring the direction of change is therefore as important as the current category.

5.4 Agriculture still dominates groundwater extraction

Although urbanization is adding new water users, irrigation remains overwhelmingly dominant in the district's groundwater budget. The 2020 sectoral dataset reports 480.06 MCM of groundwater extraction for irrigation out of a total 486.02 MCM across Hisar's nine assessment units. Irrigation therefore accounted for approximately 98.77 per cent of reported groundwater extraction. Industrial extraction was 2.29 MCM and domestic extraction 3.67 MCM. This result is important because it prevents an exaggerated interpretation of urban impact: the urban fringe is changing the geography and timing of demand, but the largest opportunity for reducing total groundwater withdrawal remains within agriculture.

Table 3. Sectoral groundwater extraction in Hisar District, 2020

Block	Irrigation (MCM)	Industrial (MCM)	Domestic (MCM)	Total (MCM)	Irrigation share (%)
Adampur	36.55	0.00	0.15	36.70	99.6
Agroha	55.45	0.00	0.13	55.58	99.8
Barwala	106.41	0.00	0.36	106.77	99.7
Hansi-I	48.73	0.03	0.32	49.08	99.3
Hansi-II	35.36	0.00	0.43	35.79	98.8
Hisar-I	56.55	2.26	0.54	59.35	95.3
Hisar-II	57.65	0.00	0.43	58.08	99.3
Narnaund	78.21	0.00	0.11	78.32	99.9
Uklana	5.15	0.00	1.20	6.35	81.1
District total	480.06	2.29	3.67	486.02	98.77

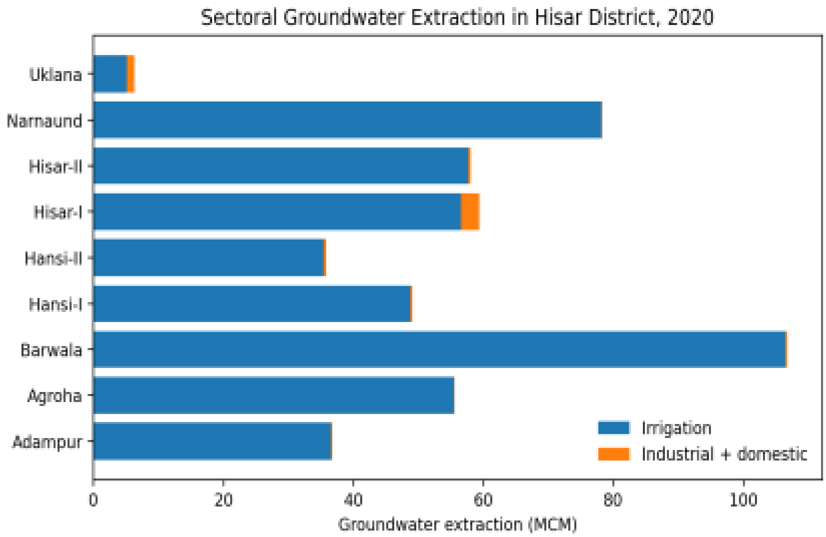

Figure 4. Sectoral composition of groundwater extraction in Hisar District, 2020

Barwala recorded the highest irrigation groundwater extraction in this dataset at 106.41 MCM, followed by Narnaund at 78.21 MCM. Hisar-I and Hisar-II together accounted for 114.20 MCM of irrigation extraction. The figures indicate that peri-urban groundwater management cannot be separated from farm-water management in surrounding blocks. Even a modest percentage improvement in irrigation efficiency can offset a comparatively large quantity of new domestic or institutional demand.

At the farm level, however, groundwater offers a flexibility that canal water does not always provide. Farmers can irrigate at a chosen time, respond to a dry spell, and protect higher-value crops. This helps explain why groundwater pumping can remain attractive even where canal infrastructure exists. The management challenge is therefore not simply to replace groundwater with canals, but to coordinate both sources so that groundwater functions as a strategic buffer rather than the default source for every irrigation event.

5.5 District-wide water levels show recharge effects as well as stress

A striking feature of the Hisar data is that long-term water-level change does not mirror the extraction categories in a simple way. Post-monsoon comparison for October 2013 to October 2023 shows positive groundwater-level fluctuation over about 663,685 acres, equivalent to approximately 67.43 per cent of the district's geographical area. Negative fluctuation occurred over about 32.57 per cent. The Haryana Water Resources Atlas notes that Hisar had the highest share of rising area among districts showing a positive decadal trend.

This finding does not contradict the critical and over-exploited block assessments. The two indicators describe different aspects of the system. Groundwater level reflects the combined result of recharge and withdrawal during a period; the stage of extraction compares annual extraction with annual extractable resources. Canal seepage, irrigation return flow, rainfall concentration and recharge interventions may raise the water table locally even where the annual groundwater balance is under pressure. CGWB's 2023-24 yearbook also notes rising trends at Balsamand and Adampur piezometers in Hisar and links them to recharge interventions, while emphasizing that groundwater extraction for irrigation remains the dominant withdrawal pressure.

For the peri-urban fringe, the implication is that management should be spatially targeted. A general district narrative of 'falling groundwater' would overlook areas where water levels are stable or rising and where salinity

 DOI: 10.5281/zenodo.22164522

or waterlogging may be more serious than depletion. Conversely, a district-wide rising trend should not be used to justify unrestricted pumping in units already close to or beyond critical thresholds.

5.6 Water quality is shaping irrigation practice as strongly as quantity

Groundwater availability is only useful to agriculture when its quality is suitable for crops and soils. Electrical-conductivity mapping for 2023 shows that only 262,822 acres, or 26.70 per cent of Hisar District, fall in the fresh-water class below 2,000 micromhos/cm. The largest share, 63.39 per cent, is marginal-fresh (2,000-4,000 micromhos/cm). Another 7.73 per cent is marginal and 2.18 per cent is saline. Thus, almost three-quarters of the district lies outside the fresh-water category. This pattern is consistent with western Haryana's semi-arid setting and long-standing salinity concerns.

Table 4. Groundwater quality distribution in Hisar District, 2023

EC class	EC range (micromhos/cm)	Area (acres)	Share (%)	Irrigation implication
Fresh	< 2,000	262,822.41	26.70	Generally suitable for a wide range of crops and soils
Marginal fresh	2,000-4,000	623,910.76	63.39	Usable with attention to crop, soil and irrigation management
Marginal	4,000-6,000	76,039.12	7.73	Restricted; mix with canal water and use salt-tolerant crops
Saline	>= 6,000	21,446.93	2.18	Generally unsuitable without special management

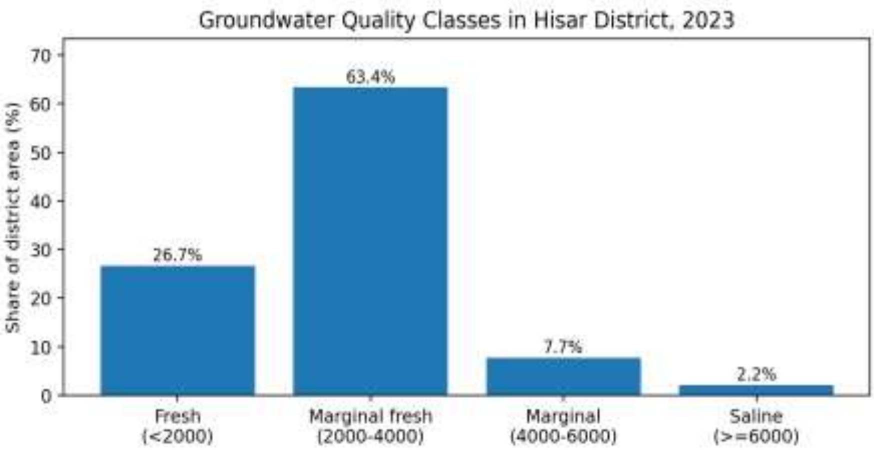

Figure 5. Groundwater quality classes in Hisar District, 2023

Quality conditions encourage conjunctive irrigation. Where groundwater is marginal, canal water can be mixed with it to reduce salinity risk, or the two sources can be alternated. This practice has a hydrological advantage as well: it reduces the amount of groundwater required during periods when canal supplies are available. In more saline locations, crop choice becomes part of water management because salt-tolerant crops and varieties can use water that would be unsuitable for sensitive crops.

Peri-urban growth may intensify this quality challenge in two ways. First, reduction of open recharge surfaces can decrease the local dilution benefit of fresh rainfall infiltration. Second, unsewered or partially sewered development can introduce nitrate and other contaminants into shallow aquifers, a problem documented in other semi-arid peri-urban Indian settings (Frommen et al., 2021). The available Hisar datasets do not provide a direct peri-urban nitrate trend, so this pathway should be treated as a monitoring priority rather than as an established local result.

6. DISCUSSION: PERI-URBANIZATION AS HYDROLOGICAL REDISTRIBUTION

Taken together, the evidence suggests that the groundwater impact of Hisar's peri-urban expansion is best described as hydrological redistribution. Urban growth is redistributing water demand across sectors, seasons and locations. Agricultural land conversion removes irrigation demand from some plots, yet built development brings permanent users and can alter recharge. At district scale, irrigation still dominates extraction, but near the city edge the relative importance of domestic, institutional and commercial demand is likely to rise. This creates competition not because urban use already exceeds irrigation in volume, but because new demand is concentrated in places where groundwater categories are approaching stress thresholds.

Hisar-I illustrates this transitional risk. Its stage of extraction rose from 57.70 to 69.90 per cent between the two assessments. It remained technically safe in 2024, but only marginally below the semi-critical threshold. The pattern is different in Narnaund, where over-exploitation is already severe, and different again in Uklana, where extraction remains low. A single district policy would therefore be inefficient. Preventive measures are appropriate around the expanding urban fringe, while demand reduction is more urgent in over-exploited areas.

The apparent contradiction between rising post-monsoon groundwater levels in much of Hisar and high extraction pressure in selected blocks is analytically valuable. It shows that water levels alone are not a sufficient measure of sustainability in a canal-influenced alluvial system. MacDonald et al. (2016) similarly emphasized that parts of the Indo-Gangetic Basin can have stable or rising groundwater because of recharge from irrigation systems while still facing serious quality constraints. In Hisar, canal leakage and irrigation return flow can partly buffer groundwater storage, but this buffering should not be interpreted as unlimited renewable supply.

Irrigation practice is therefore moving within a three-way constraint: reliability, quality and cost. Groundwater is reliable but requires pumping and can be saline; canal water can improve quality and reduce pumping but is less flexible in timing; rainfall is free but highly variable. Farmers combine these sources according to local access. As peri-urban land values rise and farm sizes become more fragmented, the willingness to invest in deep tubewells may also change. Larger or commercially oriented farmers can continue 'chasing water' through deeper pumping, while smaller farmers may prefer shared wells, canal water, rented irrigation services or less water-demanding crops. Comparable responses have been documented in peri-urban Bangalore, where groundwater access and proximity to urban markets influenced crop choices (Patil et al., 2019).

This also changes how the term 'impact' should be understood. The evidence does not support a claim that Hisar's urban expansion has produced a uniform district-wide groundwater decline. Rather, expansion is adding a new layer of demand and modifying recharge in a groundwater system already shaped by intensive agriculture, canal networks, variable rainfall and salinity. The most serious risk is cumulative: if urban demand grows while irrigation pumping remains unchanged, assessment units presently close to the threshold can deteriorate quickly.

7. IRRIGATION ADAPTATION AND MANAGEMENT PRIORITIES

The policy response should connect peri-urban planning with agricultural water management instead of treating them as separate sectors. Five priorities emerge from the analysis.

Table 5. Priority actions for groundwater-sensitive peri-urban development in Hisar

Priority	Problem addressed	Operational response	Spatial emphasis
Protect recharge in new development	Loss or concentration of infiltration as built-up surfaces expand	Mandatory plot-level recharge, recharge trenches, preservation of ponds and open drainage paths	Peri-urban Hisar-I/Hisar-II and major growth corridors
Use canal and groundwater conjunctively	Marginal-fresh and saline groundwater over a large part of district	Mix/alternate canal and groundwater; schedule groundwater as a supplementary source	Areas with marginal groundwater quality
Reduce irrigation demand per unit output	Irrigation accounts for about 98.77% of groundwater extraction	Drip/sprinkler where suitable, underground pipelines, laser levelling and improved irrigation scheduling	Critical/near-threshold assessment units
Adjust crops to water conditions	High pumping stress and variable rainfall	Shift from water-intensive crops where feasible; promote drought/salt-tolerant varieties	Critical and over-exploited units
Monitor peri-urban wells separately	Block averages can hide fringe-specific stress	Dedicated observation wells and annual water-level/EC monitoring around urban expansion zones	Hisar city fringe
Reuse treated urban water	Urbanization increases wastewater generation	Use treated wastewater for non-food crops/green belts where quality standards are met	Suitable peri-urban command areas

First, urban development should be made recharge-conscious. Recharge structures are often added as engineering accessories after layout approval; they should instead be planned as part of the hydrological design of colonies, campuses and industrial estates. Existing village ponds and low-lying infiltration zones deserve protection because they provide recharge opportunities that are difficult to recreate once built over. The CGWB aquifer management plan for Hisar explicitly identifies artificial recharge, village ponds and drainage channels as part of the district strategy.

Second, the district should strengthen conjunctive use rather than promote a simple hierarchy of water sources. In areas with marginal groundwater, planned blending with canal water can protect soils while reducing groundwater abstraction. Canal schedules, groundwater-quality maps and crop calendars should therefore be considered together at the local level. This approach is more realistic than advising farmers to abandon groundwater, because the flexibility of a private or shared tubewell remains valuable during canal shortages and dry spells.

Third, irrigation-efficiency investment should be geographically targeted. Because irrigation constitutes almost the entire groundwater extraction volume, efficiency measures have far greater leverage than restrictions focused only on small domestic users. Micro-irrigation is useful for suitable crops, but it is not the only option. Underground pipeline conveyance, field levelling, timely irrigation, soil-moisture-based scheduling and reduction of conveyance losses can also lower pumping requirements. CGWB's Hisar management plan specifically recommends replacing unlined field channels with underground pipeline systems in stressed areas.

Fourth, crop adjustment should be treated as a water-management instrument rather than merely an agricultural-marketing programme. The appropriate change varies by location. Where groundwater is saline, salt-tolerant crops and varieties may be more important than reducing crop water use alone. Where extraction is critical, lower-water-demand crops can directly reduce pumping. Near the city, higher-value horticulture may appear attractive because of market proximity, but such shifts should be evaluated against their water requirement and irrigation source.

Finally, the peri-urban fringe needs its own monitoring network. District and block statistics are necessary but too coarse to identify the influence of a new colony, institutional cluster or transport corridor on local wells. Observation wells placed across the urban-rural transition, with repeated measurements of depth, EC and selected contamination indicators, would allow actual peri-urban effects to be separated from rainfall and canal-recharge effects. This would also provide a stronger evidence base for future land-use permissions in water-stressed zones.

8. CONCLUSION

The expansion of Hisar city into its surrounding agricultural landscape is changing the district's water system, but the change is neither uniform nor adequately described by a single groundwater-decline narrative. Built-up land in Hisar city and its peri-urban zone nearly doubled between 2001 and 2021, and a substantial share of this expansion occurred on agricultural land. The conversion has altered the spatial distribution of water demand and the surface conditions controlling recharge. At the same time, agriculture remains the dominant groundwater user: the 2020 sectoral data attribute about 98.77 per cent of groundwater extraction in the district to irrigation.

Groundwater stress is strongly differentiated. Narnaund is over-exploited, Agroha and Barwala are critical, while Hisar-I and Hisar-II remain just below the semi-critical threshold. Hisar-I's sharp rise in the stage of extraction between 2023 and 2024 deserves particular attention because it overlaps the wider zone influenced by urban growth. Yet the decadal post-monsoon record shows rising water levels across about two-thirds of the district area. This is not evidence against groundwater pressure; rather, it reflects the importance of spatially variable recharge from rainfall, canals, irrigation return flows and artificial-recharge interventions.

Water quality further narrows the irrigation options. Fresh groundwater occupies only about 26.70 per cent of the district area, whereas marginal-fresh water is dominant and additional areas are marginal or saline. In this setting, sustainable irrigation depends on how farmers combine groundwater with canal water, select crops and manage the timing and efficiency of irrigation. Peri-urban expansion therefore affects agriculture through a chain of linked changes: land conversion, new year-round water demand, altered recharge conditions, pressure on local aquifers and adjustments in irrigation practice.

The practical implication is that Hisar's peri-urban planning and groundwater management should be brought into the same decision framework. Recharge-sensitive urban design, dedicated fringe monitoring, conjunctive canal-groundwater use, efficient irrigation conveyance, micro-irrigation where agronomically suitable, crop adjustment and reuse of treated wastewater can reduce cumulative pressure. Such measures are most effective when they are targeted to local groundwater category and quality rather than applied uniformly across the district. The future sustainability of agriculture around Hisar will depend not simply on how much land remains under cultivation, but on whether the remaining farms continue to have reliable access to water of usable quality at an economically manageable cost.

REFERENCES

[1] Asoka, A., Gleeson, T., Wada, Y., & Mishra, V. (2017). Relative contribution of monsoon precipitation and pumping to changes in groundwater storage in India. Nature Geoscience, 10, 109-117. https://doi.org/10.1038/ngeo2869

[2] Butsch, C., Chakraborty, S., Gomes, S. L., Kumar, S., & Hermans, L. M. (2021). Changing hydrosocial cycles in periurban India. Land, 10(3), 263. https://doi.org/10.3390/land10030263

[3] Central Ground Water Board. (2017). Aquifer mapping and management plan: Hisar District, Haryana. Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India.

[4] Central Ground Water Board. (2024). Summary on status of dynamic ground water resources of Haryana (as on 2023) and Dynamic Ground Water Resources assessment, 2024. Ministry of Jal Shakti, Government of India.

[5] Central Ground Water Board. (2024). Ground water year book: Haryana, 2023-24. North Western Region, Chandigarh, Ministry of Jal Shakti, Government of India.

[6] Frommen, T., Groeschke, M., Nölscher, M., Koeniger, P., & Schneider, M. (2021). Anthropogenic and geogenic influences on peri-urban aquifers in semi-arid regions: Insights from a case study in northeast Jaipur, Rajasthan, India. Hydrogeology Journal, 29, 1261-1278. https://doi.org/10.1007/s10040-021-02301-7

[7] Haryana Water Resources (Conservation, Regulation and Management) Authority. (2023). Integrated Water Resources Plan Haryana 2023-2026. Government of Haryana.

[8] Haryana Water Resources (Conservation, Regulation and Management) Authority. (2025). Haryana Water Resources Atlas 2025. Government of Haryana.

[9] MacDonald, A. M., Bonsor, H. C., Ahmed, K. M., Burgess, W. G., Basharat, M., Calow, R. C., Dixit, A., Foster, S. S. D., Gopal, K., Lapworth, D. J., Lark, R. M., Moench, M., Mukherjee, A., Rao, M. S., Shamsudduha, M., Smith, L., Taylor, R. G., Tucker, J., van Steenbergen, F., & Yadav, S. K. (2016). Groundwater quality and depletion in the Indo-Gangetic Basin mapped from in situ observations. Nature Geoscience, 9, 762-766. https://doi.org/10.1038/ngeo2791

[10] Patil, V. S., Thomas, B. K., Lele, S., Eswar, M., & Srinivasan, V. (2019). Adapting or chasing water? Crop choice and farmers' responses to water stress in peri-urban Bangalore, India. Irrigation and Drainage, 68(2), 140-151. https://doi.org/10.1002/ird.2291

[11] Rahul, & Kaur, R. (2024). Peri-urban delineation and urban expansion quantification from 2001 to 2021 of Hisar City, India, using geospatial techniques. International Journal of Geoinformatics, 20(4), 86-99. https://doi.org/10.52939/ijg.v20i4.3155

[12] Shah, T. (2012). Community response to aquifer development: Distinct patterns in India's alluvial and hard rock aquifer areas. Irrigation and Drainage, 61(S1), 14-25. https://doi.org/10.1002/ird.1656

[13] Sharma, M., & Kumar, V. (2023). Assessment of urban sprawl, land use/land cover changes and land consumption rate in Hisar City, Haryana, India. Human Geographies: Journal of Studies and Research in Human Geography, 17(1). https://doi.org/10.5719/hgeo.2023.171.3