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Groundwater Dependence and Surface Water Gaps in Hamirpur District, India: Insights from GIS Mapping

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Abstract

The district of Hamirpur in the drought prone Bundelkhand region of Uttar Pradesh is dependent on the ground water sources to provide irrigation to the fields, with the surface water supply being provided by canals and tanks. The primary dataset used in this paper to map and quantify groundwater dependence and identify zones of surface-water gap using the available data and GIS layers, which are block-wise counts of wells, tube wells, solar wells, pumpsets and canal coverage (7 development blocks Gohand, Kurara, Maudaha, Muskara, Rath, Sarila and Sumerpur). These are superimposed with published hydro-meteorological and institutional data (CGWB groundwater evaluations, IMD rainfall examinations, NRSC/Bhuvan LULC, and CPCB river-water quality reports) to consider trends. Findings indicate that there are very dense point-source collections of groundwater infrastructure in Sumerpur, Maudaha and Sarila, but there is greater canal coverage in Muskara, Gohand and Rath. A dependence ratio (groundwater points versus surface proxies) attests to a district-wide shift to well-based irrigation which is supported by monsoon variability, a limited canal command in uplands and hard-rock aquifer limitations beyond the Yamuna- Betwa river corridors. The paper suggests a block-prioritized water-balance approach, which includes: revival of tanks and minors, aquifer-specific recharge (check dams, percolation tanks), groundwater demand management, and near-real-time GIS dashboards, to decrease abstraction pressure and enhance conjunctive use on a district level.

Keywords: Groundwater, Surface Water, GIS Mapping, Hamirpur District, Bundelkhand, Water Resource Management

Introduction

The semi-arid areas in central India have been undergoing a multi-decadal shift in irrigation methods away from the use of canals and tanks in favor of privately drilled wells and tube wells. This is not just a change of infrastructure, but of a more fundamental hydrological and institutional adjustment to variability and risk. This evolution can be symbolized by Bundelkhand which cuts across Uttar Pradesh and Madhya Pradesh. Rainfall is unpredictable annually; soils are frequently shallow and lie upon terrains of hard rock where it is not possible to store much water and where recharge is intermittent; and old canal networks are more likely to distribute water unevenly, particularly in non-command or upland tracts where the topography, seepage, and maintenance hunches diminish the conveyance efficiency. Against this context, farmers have given themselves the rational investment in the distributed, on-demand access to groundwater, which, at first, through dug (brick) wells and, more recently, through shallow, medium and deep tube wells, they think, is more responsive to the times of crop water demand, especially during the Rabi season, and provides a degree of autonomy between rotation schedules and the unreliability of canals. The spatial contrasts which cause this behavior are shown by Hamirpur, located at the confluence of Yamuna and Betwa rivers. Aluvial deposits along the river corridors will be relatively more storative, well productive, and will have a higher capacity to conjunctively utilize surface flows. The topography of the region abandoned the valleys and upraises to the uplands of low undulations supported by granite, gneiss, and Vindhyan sandstones, where the aquifer is controlled by fractures and is heterogeneous. In this case, canal orders are thinned, underage performers are

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more common, and recharge pulses are not so lasting - circumstances which encourage those that have their households diversified into more than one tube well or rather deepen their bores. The solar-powered pumping introduced during the last decade is a new potential vector that minimizes the variable cost of extraction and even promotes its use where the capital and location is possible and affordable by groundwater.

The challenge of sustainability that arises is two-fold. To start with, the monsoon-dependent recharge in these heterogeneous aquifers has to be stabilized by site-specific, aquifer-proportional interventions: check dams and percolation tanks on first- and second-order streams; recharge shafts along mapped fracture belts in hard-rock belts; and spreading structures or bank infiltration galleries in alluvial reaches. These measures need to be linked in micro-catchments to ensure that their resultant effect is substantial enough to be felt in the level of intense well fields. Second, the spatial gaps in surface delivery must be bridged, which is possible through telemetry-based canal control, selective lining of reaches incurring losses, and through plausible and verifiable rotation schedules and/or rotation plans that are visible to farmers, enabling groundwater to be used as a strategic supplement, not a structural alternative. The new recharge will be lost very fast in the deep waters of the growing private abstraction unless there is a more robust surface backbone and demand management-crop choice, micro-irrigation, and energy-smart irrigation windows. To put it briefly, the future of the irrigation of Hamirpur can be achieved by improving surface systems as well as institutionalizing conjunctive use, that is, increase the reliability of canals where they are practical, increase the recharge of the aquifers where they not, and liberalize the pumping and transparently block-level water budgeting of the pumping in a way that makes the groundwater a buffer and not a crutch.

Study Area: Hamirpur district lies in the Chitrakoot Dham division of Uttar Pradesh, between ~25°27′–25°57′ N and 79°11′–80°19′ E, with a geographic area of ~4,100–4,280 km². The district comprises four tehsils (Hamirpur, Maudaha, Rath, Sarila) and seven development blocks (Gohand, Kurara, Maudaha, Muskara, Rath, Sarila, Sumerpur). Hamirpur town sits just above the Yamuna–Betwa confluence. Climate is semi-arid, with hot summers and a monsoon-dominated rainfall regime. Physiographically, riverine alluvium along Yamuna–Betwa transitions to gently undulating Bundelkhand uplands underlain by granite, gneiss and Vindhyan sandstones—conditions that shape aquifer storativity, well yields and canal command reach.

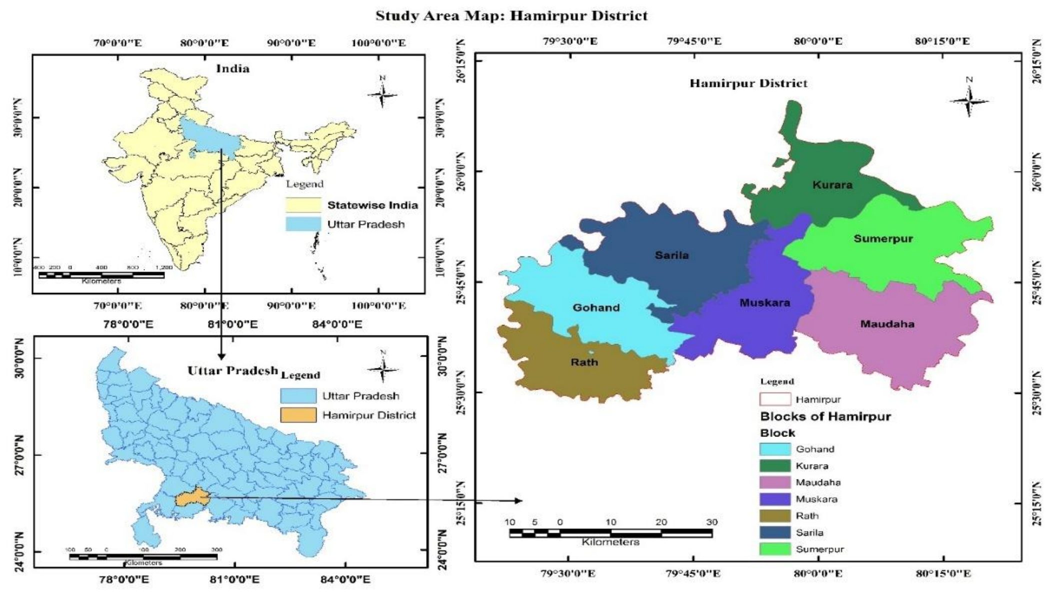

Figure 1: Study Area Map

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Data and Methodology

Data are taken from Government official and block-wise statistics (canal coverage/density; counts of government tube wells, dug/brick wells, shallow/medium/deep tube wells, solar tube wells, and geostationary pump sets). These were structured into a geodatabase for analysis. Secondary layers included CGWB groundwater status and year-book tables, IMD gridded rainfall analyses for Bundelkhand, Bhuvan/NRSC land-use-land-cover products, and CPCB river water quality. Workflow: (i) block polygon boundary harmonization; (ii) attribute join of govt. Official block-wise irrigation counts; (iii) derivation of two indicators—(a) Groundwater Point Density (sum of well/tube-well classes per block) and (b) Dependence Ratio (Groundwater Points : Surface Proxies, where surface proxies include canal coverage and geostationary pumpsets); (iv) choropleth and bivariate maps; (v) overlay with rainfall and lithology to interpret controls; and (vi) identification of priority micro-basins for recharge and conjunctive use.

Table 1. Block-wise irrigation sources and derived indicators.

Block	CanalCoverage sqkm	Govt TW	Brick Wells	Pumpsets	Shallow TW	Medium TW	Deep TW	Solar TW	Canal Density per20sqkm	Groundwater Points	Surface Proxies	Dependence Ratio GW to Surface
Kurara	78	155	3	220	650	386	425	0	3.61	1619	298	5.43
Sumerpur	58	135	176	376	2296	409	556	11	1.94	3583	434	8.26
Sarila	73	127	199	269	1582	337	462	18	2.31	2725	342	7.97
Gohand	147	43	2039	794	897	325	369	49	5.73	3722	941	3.96
Rath	115	2	360	434	3169	282	288	128	5.41	4229	549	7.7
Muskara	235	14	855	434	1581	149	145	34	9.52	2778	669	4.15
Maudaha	125	81	250	394	2366	401	464	6	3.82	3568	519	6.87

Source: Directorate of Economics & Statistics, Government of Uttar Pradesh. (2025).

Analysis and Discussion:

The table shows a clear, district-wide tilt toward groundwater-based irrigation across all seven blocks of Hamirpur. Groundwater points (sum of government tube wells, brick/dug wells, and shallow/medium/deep/solar tube wells) dominate surface proxies (canal coverage + pumpsets) everywhere, with Dependence Ratios ranging from ~3.96 to 8.26. The highest totals of groundwater points occur in Rath

Figure 2

(4,229), Gohand (3,722), Sumerpur (3,583), and Maudaha (3,568)—a pattern consistent with intensive well development for Rabi irrigation.

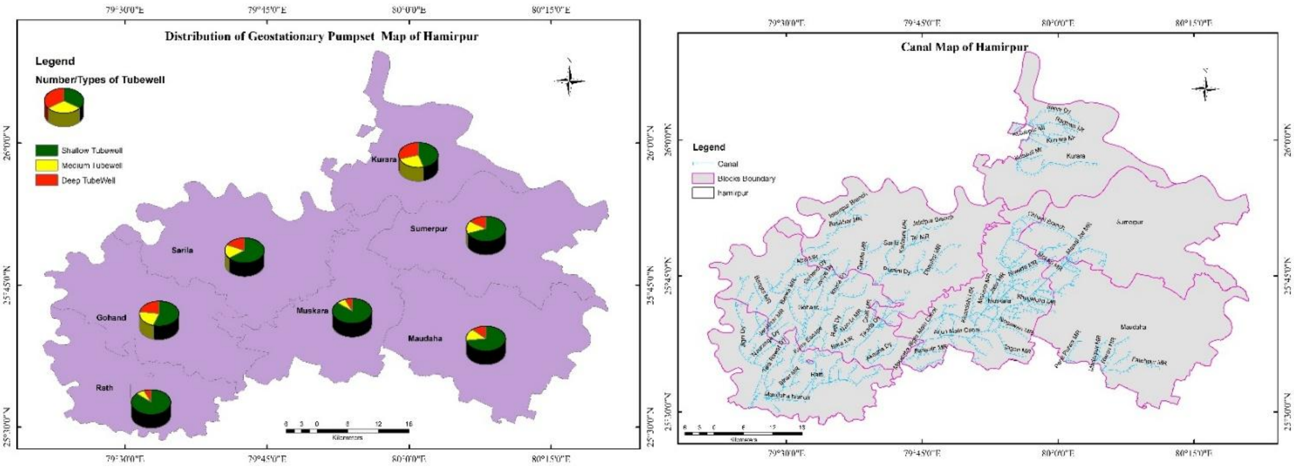

Figure 3

Two blocks stand out for distinct reasons. Gohand has an exceptional number of brick/dug wells (2,039) alongside substantial canal support

(surface proxies = 941), yielding the lowest dependence ratio (3.96). This suggests relatively better conjunctive potential: canals help, but groundwater remains substantial. Rath, by contrast, combines very high shallow tube wells (3,169) with notable solar wells (128) and moderate canal support, leading to a high dependence ratio (7.70)—indicating strong private pumping capacity and rising energy-enabled abstraction.

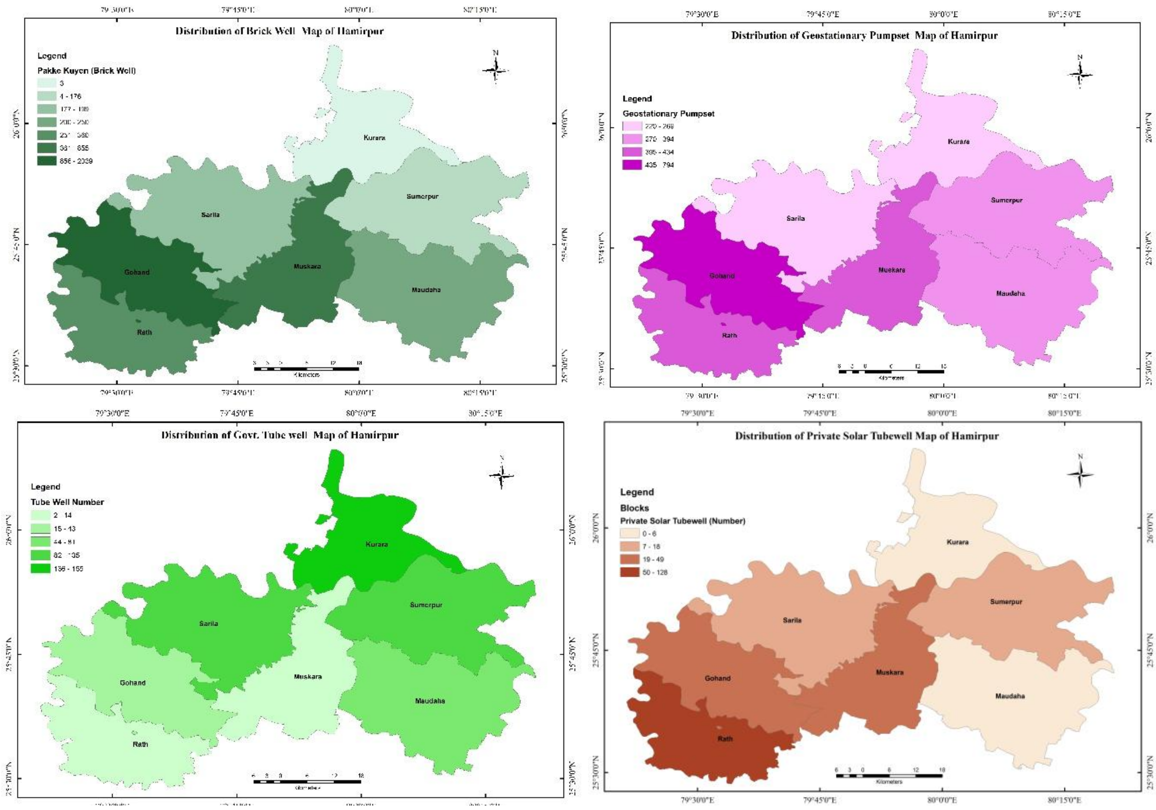

Figure 4

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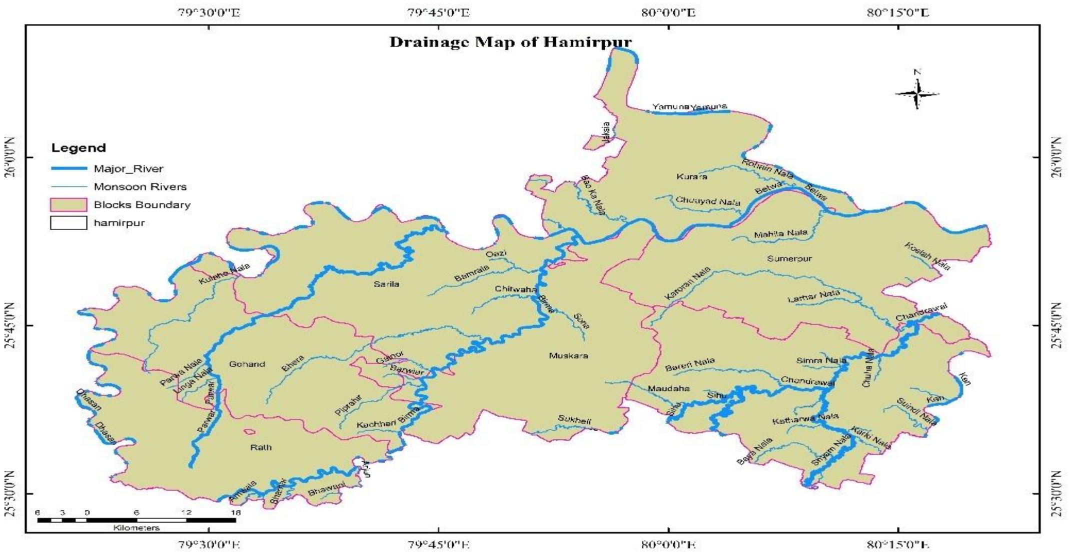

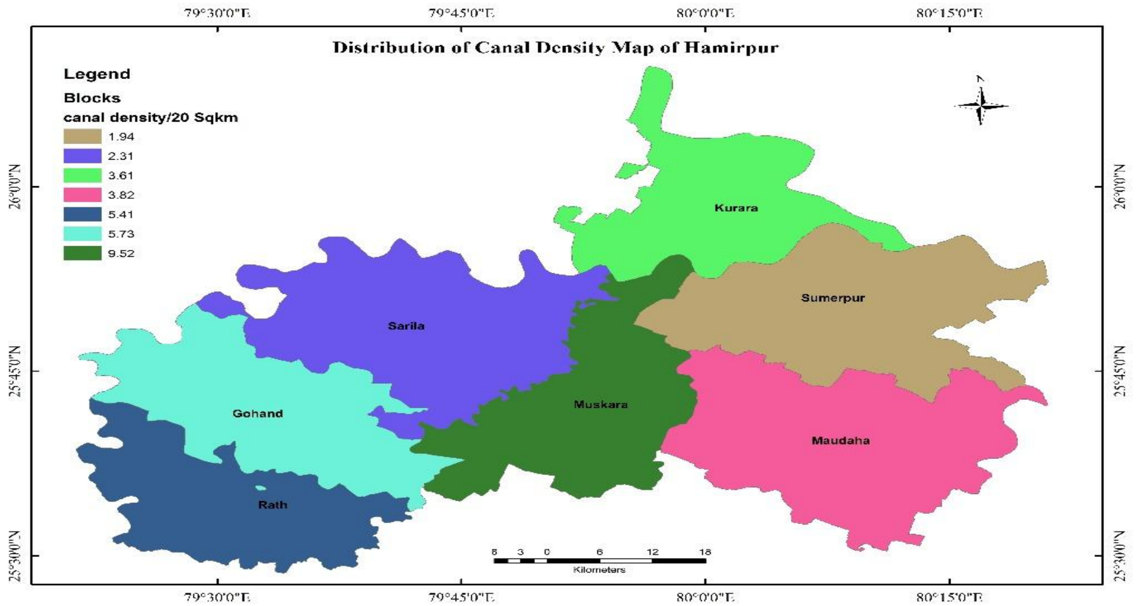

On the surface-water side, Muskara shows the highest canal coverage (235) and canal density (9.52 per 20 km²) with sizable surface proxies (669), yet its dependence ratio (4.15) still signals a groundwater-leaning system. Gohand similarly benefits from higher canal coverage and pumpsets but does not escape high well reliance. In contrast, Sumerpur (8.26) and Sarila (7.97) have the highest dependence ratios—classic gap zones where groundwater infrastructure is dense but surface proxies are comparatively low. Maudaha (6.87) and Kurara (5.43) fall in the mid-to-high range.

Results

Spatial patterns show that Sumerpur, Maudaha and Sarila host very large numbers of shallow tube wells, indicating strong reliance on phreatic aquifers during the Rabi season. Muskara, Gohand and Rath exhibit higher canal coverage/density, but are not uniformly less groundwater-dependent—each also carries substantial tube-well counts. Kurara appears intermediate in both canal coverage and groundwater point totals. A dependence ratio confirms that, district-wide, wells substantially outnumber surface proxies, especially in blocks with upland physiography and

Figure 5

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away from main canal commands. Rainfall variability and hard-rock aquifer characteristics (fracture-controlled yields) help explain the preference for distributed well infrastructure, while under-performing minors and seasonal flows limit canal effectiveness in uplands. The Yamuna–Betwa corridor shows greater scope for conjunctive use due to alluvial storage and river-fed recharge.

Causes and Implications

Over-abstraction in localized pockets risks seasonal declines in water levels, pump-lifting costs, and energy burdens. Ecologically, reduced baseflow can degrade small streams and tanks; socio-economically, farm gate profitability becomes sensitive to diesel/electricity prices and pre-monsoon drawdown. Where canal delivery remains erratic, farmers hedge with more private wells, creating a reinforcing loop. Without demand management, the benefits of new recharge structures disperse quickly across large well densities.

Suggestions and Policy Recommendations

We propose a district-level, GIS-enabled water-balance plan: (1) revive tanks/ponds in upland micro-catchments that feed minors; (2) construct check dams and percolation tanks on first/second-order streams across hard-rock tracts; (3) adopt aquifer-specific recharge (fracture-aligned recharge shafts in granite/gneiss; recharge trenches near alluvium) and mandate rooftop rainwater harvesting in gram panchayat assets; (4) modernize canal operation with rotation schedules, telemetry at head regulators and farmer advisory; (5) create a water budgeting app at block level linked to piezometer networks and public dashboards; (6) incentivize low-duty crops in late Rabi/Zaid and drip in high-duty crops where feasible; and (7) regulate high-capacity borewells via block-level permits tied to annual water budgets.

Conclusion

GIS evidence from the authentic data confirms a structural tilt toward groundwater across Hamirpur's blocks, with surface delivery concentrated in select canal-command tracts. Bridging the surface-water gap requires targeted recharge, revival of storages, smarter canal operation, and block-wise demand management. A conjunctive-use strategy—driven by near-real-time monitoring and community governance—can reduce abstraction pressure while stabilizing irrigation reliability in a variable monsoon climate.

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