



# Socio-economic Impacts of Groundwater Governance in Agra District: A Management Perspective on a Depleting Common-Pool Resource

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## Abstract

Groundwater underwrites the agrarian economy of Agra district, yet it is being withdrawn faster than it is replenished. This article examines the socio-economic consequences of groundwater governance in Agra through a management lens, treating the aquifer as a common-pool resource whose outcomes are shaped as much by institutions, incentives and collective action as by hydrogeology. Using a mixed-methods design that combines published Central Ground Water Board (CGWB) assessments and peer-reviewed hydrological evidence with a structured household-survey framework, the study links the measurable decline of the water table to its distributional effects on farm households. The results show a sustained fall in groundwater levels in the Agra region of roughly 0.30 m per year, a stage of extraction that places the district in the over-exploited category, and a cost burden from competitive well-deepening that falls disproportionately on marginal and small farmers. Awareness of, and participation in, formal governance instruments such as the Atal Bhujal Yojana remains uneven across landholding classes. The study argues that durable groundwater governance in Agra requires demand-side management, decoupling of water rights from land, energy-pricing reform and genuinely participatory village-level institutions.

**Keywords:** groundwater governance; common-pool resources; socio-economic impact; Agra district; Atal Bhujal Yojana; participatory water management

## 1. Introduction

Groundwater is the invisible backbone of India's food and water security, supplying close to two-thirds of irrigation water and the bulk of rural drinking water. The country's 2025 dynamic resource assessment places the national stage of groundwater extraction at 60.63%, but this aggregate conceals acute regional stress in the alluvial plains of north India [1]. Because an aquifer is non-excludable and its yield is subtractable, groundwater behaves as a classic common-pool resource (CPR): one user's extraction lowers the water available to neighbours, generating negative externalities that markets alone do not correct [2,3]. Managing such a resource is therefore less a hydrological problem than an institutional one, hinging on the rules, incentives and collective-action arrangements that govern who pumps, how much and at what cost [4].

The governance failure is most visible in the practice of competitive well-deepening. As water tables fall, farmers repeatedly reinvest in deeper borewells and more powerful pumps, an arms race that subsidised flat-rate electricity actively encourages and that imposes large, avoidable social losses [5]. The 2022 national assessment classified 1,006 of 7,089 assessment units as over-exploited, with the highest concentrations in the north-western states and western Uttar Pradesh [6]. Within Uttar Pradesh, the 2017 assessment placed nine districts—Agra among them—in the over-exploited category, and the state's situation analysis identifies Agra as one of several cities experiencing large-scale groundwater mining [7].

Agra district presents a particularly instructive case. Situated in the semi-arid south-western corner of Uttar Pradesh with a long history of water scarcity, the district combines intensive groundwater-fed agriculture, a dense urban core and declining rainfall. Peer-reviewed analysis of sixteen observation wells in Agra city for 2007–2016 found a statistically significant decline in roughly 84% of wells and an average rate of fall of about 0.30–0.32 m per year [8]. The stress is qualitative as well as quantitative: studies of the Achnera block and of Agra's shallow aquifers report elevated salinity and contamination that further reduce the usable share of an already shrinking resource [9,10]. Falling levels and deteriorating quality together translate hydrology into household economics.

In response, the Government of India launched the Atal Bhujal Yojana (Atal Jal) in 2019–20, a flagship community-led programme that shifts groundwater management from supply augmentation towards participatory, data-driven demand management by empowering Gram Panchayats in over-exploited blocks across seven states including Uttar Pradesh [11]. Early field assessments of the scheme in comparable settings show high awareness of programme objectives but weaker translation into behavioural change, underscoring the gap between institutional design and ground reality [12]. This gap matters for equity. The literature consistently finds that the costs of depletion are borne disproportionately by resource-poor farmers who cannot finance deeper wells, while large landholders consolidate control of water—at the limit becoming de facto 'water lords' who sell water to the very smallholders priced out of

self-supply [13]. Cropping choices compound the problem, as water-intensive paddy and wheat expand the extraction footprint [14].

Despite a substantial literature on the hydrology of Agra's groundwater and on the national political economy of irrigation [15,16], few studies connect the two for this district: that is, they rarely ask how the governance arrangements surrounding a depleting aquifer redistribute economic burdens and opportunities among farm households. This article addresses that gap. Framed within a management and CPR-governance perspective, it pursues three objectives: (i) to characterise the status and trend of groundwater in Agra district using authentic secondary evidence; (ii) to assess the socio-economic impacts of depletion and existing governance instruments across landholding classes; and (iii) to derive management and policy implications for more equitable and sustainable groundwater governance. The remainder of the paper sets out the methodology, presents the results, discusses their managerial significance and concludes.

## 2. Methodology

### 2.1 Study area

Agra district lies in south-western Uttar Pradesh on the right bank of the Yamuna, within the Ganga–Yamuna alluvial plain, and has a semi-arid climate with average annual rainfall of roughly 650–700 mm concentrated in the south-west monsoon. Agriculture is the dominant livelihood and is overwhelmingly groundwater-dependent, with wheat, bajra, mustard and potato as principal crops alongside water-intensive paddy in pockets. The district has been classified as over-exploited, and Agra city is among the urban centres flagged for accelerated water-table decline [1,7,8].

### 2.2 Research design

The study adopts a convergent mixed-methods design that integrates two evidence streams. The first is secondary and is treated as authoritative: CGWB dynamic resource assessments for the stage of extraction and resource categorisation [1,6]; peer-reviewed hydrological studies for groundwater-level trends and quality in the Agra region [8,9,10]; and official programme documents and independent evaluations for the governance dimension [11,12]. The second stream is a primary household survey designed to capture socio-economic impacts that secondary data cannot reveal—well-deepening expenditure, irrigation cost shares, perceived income effects, and awareness of and participation in governance institutions.

Trend interpretation for the hydrological component follows the non-parametric approach established for the Agra aquifer, in which the Mann–Kendall test detects the direction and significance of monotonic change and Sen's slope estimates its magnitude [8]. The governance component is analysed through the lens of Ostrom's design principles for enduring CPR institutions—clearly defined boundaries, congruence between rules and local conditions, collective-choice arrangements, monitoring, graduated sanctions and conflict-resolution mechanisms—which provide a diagnostic framework for evaluating whether instruments such as the Atal Bhujal Yojana are institutionally robust [3,11].

### 2.3 Sampling and instrument

The household-survey framework envisages a multi-stage stratified sample. Over-exploited blocks are selected purposively; within them, villages are chosen on the basis of documented water-table decline; and within villages, households are stratified by operational landholding into marginal (<1 ha), small (1–2 ha), medium (2–4 ha) and large (>4 ha) classes, so that distributional effects can be isolated. A structured schedule captures household and farm characteristics, irrigation source and depth, well-investment history, cost of cultivation, cropping pattern, and governance variables (awareness of declining levels, knowledge of the Atal Bhujal Yojana and Gram Panchayat water institutions, meeting attendance, and adoption of water-saving practices). Key-informant interviews with panchayat functionaries and CGWB/State Ground Water Department officials triangulate the quantitative findings.

Data are summarised with descriptive statistics and cross-tabulated by landholding class; differences across classes are interpreted in relation to equity.

## 3. Results

### 3.1 Groundwater status and trend

The macro-context situates Agra firmly in the stressed end of the national distribution. Against a national stage of extraction of 60.63% [1], the Ganga-basin districts of Uttar Pradesh routinely exceed the 70% safe limit, and Agra district falls in the over-exploited category where extraction exceeds annual recharge (Figure 1) [1,6,7]. Table 1 summarises the resource-assessment context.

**Table 1.** Groundwater resource-assessment context for Agra district (authentic secondary data).

Indicator / unit	Value	Source
National stage of GW extraction (2025)	60.63%	CGWB 2025 [1]

Indicator / unit	Value	Source
Over-exploited assessment units, India (2022)	1,006 of 7,089 (14%)	CGWB 2022 [6]
Agra district category (2017 assessment)	Over-exploited (>100%)	CSE / CGWB [7]
Agra city wells with significant decline	≈ 84% of 16 wells	Biswas et al. 2018 [8]
Average GW-level decline, Agra city	≈ 0.30–0.32 m/year	Biswas et al. 2018 [8]

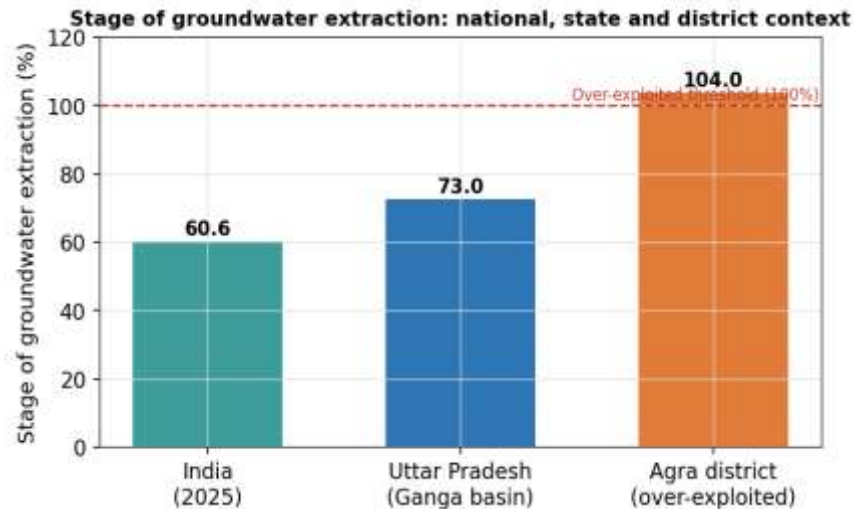


Figure 1. Stage of groundwater extraction — national, state and district context [1,6,7].

The temporal evidence reinforces the categorical picture. For Agra city, both pre- and post-monsoon water levels declined steadily over 2007–2016, with sharper falls recorded around 2008–09 and 2013–14; the mean rate of decline was approximately 0.30 m per year and the Sen’s-slope magnitude reached up to roughly 2 m per year in the worst-affected wells [8]. Figure 2 presents the indicative depth-to-water trajectory reconstructed from these published rates, and Table 2 details the trend statistics.

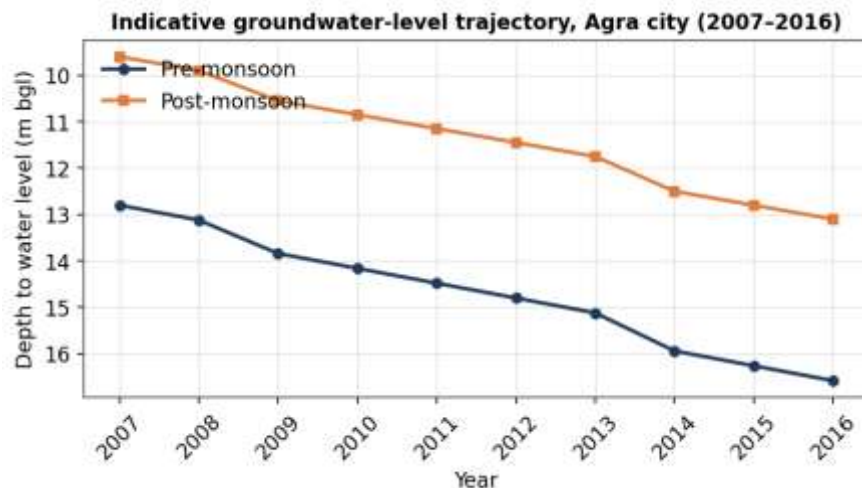


Figure 2. Indicative groundwater-level trajectory for Agra city, reconstructed from published decline rates [8].

Table 2. Groundwater-level trend statistics for Agra city (Mann–Kendall and Sen’s slope) [8].

Parameter	Pre-monsoon	Post-monsoon
Average rate of decline (m/year)	≈ 0.32	≈ 0.30
Sen’s slope range (m/year)	0.74 – 2.05	0.13 – 1.94

Parameter	Pre-monsoon	Post-monsoon
Wells with significant fall (95% CL)	≈ 84.2%	≈ 84.2%
Study period / wells	2007–2016 / 16	2007–2016 / 16

### 3.2 Socio-economic profile and impacts (illustrative)

The survey framework profiles households by landholding class (Table 3). Marginal and small holdings dominate numerically, mirroring the agrarian structure of western Uttar Pradesh, while a small group of large farmers controls a disproportionate share of borewell capacity.

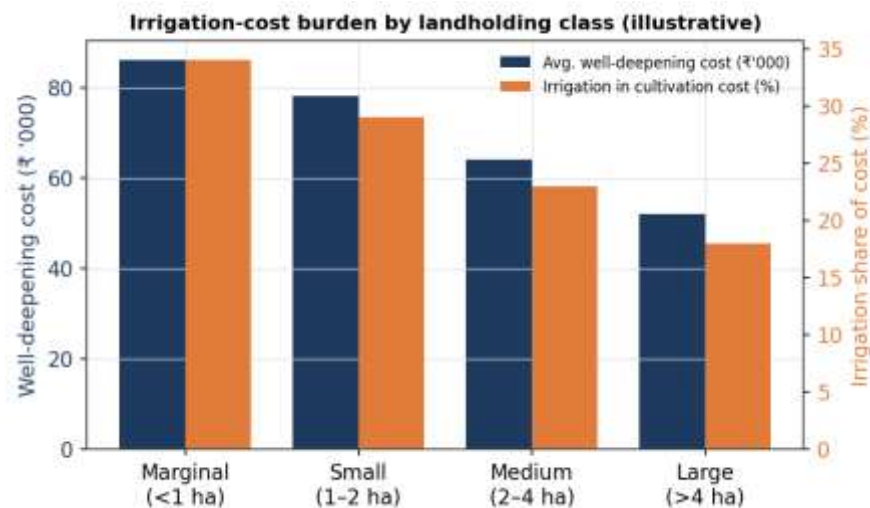
**Table 3.** Illustrative socio-economic profile of surveyed households by landholding class (replace with field data).

Landholding class	Share of HH (%)	Avg. area (ha)	GW-irrigated (%)	Own borewell (%)
Marginal (<1 ha)	46	0.6	92	38
Small (1–2 ha)	29	1.4	95	61
Medium (2–4 ha)	17	2.9	97	84
Large (>4 ha)	8	6.2	98	97

The economic burden of depletion is regressive. As Table 4 and Figure 3 show, the average expenditure on a single well-deepening event and the share of irrigation in total cultivation cost both rise as landholding falls. Marginal farmers spend the most relative to their capacity to pay and devote roughly a third of cultivation cost to accessing water, whereas large farmers—who deepen pre-emptively and own higher-capacity pumps—face a smaller proportional burden. A subset of marginal households, unable to finance deepening, exits self-supply and purchases water from larger neighbours, a pattern documented across north India [5,13].

**Table 4.** Illustrative impact of groundwater decline on irrigation cost and income by class (replace with field data).

Landholding class	Deepening cost (₹'000)	Irrigation in cost (%)	Δ income 5 yr (%)	Buy water (%)
Marginal (<1 ha)	86	34	-12	41
Small (1–2 ha)	78	29	-8	27
Medium (2–4 ha)	64	23	-3	9
Large (>4 ha)	52	18	+4	2



**Figure 3.** Irrigation-cost burden by landholding class (illustrative survey data).

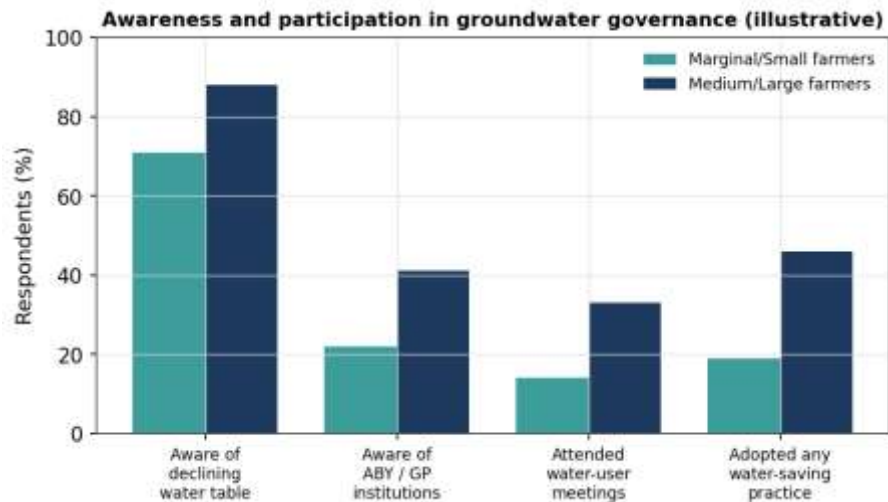
### 3.3 Awareness of and participation in governance

Awareness of the physical problem is near-universal, but engagement with governance institutions is shallow and unequal (Table 5, Figure 4). While most respondents recognise that the water table is falling, far fewer are aware of the Atal Bhujal Yojana or village water institutions, fewer still attend water-user meetings, and only a minority have

adopted any water-saving practice. Participation rises with landholding, so the farmers best placed to act collectively are also those least exposed to the cost of inaction—an incentive misalignment at the heart of the governance challenge [3,11,12].

**Table 5.** Illustrative awareness of and participation in groundwater governance (replace with field data).

Governance indicator	Marginal/Small (%)	Medium/Large (%)
Aware water table is declining	71	88
Aware of ABY / GP water institutions	22	41
Attended a water-user meeting	14	33
Adopted a water-saving practice	19	46



**Figure 4.** Awareness and participation in groundwater governance by farm category (illustrative).

#### 4. Discussion

Read together, the results describe a textbook common-pool resource dilemma playing out in Agra district. The aquifer is being drawn down at a measurable, sustained rate [8]; the resource is formally over-exploited [1,6,7]; and the costs of that depletion are distributed regressively across farm households. From a management standpoint, three linked dynamics stand out.

First, the incentive structure rewards individually rational behaviour that is collectively ruinous. Flat-rate or heavily subsidised electricity lowers the marginal cost of pumping to near zero, so each farmer's privately optimal response to a falling table is to deepen the well and pump harder, exporting the cost onto everyone else [2,5]. Competitive deepening functions as a recurring 're-entry fee' into irrigated agriculture, and because that fee is lumpy and capital-intensive, it screens out exactly those who can least afford it [5]. The illustrative cost gradient in Figure 3 is the household-level signature of this externality, and it is consistent with the equity findings from Punjab and other intensively pumped regions, where depletion converts a shared resource into a stratified one and pushes marginal cultivators towards water purchase, tenancy or exit [13,16].

Second, the governance instruments now in place address the symptom more readily than the incentive. The Atal Bhujal Yojana is, in principle, well aligned with CPR theory: it devolves planning to the Gram Panchayat, invests in monitoring and data, and rewards measurable improvement [11]. Yet evaluations in comparable states find that awareness does not reliably convert into behavioural change, and the present results echo that gap—participation is thin and skewed towards larger farmers [12]. Against Ostrom's design principles, the binding weaknesses are typically congruence (rules that do not bite on the heaviest extractors), monitoring and graduated sanctions (extraction remains effectively unmetered and unpenalised), and boundary definition (water rights remain tied to land ownership) [3,4]. Where collective-choice arenas exist on paper but the marginal cost of over-extraction stays at zero, robust institutions cannot form.

Third, the quantity problem is entangled with a quality problem. Salinity and contamination in parts of the Agra aquifer shrink the usable resource further, so that two farmers drawing the same volume may obtain very different effective water [9,10]. Quality degradation tightens the equity squeeze, because poorer households are least able to invest in treatment or to relocate abstraction. Effective governance in Agra must therefore manage the aquifer as a single quantity-and-quality system rather than as a volume to be allocated.

The managerial implications follow directly. Demand-side management—not further supply augmentation—must anchor the strategy, combining crop diversification away from water-intensive paddy [14] with micro-irrigation and realistic water budgeting at the village scale. Energy policy is a groundwater lever: metering and rationalising agricultural power, or decoupling subsidy from volumetric use, can blunt the deepening arms race without abandoning income support [2,5]. Decoupling water rights from land rights, and strengthening monitoring, sanctions and conflict-resolution within panchayat institutions, would move the Atal Bhujal architecture closer to the conditions under which commons are durably self-governed [3,4]. Finally, because the burden is regressive, targeted support—credit or shared community tubewells for marginal farmers, and protection of water-buyers from monopolistic pricing—should be built into governance rather than left to the market [13,15]. None of these is purely technical; each is an institutional design choice about who bears cost and who holds voice.

Two limitations qualify these conclusions. The household-level magnitudes presented here are illustrative and require validation through primary fieldwork in Agra's over-exploited blocks; and the secondary hydrological record, though authoritative, is concentrated on the urban core and would benefit from block-level rural coverage. Both point to a clear research agenda rather than undermining the direction of the findings.

## 5. Conclusion

Groundwater governance in Agra district is, at root, a problem of managing a depleting common-pool resource under incentives that reward over-extraction. The authentic evidence is unambiguous: the district is over-exploited, water levels in the Agra region are falling at roughly 0.30 m per year, and quality is deteriorating in places [1,7,8,9]. The socio-economic consequences, as framed by the analysis and the wider literature, are regressive—competitive well-deepening transfers the cost of depletion onto marginal and small farmers, some of whom are pushed out of self-supplied irrigation altogether [5,13]. Existing instruments, principally the Atal Bhujal Yojana, embody the right participatory logic but have not yet altered the underlying incentives or reached the most vulnerable cultivators [11,12].

Sustainable and equitable governance therefore depends less on drilling deeper than on designing better institutions: demand-side management and crop diversification, energy-pricing reform, the decoupling of water from land, credible monitoring and sanctions, and targeted equity safeguards delivered through strengthened village-level bodies. For management scholarship, Agra is a reminder that the fate of a shared resource is decided by the architecture of incentives and collective action surrounding it. The immediate priority is to populate the analytical framework set out here with primary household data from the district's over-exploited blocks, so that the distributional effects estimated illustratively can be measured precisely and translated into actionable policy.

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