POLICY BRIEF 63

Tiered Electricity Pricing for Sustainable Groundwater Use for Irrigation

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Irrigation, in conjunction with high-yielding seeds and agro-chemicals, has been a crucial factor in the intensification of Indian agriculture, contributing to improvements in productivity, farmers' incomes, and food security. The net irrigated area increased from 25 million hectares in 1960-61 to 79 million hectares in 2023-24, representing an increase from 19% to 56% of the net sown area. However, over three-fourths of the increase in irrigated area occurred due to groundwater extraction, the share of which in net irrigated area doubled from 30% to 60%. Concurrently, a transition occurred in energy sources for groundwater extraction devices (GEDs), from diesel to electricity. The number of electric-operated GEDs increased almost four-fold from 4.7 million in 1986-87 to 16.5 million in 2017-19.

The increasing reliance on groundwater resources for irrigation has raised concerns regarding their long-term sustainability. According to the Central Ground Water Board (CGWB)[1], over 11% of groundwater assessment units (blocks/mandals/talukas) have been over-exploited, and 14% are at a critical or semi-critical stage of exploitation[2]. Agriculture accounts for 87% of groundwater withdrawal; the possibilities of its conservation lies within this sector.

While the management of groundwater resources is a critical issue; the most states provide heavily subsidized or free electricity for irrigation to ensure farmers' affordable access. This policy results in a zero or near-zero marginal cost of water extraction, hence is a disincentive for conservation of water and investment in efficient irrigation technologies. Thus, a nuanced approach to energy pricing is essential for promoting sustainable use of groundwater.

The tiered pricing of electricity can serve as an effective mechanism to address the twin objective of enhancing farmers' affordability to electric power while promoting sustainable groundwater use. This involves a graduated pricing structure, in which the price of electricity increases when its consumption crosses the established thresholds. The appropriate consumption thresholds and tariffs for electricity can ensure farmers an affordable access to it. Higher prices for the subsequent use of electricity may compel farmers to adopt water-saving practices.

Here we evaluate how tiered electricity pricing can optimize the trade-off between affordable access and sustainable use of groundwater focusing on diverse groundwater endowments in Uttar Pradesh.

Groundwater-energy nexus in Uttar Pradesh

Approximately 87% of the net cropped area in Uttar Pradesh is irrigated, primarily using groundwater (83%). Water-intensive crops such as paddy, wheat, and sugarcane account for 63% of the cropped area. The state has four distinct regions: Eastern, Western, Central, and Bundelkhand regions, exhibiting significant variation in climate, water resources, and cropping patterns.

The average stage of groundwater extraction is 70%: 64% for the Eastern and Central regions, 69% for the Bundelkhand region, and 82% for the Western region. The groundwater depth is relatively shallow in the Eastern and Central regions (Figure 1), whereas it is deeper in the Western region. Shallow groundwater depth is an opportunity for its gainful exploitation, while a deeper level suggests its regulated use. Over time, groundwater recharge rate decreased relative to its extraction rate, leading to a decline in groundwater

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[1] CGWB. (2024). *National compilation on dynamic ground water resources in India*. Central Ground Water Board, Ministry of Jal Shakti, Government of India.

[2] Over-exploitation of groundwater occurs when its withdrawal exceeds its availability. If withdrawal is between 70-100% of the available groundwater, it is classified as a semi-critical or critical stage.

levels (Figure 1). Approximately 5.5% of assessment units are over-exploited, and 23.5% are at critical or semi-critical stage of exploitation, mostly located in the Western region.

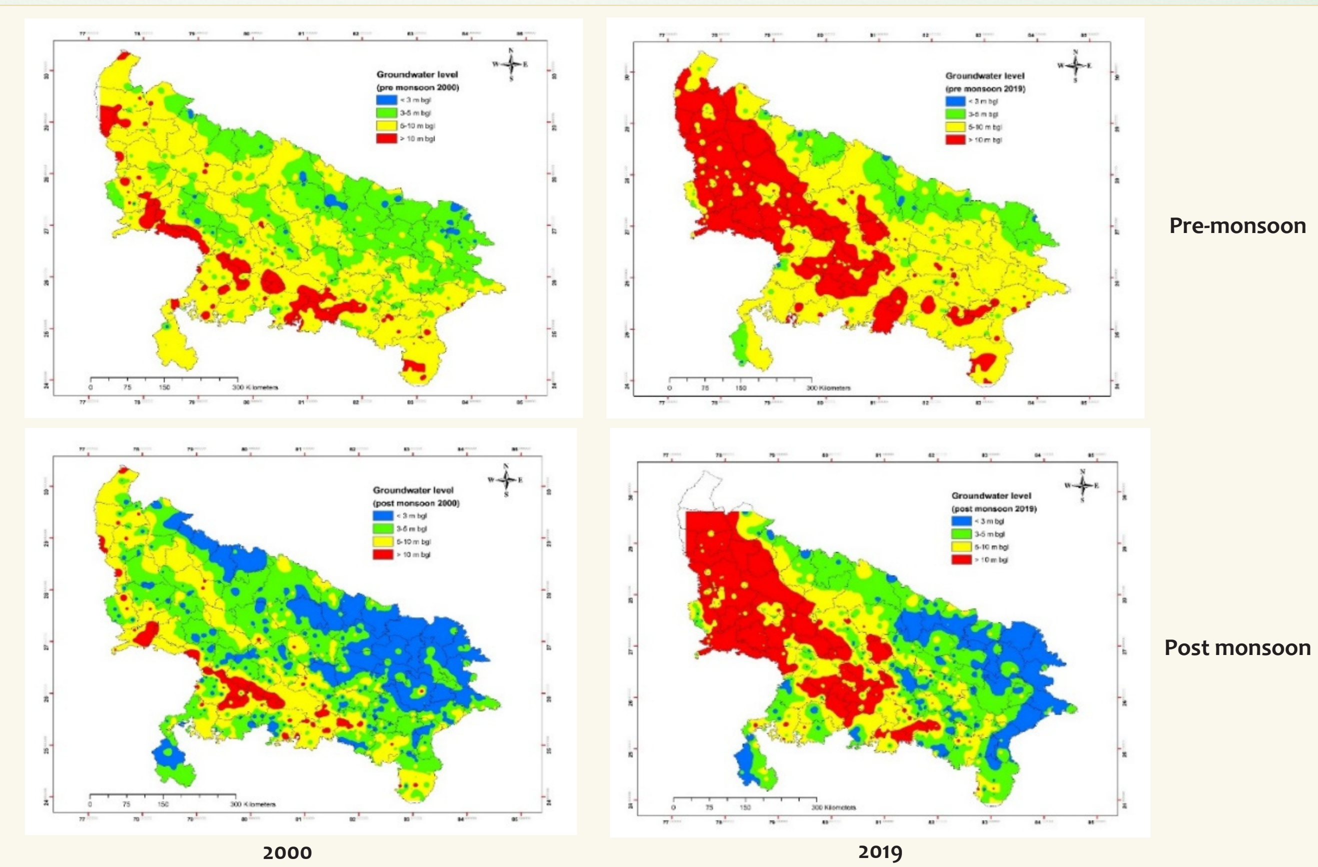
The state has approximately 0.8 million electrical tubewells (approximately 20% of total wells), consuming 18957 million units (kwh) of electricity in 2021-22. The electricity use increased from 410 units in 2011-12 to 1137 units per hectare of cropped area in 2021-22, primarily due to improvements in power infrastructure, a transition towards high-capacity water pumps, and most notably, the provision of electricity subsidy. Notably, electricity subsidy (at real prices)[3] for irrigation doubled from Rs 10.98 billion in 2011-12 to Rs 21.37 billion in 2020-21.

Tiered electricity pricing scheme

In March 2024, the Uttar Pradesh announced an electricity pricing scheme, wherein farmers are provided a 100% subsidy on monthly fixed charges for pumps upto 10 HP (7.46 KW) and on energy charges up to 1045 units per month (140 units/kW per HP).[4] Beyond this, electricity use is subject to full tariffs. For pumps over 10 HP, the subsidy for fixed charges is reduced to half. For Bundelkhand, the agriculturally backward region, the thresholds are fixed at 12.5 HP (9.32 kW) for pumps and 1300 units per month for electricity use. Farmers need to install meters to avail the benefits and restrict the use of free electricity for irrigation purpose only. The counterfactual to this scheme is the electricity supply at a subsidized flat rate of Rs 3.73 per unit (PFCL, 2023)[5].

The economic rationale for introducing a tiered electricity pricing scheme is to financially support farmers while promoting the sustainable use of groundwater by putting an incremental marginal cost on it. As the use of free electricity exceeds the established threshold, farmers are charged applicable

Figure 1. Spatio-temporal changes in groundwater level in Uttar Pradesh



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3 Electricity subsidy at market prices deflated using Consumer Price Index for Agricultural Labour (CPI-AL) of 100 for 2011-12 and 156 for 2020-21.

4 https://uppcl.org/site/writereaddata/siteContent/PTW-OM.pdf

5 PFCL. (2023). Report on Performance of Power Utilities, 2020-21. Power Finance Corporation Limited, New Delhi.

6 The findings are based on a field survey of more than 300 farmers from each district conducted in 2022-23. The surveys in Sitapur and Baghpat were conducted under ICAR-Consortium Research Program (CRP) on Water: "Improving Groundwater Sustainability by Analyzing Groundwater-Energy Nexus". The survey in Jalaun was conducted under the project "Assessing Benefits of Solar Powered Micro Irrigation".

tariff, which discourages them to avoid wastage of water. The effectiveness of this policy depends on whether the subsidized electricity quota adequately covers typical irrigation needs, and whether full tariffs sufficiently reflect the true scarcity value of water.

This study empirically investigates these aspects by comparing the electricity required to meet the peak-season irrigation demand of the existing cropping pattern with freely available electricity in Sitapur district in the central region, Baghpat district in the western region, and Jalaun district in the Bundelkhand region.[6] These districts differ in groundwater development. The stage of groundwater extraction in Sitapur and Jalaun is 57.35% and 55.73%, respectively with all assessment units classified as safe, whereas in Baghpat approximately half of the units are over-exploited with none classified as safe. During May 2023, average groundwater levels in Sitapur and Jalaun are 6.31 and 8.07 meters below ground level (mbgl), respectively, compared to 16.36 mbgl in Baghpat.

The typical farm size in Sitapur and Baghpat is small; 1.19 and 1.45 hectares, respectively, with approximately 80% of farms not exceeding two hectares. However, in Jalaun, the farm size is 4.41 hectares, with 80% farms being of more than two hectares (Table 1).

Despite the contrasting hydrological conditions, Sitapur and Baghpat have nearly identical cropping patterns, with paddy, wheat, and sugarcane accounting for 83.47% and 98.19% of the cropped area, respectively (Table 2). In contrast, green pea, a high-value crop, dominate the crop portfolio in Jalaun.

For the existing cropping patterns on a typical farm in Sitapur, Baghpat, and Jalaun, annual irrigation water requirements are estimated to be 14242, 24386, and 28386 cubic meters, respectively (Table 2), which translates to 11968, 16818 and 6437 cubic meters per hectare, respectively.

Table 2 also presents the electricity required for pumping the required quantity of groundwater on a representative farm to meet the peak-season irrigation demand. In Sitapur, where groundwater is shallow, approximately 393 units/month of electricity are sufficient to pump the required quantity of groundwater for a farm of 1.2 hectares or 330 units per hectare. For Baghpat, where groundwater is deeper, 869 units/month of electricity can fulfil peak-season irrigation demand on a farm size of 1.45 hectares or 599 units per hectare. In contrast, the electricity requirement in Jalaun is 1024 units/month for a farm size of 4.41 hectares

Table 2. Electricity requirement for irrigation

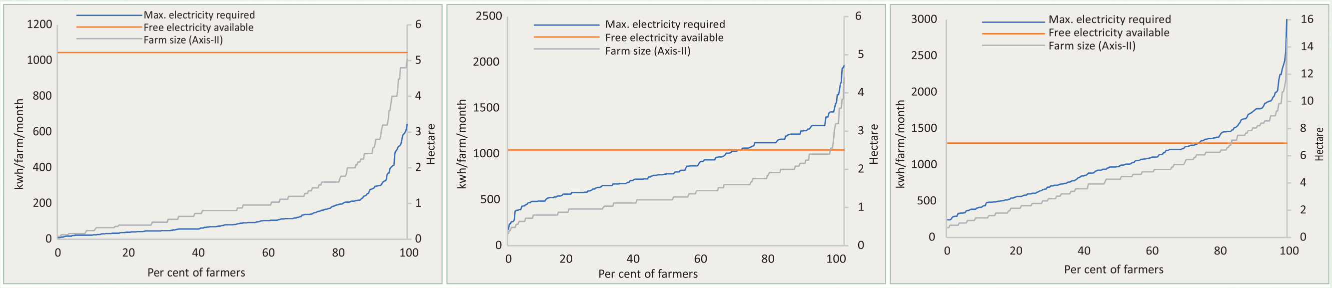
Particulars	Sitapur	Baghpat	Jalaun
Cropping pattern (% share in gross cropped area)			
Paddy	27.16	19.59	7.43
Wheat	20.59	30.02	24.28
Sugarcane	35.72	48.58	-
Green pea	-	-	52.86
Sesamum	0.84	-	9.96
Other crops	15.69	1.81	5.47
Total	100	100	100
Rainfall (mm)	692	566	910
Farm size (ha)	1.19	1.45	4.41
Irrigation water required (m^3/farm/year)	14242	24386	28386
Irrigation water required (m^3/ha/year)	11968	16818	6437
Maximum electricity required (units/farm/month)	393	869	1024
Marginal (<1 ha)	199	619	377
Small (1-2 ha)	457	848	555
Semi medium (2-4 ha)	812	1290	774
Medium (4-10 ha)	1427	1791	1377
Large (>10 ha)	-	-	2665
Maximum electricity required (units/ha/month)	330	599	232
Freely available electricity (units/month)	1045	1045	1300
Sample size	371	351	300

Table 1. Distribution of households by farm size (%)

District	Marginal (<1 ha)	Small (1-2 ha)	Semi-medium (2-4 ha)	Medium (4-10 ha)	Large (>10 ha)	Total
Sitapur	60.81 (0.55)	21.62 (1.39)	12.70 (2.59)	4.86 (4.58)	-	370 (1.19)
Baghpat	28.49 (0.82)	52.42 (1.42)	18.80 (2.45)	0.28 (4.45)	-	351 (1.45)
Jalaun	4.86 (0.80)	15.72 (1.47)	27.42 (3.06)	50.50 (6.15)	1.67 (11.84)	300 (4.41)

**figures within parenthesis are average land holding in hectare.*

Figure 2. Cumulative distribution curve of required electricity and cultivated area of the sample farmers



Sitapur Baghpat Jalaun

or 232 units per hectare. This means that the threshold set for free electricity is higher by 20% in Baghpat, 27% in Jalaun, and 166% Sitapur.

Thus, at the established thresholds of free electricity, all farms in Sitapur, 74% in Jalaun and 68% in Baghpat can meet their peak-season irrigation demand indicating that the scheme effectively covers all smallholders who need policy support.

However, the free electricity exceeding the peak season requirement does not reflect the scarcity value of groundwater and potentially undermines the objective of changing farmers' behaviour towards its efficient use. Particularly, in shallow water regions, it might fail to incentivize farmers to adopt water-saving technologies and practices and could result in a cycle of increased groundwater extraction. Surplus free electricity may also dis-incentivise farmers to use solar energy for irrigation in the state.

The intended positive effect of the full tariff on the groundwater saving depends on the extent to which the level of the full tariff deviates from the marginal value product of groundwater. If the incremental cost of water by charging the full tariff (after the threshold) is less than the incremental return, farmers will find it economical to apply more units of water until marginal return equals marginal cost. This suggests considering incremental returns from groundwater use while determining tariffs for the chargeable portion of electricity supply.

Policy implications

A few generic implications of this study are as follows:

First, one of the straightforward implications is the need to recalibrate subsidy thresholds for different regions, considering hydrological differences that may stem from differences in rainfall patterns, groundwater levels, and local water infrastructure. Adjusting subsidies based on hydrological differences can better incentivize sustainable water use practices and promote water-saving technologies.

Second, subsidy thresholds should be established for different farm sizes even in a specific region to ensure equitable distribution of subsidy support.

Third, the established thresholds should be periodically reviewed and adjusted to reflect changing hydrological conditions and farm characteristics, which may evolve over time owing to changing climate, consumer preferences, and demographic pressure.

Fourth, because irrigation requirement, and consequently electricity demand, are not uniform throughout the year, the policy must recognize crop growth stages and crop cycles while establishing the support thresholds. For example, more free electricity can be made available during peak periods, such as the growing season or drier months, when farmers require more water, and less for periods of lower water demand.

Fifth, the study proposes considering the marginal value of groundwater use in determining electricity tariffs on the chargeable portion of electricity use to reflect the scarcity value of groundwater. This pricing mechanism could serve as a powerful tool for promoting the judicious use of groundwater resources.

Considering the increasing use of electricity, limiting financial benefits to its required consumption is rational and politically less contentious, particularly in a scenario where populist measures are becoming prevalent. These findings are equally applicable to states such as Punjab, Haryana, Tamil Nadu, Andhra Pradesh, and Telangana, where electricity for irrigation is either provided without charge or heavily subsidized so as to optimize trade-off between economic welfare and groundwater sustainability.

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