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Groundwater Monitoring and Learnings from 24-Hour Agricultural Power in Hard Rock Aquifers

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Key takeaways

- *Unrestricted, and free power supply drives higher electricity and groundwater use.*
- *Power use in Telangana rose by over 50% after 24-hour supply.*
- *Rice area expanded by 60% in kharif and 30% in rabi, reflecting greater groundwater use.*
- *Monitoring wells failed to detect depletion, showing gaps in current systems.*
- *Recommendations: Strengthen groundwater monitoring in hard rock aquifer regions and redesign incentives so that power and groundwater are used efficiently.*

INTRODUCTION

Electricity is one of the most critical inputs for groundwater-based irrigation in India, where tubewells account for nearly two-thirds of the irrigated area and drive much of agricultural production. Since electricity is supplied to farmers at a monthly fixed cost (implying zero marginal cost) in nearly all states, most states ration the number of hours of supply to avoid overuse of both electricity and groundwater. In January 2018, Telangana became the first state in India to extend free agricultural electricity supply from nine to 24 hours a day. The policy was piloted in three districts in July 2017 before state-wide implementation.¹ The policy was piloted in July 2017 in three districts. This unique policy shift created a natural experiment to understand the implications of unrestricted electricity supply for power consumption and groundwater, particularly in a region dominated by hard rock aquifers.

¹ Telangana and neighboring states supply electricity for agriculture according to their policies, but definitely there are disruptions and quality issues. Most farmers use electricity operated pumps.

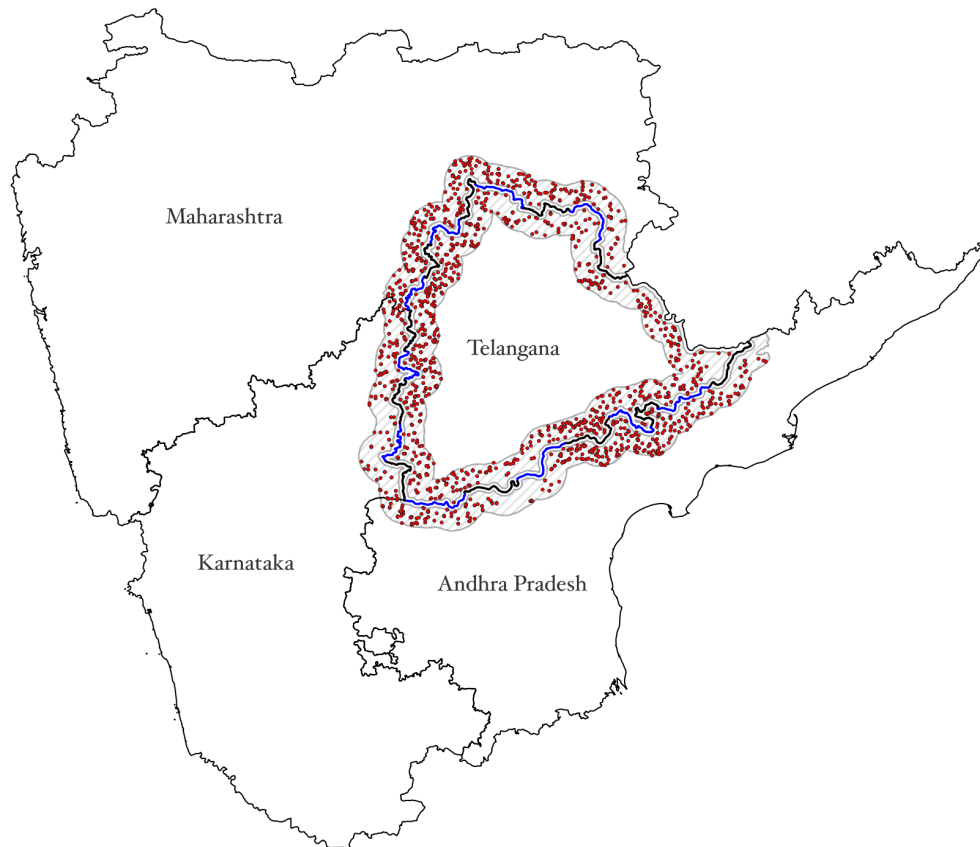
This policy brief addresses three central questions. First, how much did agricultural power consumption increase when rationing was removed? Second, did the policy lead to a rise in water extraction as well as groundwater depth? Third, are current groundwater monitoring systems capable of detecting the change in groundwater availability for farmers? The relevance of these questions is heightened by two factors. First, rationed electricity is the dominant irrigation power policy across India. Removing rationing is therefore a significant policy departure with potential consequences for the power sector, groundwater resources, and agricultural outcomes. Second, Telangana's geology is characterized by spatially fragmented hard rock aquifers with low storage capacity, making groundwater highly vulnerable to over-extraction and low recharge. Notably, hard rock aquifers account for about 60% of those in India and 20% worldwide. Figure 2 illustrates the fragmented nature of hard rock aquifers. Understanding the effects of twenty-four hour power supply in this context can inform water and energy policy in similar regions across India and other countries.

METHOD AND FINDINGS

To evaluate the impact of Telangana's policy, we constructed a monthly district-level panel dataset covering January 2014 to December 2019 for agricultural power consumption in Telangana and in neighboring districts in Andhra Pradesh, Karnataka, and Maharashtra. We also compiled a detailed monthly panel of groundwater depth from monitoring wells located within 5 to 32 kilometers of the state boundary (see Figure 1 for visual clarity), along with weather variables such as precipitation and temperature. Our methodology comprises comparing outcomes in very similar locations where one location in Telangana (with 24 hour power supply to agriculture)

being compared to a close neighbor outside Telangana without that policy. This comparison makes it possible that other factors affecting the outcomes like aquifer characteristics, agro-climatic suitability and other physical conditions are accounted for, helping to isolate the impact of Telangana policy per se.

Figure 1: Monitoring wells spanning 5 to 32.18 km on both sides of the boundary segments



Notes: There are 1,658 monitoring wells located within 5 to 32.18 km on both sides of the boundary segments, as indicated by red dots within the hatched lines. There are 21 Telangana boundary segments, indicated by blue and black colors. The lengths of the segment curves range from 97 km to 105 km. We exclude the state of Chhattisgarh, located to the northeast of Telangana, because of insufficient data.

Source: State shapefile is downloaded from gadm.org. Monitoring well data is downloaded from INDIAWRIS.

The results reveal a huge increase in agricultural electricity consumption following the removal of rationing. Agricultural power use in Telangana rose by approximately

fifty-three percent relative to neighboring states, and this increase appeared in two years post-policy, indicating that farmers quickly responded to the availability of unrestricted electricity by increasing their pumping. We also observe a sharp expansion in the area under rice cultivation—a major and water-intensive crop—during both the kharif (60%) and rabi (30%) seasons. This means that groundwater use has definitely increased, since rice cultivation in Telangana relies predominantly on tubewell irrigation. However, when we examine groundwater depth using the government’s monitoring well network, we do not find a statistically significant change in groundwater depth in the two years following the policy, which is robust to accounting for increase in procurement infrastructure, surface water expansion, and a set of robustness checks. Nor do we find evidence of a rise in the fraction of missing observations in the monitoring data, which could have served as an indirect indicator of wells running dry. These apparently contradictory findings—large increases in electricity use and rice area without a decline in groundwater levels in monitoring wells—can be reconciled by recognizing the limitations of the monitoring network.

Government monitoring wells are intentionally located away from farmer wells to avoid local drawdown effects. In the context of Telangana’s highly localized hard rock aquifers, such wells can be disconnected from the farmer wells that are actually used for irrigation. Consequently, they may fail to detect depletion that directly affects outcomes of economic interest.

A figure from hydrogeology studies (Figure 2) by Guih’eneuf et al. (2014) and Mar’echal et al. (2018) that focus on the Experimental Hydrogeological Park (EHP) in the Nalgonda district of Telangana and the Maheshwaram watershed near Hyderabad in Telangana, respectively, clearly illustrates the discontinuous/fragmented nature of the aquifer during the pre-monsoon season on a horizontal scale of 200 meters. Additionally, 450 borewells, covering an area of approximately 20km² in Karnataka

state (based on a figure from Blakeslee, Fishman, and Srinivasan (2020)), include a mix of active and dry wells with some right next to each other, we infer that the hard rock aquifer even in this small region is not well-connected. Field visit conducted as part of this study in Telangana, confirms this fragmentation in hard rock aquifers.

Figure 2: Groundwater flow diagram showing discontinuous aquifer in pre-monsoon period

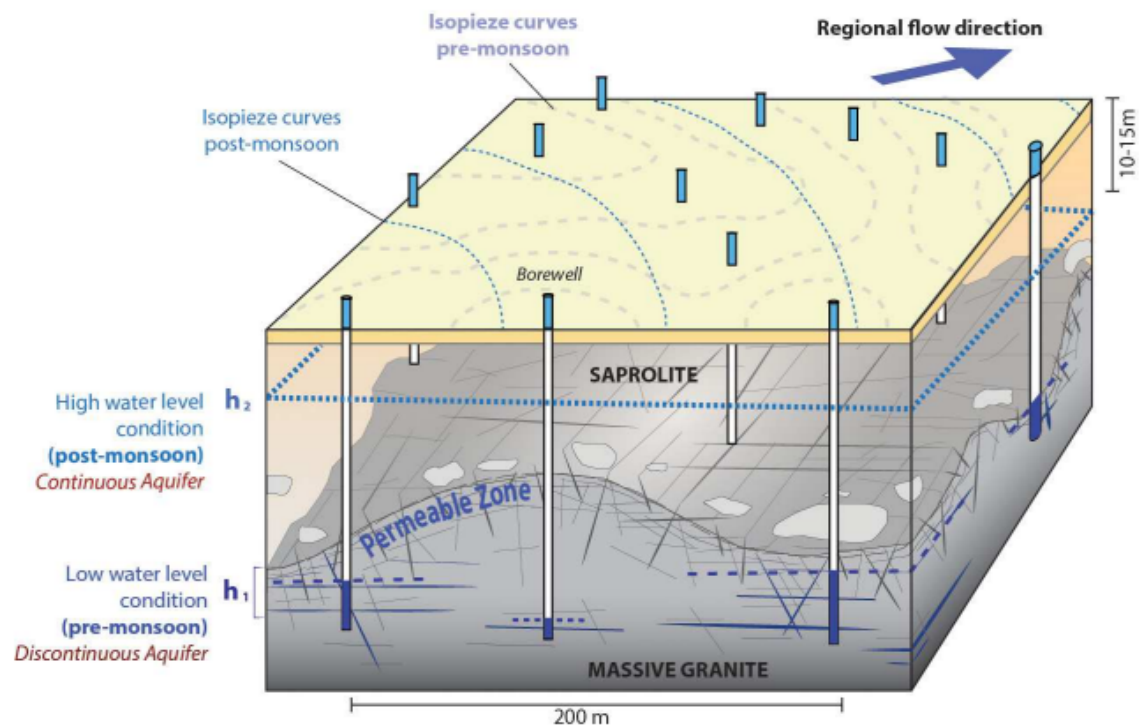


Fig. 8. Schematic conceptual model of groundwater flow at watershed scale (modified from Guihéneuf et al. 2014).

Source: Mar'échal et al. (2018)

We did not explicitly examine water trade, as it was not evident from general media. Our field visits to border villages in northern and southern Telangana in December 2022 also did not reveal signs of water trade. However, systematic evidence is lacking, making this an open question for further research.

RECOMMENDATIONS

First, providing electricity at zero marginal cost without rationing encourages overuse of power in agriculture, which is likely to be economically inefficient and contributes to financial stress for state-owned distribution companies. Alluvial aquifers hold more storage than hard rock, but similar inefficiencies could also arise in them, because zero marginal cost pumping under free or fixed-price electricity and unrationed electricity can encourage over-extraction. Free electricity has become a routine election promise in many states, locking utilities and farmers into unsustainable patterns. Well-designed incentives or pricing mechanisms could help ensure that groundwater is used judiciously while still protecting the interests of smallholder farmers.

Second, there is an urgent need to strengthen the groundwater monitoring system in regions with hard rock aquifers. The current practice of monitoring rest water levels at dedicated observation wells may be sufficient in alluvial regions where aquifers are well-connected but fails to capture changes in economically important farmer wells in fragmented aquifers. A redesigned monitoring regime should also integrate a sample of farmer wells into the network, so that observed water levels correspond to the wells that farmers actually depend on. This should include both depth measurements and information on well functionality, such as whether wells have run dry or have reduced yields. Additionally, digital reporting by farmers, combined with appropriate verification by the government could enable real-time tracking of aquifer conditions and support evidence based decision-making. Without such improvements, policy responses to groundwater stress will continue to be based on incomplete information, risking both underestimation of depletion and delayed corrective action.

Note: This policy brief is based on our research paper titled—“Removing Rationing: Power Consumption and Groundwater Monitoring in South India” (Forthcoming in JEEM).

FURTHER READING

1. Blakeslee, David, Ram Fishman, and Veena Srinivasan (2020). “Way down in the hole: Adaptation to long-term water loss in rural India”. In: *American Economic Review* 110.1, pp. 200–224.
2. Guih'eneuf, Nicolas, Alexandre Boisson, Olivier Bour, Benoît Dewandel, Jerome Perrin, Am'elie Dausse, Mathieu Viossanges, Subash Chandra, Shakeel Ahmed, and Jean Christophe Mar'echal (2014). “Groundwater flows in weathered crystalline rocks: Impact of piezometric variations and depth-dependent fracture connectivity”. In: *Journal of Hydrology* 511, pp. 320–334.
3. Mar'echal, Jean-Christophe, Adrien Selles, Benoit Dewandel, Alexandre Boisson, Jérôme Perrin, and Shakeel Ahmed (2018). “An observatory of groundwater in crystalline rock aquifers exposed to a changing environment: Hyderabad, India”. In: *Vadose Zone Journal* 17.1, pp. 1–14.



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