COMMENTARY

Groundwater, Energy, and Poverty: Research for Policy

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1. THE PREMISE

Around 50% of global groundwater irrigation occurs in South Asia (Rodella *et al.* 2023). To support food security and rural livelihoods, governments enabled farmers to privately drill tubewells and provided subsidized electricity to facilitate cheap extraction of groundwater. As a result, the region is estimated to have at least 30 million tubewells (Balasubramanya 2025a). Tubewell owners often supply irrigation water through informal groundwater markets to farmers who cannot afford to install their own wells.

While subsidized pumping has contributed to food security, some of the negative consequences include falling groundwater levels, loss-making electric utilities (which are owned by the public sector), and low irrigation efficiency (Brisco and Malik 2006; Badiani *et al.* 2012; Rodell *et al.* 2009; Jasechko *et al.* 2024; Mishra *et al.* 2018; Mishra *et al.* 2024). Falling groundwater levels can reduce the quantity and quality of drinking water and reduce ecological flows in rivers.

Ideally, policymakers would like to reduce energy subsidies, rationalize groundwater extraction, and improve irrigation efficiency without making farmers worse off (Balasubramanya 2025a). This is motivated by several reasons. Agriculture in South Asia is predominantly smallholder-based, with

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farm sizes averaging less than 2 hectares. While agriculture's share in the gross domestic product has fallen over the years across all South Asian countries, its share in employment continues to be significant, ranging from 73% in Nepal to 32% in Sri Lanka in 2022. The agricultural labour force is increasingly feminized, as more males tend to work off the farm.

The fiscal burden of energy subsidies and the resource depletion of groundwater resources, coupled with persistent poverty among those who derive their livelihoods from agriculture, present a conundrum for policymakers. While solutions exist, knowledge gaps limit their deployment at scale.

2. GROUNDWATER PRICING REFORMS

Reducing energy subsidies is, in principle, the most direct approach for improving the efficiency of water and energy use. However, improving energy and water use efficiency may not necessarily lead to reductions in their use. Paradoxically, a 'rebound effect' (also known as 'Jevons paradox') is often observed, where reductions in water and energy applied per unit of land are also accompanied by an expansion of the area under production or an increase in cropping intensity (where farmers add another crop or another season of cultivation). This increases overall water and energy requirements, even as efficiency also improves (Grafton 2018; Fishman *et al.* 2023).

Implementing pricing reforms presents several challenges. Most wells in South Asia are unmetered. For instance, only 27% of electric wells in India (Sidhu *et al.* 2020) and 1 in 34 electric wells in Pakistan are metered (Shah 2024). Diesel wells are never metered, as farmers purchase fuel directly from local markets. Metering millions of tubewells is not a trivial act, either economically (given the high transaction costs) or politically (due to the potential loss of goodwill).

The welfare effects of such pricing reforms are insufficiently understood (Balasubramanya 2025a). For example, for well owners who cultivate staple crops with elastic water demand, price increases could lead to a reduction in cultivated area, thereby reducing local food security (Hellegers and Davidson 2024). By contrast, for well owners who cultivate cash crops with inelastic water demand, higher prices may reduce farmers' profits.

Importantly, it remains unclear whether price increases faced by well owners lead to changes in the quantity or price of water supplied to smaller farmers through informal groundwater markets (Balasubramanya and Buisson 2022). Changing the dynamics between the utility and the well

owner is likely to affect the informal groundwater market between the well owner and the water buyer.

3. INDIRECT APPROACHES THAT ESTABLISH OPPORTUNTY COSTS FOR GROUNDWATER PUMPING

Since groundwater pricing reforms are complex, several pilot initiatives have experimented with allocating electricity entitlements for tubewells, with public-sector utilities buying back unused entitlements from farmers (Fishman *et al.* 2016; Mitra *et al.* 2023). Since the cost to the utility for supplying a farmer with a unit of electricity is higher than the price at which the utility 'buys back' the unused unit, this design can reduce financial losses for utilities, while giving farmers an opportunity to earn some money even when they don't pump.

Evaluations of these pilots uncover important lessons for establishing tubewell entitlements, which have been hard to achieve given the historical absence of metering at the individual well level. Setting entitlements too high defeats the purpose of the exercise, while setting them too low may lead to significant income losses for farmers, especially when tubewell owners supply water to farmers.

A key knowledge gap is whether such schemes will affect informal groundwater markets. Given the possibility of selling units back to the regulator, well owners may increase the prices at which they sell irrigation services to marginal farmers (Balasubramanya and Buisson 2022). In addition, given the presence of informal groundwater markets, such schemes may not result in a reduction in groundwater pumping (Fishman *et al.* 2016)

States are constrained by how high 'buy back' prices can be, as these cannot exceed the utility's cost of supplying a unit of electricity to the farmer. Such schemes are likely to play a limited role in reducing energy and groundwater use in agriculture, given the complexity of implementation, which necessarily involves metering millions of tubewells and periodic, credible monitoring (Mitra *et al.* 2023).

4. TECHNOLOGICAL INNOVATIONS

Directly seeded rice (DSR), in which seeds are directly planted into fields rather than seedlings being transplanted, is being subsidized by several state governments in India, as it is expected to reduce irrigation needs without reducing yields.

Alternate wetting and drying (AWD) is an irrigation approach where a perforated plastic pipe installed in the field enables farmers to space out irrigation applications for rice crops. Farmers irrigate only when soil moisture falls, thus reducing water application over the course of the cultivation season.

Despite low costs and the availability of subsidies, the uptake of DSR and AWD remain low (Balasubramanya 2025b). While DSR reduces labour costs (as it eliminates the need for transplantation), it increases weeding costs (as weed production increases in fields that cannot be flooded in the pre-vegetative stage of rice cultivation) (Kuroiwa *et al.* 2024; Bhatt and Kukal 2015). Unchecked weeds can, in turn, threaten rice yields. Emerging studies suggest that adoption of DSR is higher when governments deploy extension agents who work with farmers over a sustained period to help them realize the benefits of DSR and compensate for its undesirable qualities (Balasubramanya *et al.* 2025; Mutum *et al.* 2025).

Dedicated extension is hence vital for adoption, especially if water and energy continue to be subsidized. There is little incentive for farmers to switch to cultivation practices that reduce water and energy use and improve efficiency when both resources continue to be subsidized, as reductions in energy and water use will not make a discernible difference to their irrigation costs (Balasubramanya 2025a, 2025b). Emerging evidence from Punjab, Haryana and Tamil Nadu suggests the importance of extension for the adoption of DSR (Balasubramanya et al. 2025; Mutum et al. 2025), whereas studies on the adoption of AWD in the Barind tract of Bangladesh suggest its sensitivity to the pumping costs borne by farmers (Chakravorty *et al.* 2023). Further research on the deployment of extension to increase adoption is needed.

Whether such technological changes can affect the quantity and price of the groundwater traded in informal markets also deserves exploration, as this has implications for the distribution of water to marginal farmers.

5. SOLAR IRRIGATION

Transitioning farmers to solar-powered irrigation offers a way of converting a perpetual energy subsidy into a one-time capital subsidy for equipment (Balasubramanya *et al.* 2024). Over time, such a transition can improve the financial health of utilities.

However, the marginal cost of pumping groundwater using solar pumps is zero (Bassi 2018), which does not incentivize farmers to either improve irrigation efficiency or reduce water use. Indeed, assessments of solar-

powered irrigation show that farmers expand cultivation area and increase profits following its adoption (Gupta 2019; Durga *et al.* 2021; Kafle *et al.* 2024). Solar pumps for agriculture can also have co-benefits in the form of increasing access to water for drinking and domestic purposes, especially in areas where alternative water sources are not available or are at a considerable distance (Khandelwal 2025); however, it can also increase the extraction of groundwater.

One approach proposed to rationalize groundwater pumping in solar-powered irrigation is 'net metering' of solar pumps—connecting them to the grid and billing farmers for the difference between the units consumed for irrigation and those supplied into the grid (Balasubramanya *et al.* 2024). This allows the farmer to earn an income by selling the electricity generated by the solar panels installed on their land. However, this approach requires the grid to be able to handle hourly and daily changes in the volume of electricity entering and exiting it. It also requires all tubewells to be metered. Whether 'net metering' will rationalize groundwater extraction is not known, however (Balasubramanya *et al.* 2024).

6. RESEARCH FOR POLICY

Knowledge gaps at the nexus of groundwater, energy, poverty, and ecology present exciting opportunities for research. Understanding the trade-offs at this nexus can help policymakers make practical decisions on resource management and poverty reduction. Meaningful partnerships between scholars and policymakers to co-produce knowledge can help move the needle on this important topic.

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