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EDITED BY
Vikram Kumar,
Planning and Development, Govt. of Bihar, India

REVIEWED BY
Prakash Kumar Jha,
Mississippi State University, United States
Sayantan Sarkar,
Texas A and M AgriLife Research, United States

*CORRESPONDENCE
Ankit Chandra,
ankitchandra@nebraska.edu

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Shifting dynamics and environmental implications of the irrigation pump market in India

Ankit Chandra[1]* and Nicholas Brozović[1,2]

[1]Daugherty Water for Food Global Institute at the University of Nebraska, Lincoln, NE, United States, [2]Department of Agricultural Economics, University of Nebraska-Lincoln, Lincoln, NE, United States

India is the world's largest user of groundwater for irrigation, with approximately 32 million pumps running on diesel, electric, and solar power. Subsidized electricity has led to an increase in the adoption of electric pumps by farmers, with increasing electrification rates and rising diesel costs contributing to the trend. Government subsidies have been instrumental in enhancing smallholder irrigation pump access. However, subsidies on irrigation pumps may exacerbate undesirable groundwater depletion. In smallholder settings where the capital needed to purchase irrigation equipment exceeds farmers' means, "irrigation-as-a-service" and "rental pumps" with organized and affordable volumetric pricing could offer viable solutions. This policy brief provides key learnings on the Indian irrigation pump market and its policy and environmental implications, based on semi-structured interviews and secondary data collected.

KEYWORDS

smallholder, irrigation pump, policy, finance, solar, groundwater, environment

1 Introduction

Irrigation is a crucial tool for addressing climate change impacts on agricultural production within the framework of the Sustainable Development Goals (SDGs). As a result, irrigation continues to be a policy focus in many developing economies where drought occurs. At a country level, India is the largest user of groundwater for irrigation (Balasubramanya and Buisson, 2022). A large market for small mechanized water pumping equipment exists, with an estimated 32 million irrigation pumps already operating that use diesel, electric, or solar power (IEA, 2022). The irrigation pump market in India was valued at around $1.1 billion in 2022 (Arizton, 2020). It is expected to reach $1.6 billion by 2027, with a compound annual growth rate of 8.4%.

Amidst the rapid growth and proliferation of mechanized irrigation pumps in India, groundwater overexploitation is an ongoing concern, exacerbated by the difficulty of enforcing groundwater governance systems for millions of spatially-distributed smallholder farmers. The long-term economic and environmental implications of widespread, often uncoordinated, irrigation adoption include greenhouse gas emissions and water quality degradation associated with irrigation. Government subsidies, public-private partnerships, and blended financial models to improve irrigation access have played key roles in improving the productivity of smallholder agriculture (Shah, 2007; Singh et al., 2014; Bassi, 2018). As a result of investments in the irrigation sector the net irrigated area in India, estimated at 20.85 million hectares in 1950–51 (Singh et al., 2014), increased to 70.4 million hectares in 2020–21 (FAO AQUASTAT, 2020).

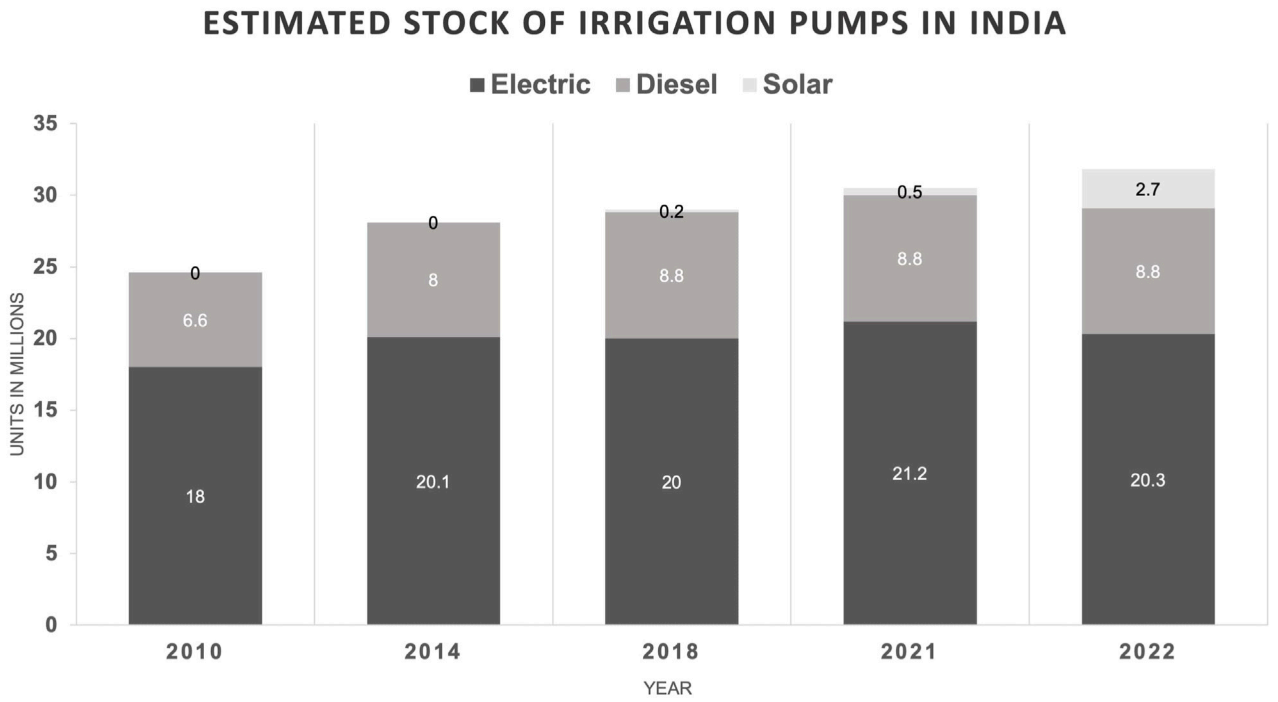

FIGURE 1
Distribution of estimated number of installed irrigation pumps in India (2010-22), adapted from IEA, 2022.

Despite the importance of private-sector dominated irrigation pump markets in India, there is limited research on the structure and key trends in these markets, including the relative influence of private and government interventions. In this policy brief, we combine data from semi-structured interviews with farmers and irrigation stakeholders and relevant secondary data to highlight and contextualize key trends emerging in Indian irrigation pump markets.

Twenty six irrigating farmers (owners of diesel and electric pumps) and irrigation dealers were interviewed in the states of Bihar and Uttar Pradesh. These two states represent typical smallholder provinces in Northern India and contain a high density of diesel and electric pumps (Singh et al., 2014). The interviews were used to provide context around the lived experience of people involved in different parts of the business ecosystem that provides irrigation pumps to smallholder farmers. The insights obtained speak to the role of government policies, as well as of private sector business strategy, in determining the trajectory of irrigation pump adoption across space and time. Although we conducted interviews within a narrow region rather than the entire country, the findings still offer insights into broader trends and patterns. While irrigation policies and guidelines vary in every state in India–even within states–the typical challenges of power and irrigation pump subsidies, unregulated use of groundwater, and the adoption of new technology in an attempt to curb water use concerns remain similar across the country. Some caution may be needed in extrapolating these findings to the national level, as regional differences and unique circumstances within individual states may influence outcomes differently.

2 Key findings

2.1 Shifts in the irrigation pump market

Irrigation in India predominantly depends on groundwater pumped through about 9 million diesel and 21 million electric pumps (IEA, 2022). These pumps are small and generally individually operated. Over the past decade, the irrigation pump market has shifted from diesel to electric irrigation pumps (Figure 1), with a growing focus on solar irrigation pumps (SIPs).

Indian farmers prefer electric pumps for a variety of reasons. Compared to diesel, which is costly, electric grid-connected pumps are cheaper. Over time, the average diesel prices have surged from Rs. 38.5 per liter ($0.46/ltr) in January 2010 to Rs. 89 per liter ($1.07/ltr) in January 2024 (Open Government Data, 2024). Several states offer subsidized or free electricity. Additionally, electric pumps have lower operational and maintenance costs. The farmers we interviewed said they did not need to worry about their electric pumps being stolen because they are installed with a one-time submersible pump set. In many states, with water tables located 300–800 feet deep, tube wells with submersible pump sets are the best option to access groundwater for irrigation. However, the rapid implementation of electric pumps has led to the excessive withdrawal of groundwater in multiple states in India, particularly in Punjab, Haryana, Rajasthan, Andhra Pradesh, and Uttar Pradesh (Standing Committee on Water Resources, 2022).

In an attempt to reduce overextraction of groundwater, the government is considering whether to discourage electric pumps.

Farmers may be required to obtain permits from the state government in the near future if they wish to drill. This represents a change from the current regulatory framework, where no permits are required. The government is also considering introducing measures such as pre-paid cards for energy, allowing charging for electricity used for irrigation and restricting power supply (Standing Committee on Water Resources, 2022). The outcomes of these potential future policy changes and associated pilot programs will be keenly observed. However, implementing these programs might be challenging due to the current absence of widespread metering of tube wells as well as regional issues such as power theft (Chaudhari et al., 2021).

Recently, both government and private entities have promoted the adoption of solar irrigation pumps (SIPs), especially to replace diesel pumps, as a means to reduce carbon emissions and groundwater depletion (Balasubramanya et al., 2024). However, diesel pumps are not scrapped as a condition of new solar pump sales. Thus, the number of available diesel-based irrigation pumps is generally unchanged by solar pump adoption and farmers who own SIPs still use diesel pumps for irrigation due to easy access and operability. Simultaneously, there is an increased emphasis on connecting solar projects to the electric grid with the goal of selling surplus electricity to energy distribution companies (DISCOMs) and creating an alternative revenue source for farmers (Balasubramanya and Buisson, 2022). Nevertheless, farmers might not sell surplus solar energy to the grid unless the tariff is sufficiently high after meeting their own pumping needs, particularly if their neighbors also have unmet pumping needs for irrigation.

The adoption of SIPs at the farm level is still in its infancy. Around 0.2 million SIPs were installed by the end of 2019. The number was expected to expand to 3 million installations by 2022 (Yashodha et al., 2021; IEA, 2022). While the total number of SIPs installed is uncertain due to lags in targeted installations and unreported sales, there is clear positive trend in the expansion of solar irrigation.

2.2 Government subsidies and financial support for irrigation pumps

Various institutions, including the government, are making efforts to promote the widespread adoption of SIPs by offering a range of subsidies and credit options. Additionally, there are a variety of subsidies for purchasing other kinds of irrigation pumps. Pump subsidies are meant to provide relief for smallholder farmers who irrigate, and these vary from state to state. The recent expansion of solar irrigation is due, in large part, to India's flagship agri-solarization program, "Pradhan Mantri Kisan Urja Suraksha evam Uthhaan Mahabhiyan" (PM-KUSUM). The program allows Central and State Government to provide a 60% subsidy for SIPs. Typically, of the remaining cost, 30% is provided through agricultural loans and farmers bear 10%. However, the level of subsidies and farmers' initial investments vary at the state level. For example, in Bihar, the government provides a subsidy of 75%. In the neighboring states, Jharkhand and Uttar Pradesh, the government provides a 60% subsidy. Economic theory would suggest that differential subsidies might lead to arbitrage across state borders. Traders or individuals can purchase the pump in the region with lower prices and then resell it in the region with higher prices, earning a profit from the price difference. This type of arbitrage can potentially distort the intended impacts of the subsidy scheme at a state level.

Even with the available subsidies, smallholder farmers still bear relatively high initial capital expenses. Banks play a crucial role in lending, but the interest from commercial banks to provide credit to smallholders for irrigation equipment financing has been limited to date. Even with subsidies, the high cost of SIPs, loans, and collateral requirements likely has a detrimental impact on adoption and market share. For example, for a 5 hp SIP in Uttar Pradesh where the expected cost is Rs. 2,73,137 ($3,277), the Central and State governments contribute Rs. 1,63,882 ($1,966), while farmers must contribute the remaining amount of Rs. 1,09,255 ($1,311) (Uttar Pradesh Dept. of Agriculture, 2023). For a farming household, this amount is a substantial sum, especially where the average monthly farmer household income is Rs. 8,000 ($96 per month) (Ministry of Agriculture and Farmers Welfare, 2022).

While SIPs have the potential to reduce emissions and lower irrigation costs, empirical evidence suggests a mix of successes and failures with solar irrigation projects in India (Mongabay, 2023). This is primarily because of high initial investment costs, together with technical issues such as lower pump capacity and flow rate in comparison to diesel pumps, inferior quality and small size of solar PV modules sourced in Indian markets, and lack of after-sales support (Source: Personal communications, January 2022).

Another potentially problematic aspect of solar pump use is that, with no variable costs of producing water and no incentives to manage natural resources in place, farmers have no reason to be careful in how much they pump and will likely overdraw groundwater (Bassi, 2018). As seen in Figure 2, only 18%–25% of wells are deemed safe for water extraction in the northwest region with a similar trend in some southern states. Currently, these regions have high concentrations of solar pumps (Bridge to India, 2021) which potentially aggravate the groundwater depletion situation.

Beyond the high levels of subsidization of electricity, subsidies are also provided for the purchase of electric and diesel pumps within some states. For example, in Bihar and Madhya Pradesh, there is up to a 50% subsidy (Rs. 8,000 or $96, whichever is lesser) on electric irrigation pump sets. Government regulators have stopped electric pump subsidies in Punjab, Haryana, Rajasthan, Karnataka, Tamil Nadu, and Uttar Pradesh to discourage farmers from pumping due to the overextraction of groundwater in these states and associated declining groundwater tables.

Typically, each state government decides subsidy levels depending on its budget situation and on local politics. For instance, in Bihar, pump subsidies were put on hold during the COVID-19 pandemic. They were revived in 2022 with changes in the agricultural budget and policies, and with the launch of subsidy distributions through Online Farm Mechanization Application Software (OFMAS) by the State Department of Agriculture in Bihar. Farmers are required to apply for subsidies through the OFMAS platform. OFMAS makes the application process easier and more transparent than previously. Farmers need to register

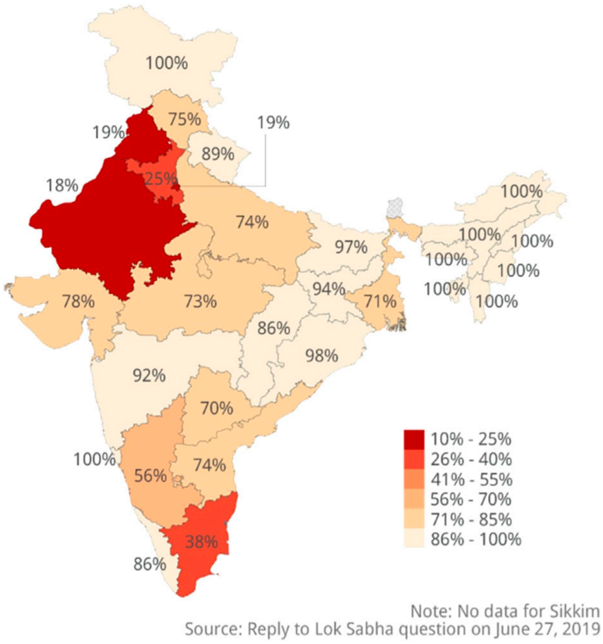

FIGURE 2
Indian map showing the states that are deemed safe for water extraction from irrigation wells. In the northwest region, only 18%–25% of wells are classified as safe (Adapted from CGWB).

and provide details of their land holdings and crops. Once the application is approved, the subsidy is facilitated through pump manufacturers, who supply irrigation equipment to the farmer. In many states, farmers apply for subsidies through irrigation dealers and distributors during "Krishi mela" (a district-level event organized by the state government during the *Rabi* and *Kharif* cropping season). Farmers receive their subsidy within 45–60 days of application through Direct Benefit Transfer (DBT). DBT is a mode of paying subsidies straight into the bank accounts of beneficiaries, seen as one of the most promising pathways to enhance the efficiency of subsidy programs (Source: Personal communication with Bihar Government Officials, December 2022).

There are government subsidies for diesel pumps in some regions, especially where the electricity supply for irrigation is irregular (Source: Personal communications, December 2022). Controversially, these subsidies often carry a political motive, often neglecting the physical reality of depleting natural resources. Subsidies on diesel pump irrigation are employed as a tool to secure political support and appease voter bases. The result of such an approach is the proliferation of diesel pumps, aggravating environmental problems. Overall, the wide range of implemented policies creates tensions between the adoption of irrigation pumps and pathways to achieve multiple SDGs through agriculture.

2.3 Informal water markets to irrigation service provision

Informal, unregulated, and localized water markets have existed in different parts of India for decades (Bajaj et al., 2023). Informal water market arrangements allow irrigation pump owners to sell water to other farmers at a mutually agreed-upon price. In a typical setup, farmers own portable irrigation pumps and rent them to other local farmers for irrigation, acting as water sellers. Pump or hosepipe rentals provide access to irrigation to those smallholder farmers who cannot afford their own well and pumping equipment. Water markets are popular among Indian farmers and encourage investment in tube wells and other irrigation equipment through the prospect of profitable water sales. In a state like Uttar Pradesh, which has the highest number of farmers in the country and in which around 80% of agricultural area is irrigated, about half of farmers either rent borewells through pipelines or purchase water from large land-owning farmers for their irrigation needs (Jain and Shahidi, 2018).

The equity, scale, and nature of water market transactions vary across space and time and with the choice of crops. For instance, in Samastipur village in Bihar, a farmer currently charges Rs. 160 ($1.92) per hour for renting his diesel pump, whereas for an electric or submersible pump, the charge is Rs. 80–90 ($0.96–$1.10) per hour. In Vaishali village, also situated in Bihar, the water charge is roughly Rs. 200 ($2.40) per acre per hour for diesel pumps. Water buyers usually take 3–4 irrigation sessions in a season and end up paying between Rs. 6,000–8,000 ($72–$96) per acre per season for 10 h of irrigation, including labor charges. Similarly, in Uttar Pradesh, water buyers primarily rely on diesel motor pumps where the rental rate is Rs. 130-200 ($1.60–$2.40) per hour. (Source: Personal communications, August 2021).

Where smallholder farmers lack capital or credit to invest in irrigation equipment, alternatives such as "irrigation-as-a-service" or "shared pump" concepts can provide access to water for agriculture. By sharing mobile irrigation equipment across multiple sites and users, such approaches allow for higher capacity utilization of the irrigation equipment, spreading fixed costs over multiple users and potentially increasing the accessibility of irrigation to the poorest smallholders. While the implementation and analysis of irrigation-as-a-service in India is still limited, preliminary observations suggest that some existing irrigation-as-a-service startups, such as AgriRain and Oorja, are providing value to their smallholder customers and to village level micro-entrepreneurs.

3 Policy recommendations

Current agricultural water policies and governance in India create challenges to long-term food and water security. Subsidies on electricity have resulted in large-scale adoption of electric pumps, which has led to groundwater overextraction and depletion of aquifers. In many parts of India, agricultural water use is still heavily subsidized through both energy pricing and irrigation equipment subsidies. Such price distortions provide farmers with little incentive to invest in water-saving technologies or to adopt efficient irrigation practices. Rethinking agricultural policies that subsidize energy can play a crucial role in addressing the broader issue of groundwater depletion. However, it is understood that this might entail significant political resistance. Therefore, it is also important to consider how to develop programs for farmers that hold the potential to reduce water and energy use without increasing poverty (Mitra et al., 2023).

Furthermore, while there is a push from both governmental and private entities to promote the expansion of SIPs, current solar strategy and program designs are deployed by the energy department (e.g., State Renewable Energy Development Agencies or nodal agencies) mainly to increase energy intensity and to decrease the electricity subsidy burden. As water, energy, and food are interlinked, it might be beneficial to design cohesive solar program strategies in conjunction with water departments (e.g., Central Ground Water Board) and other agricultural or environmental stakeholders. Doing so could lead to a comprehensive consideration of groundwater extraction, emissions reduction, and beneficial crop choices in a systems approach.

Groundwater is a state subject in India, which means that state governments are responsible for managing and regulating groundwater resources within their respective territories. The central government provides guidelines and support to the states, but state governments have found it challenging to enforce groundwater regulations. Challenges related to agricultural water use are often local and context specific. Groundwater governance in India often fails to involve local communities (Shunglu et al., 2022), with decisions being made by government agencies without adequate local consultation. Understanding behavioral and decision-making aspects on a community level while considering the links between crop choices, groundwater availability, and irrigation technology adoption can play an important role in improving sustainable irrigation. Studies involving experimental games have shown that, when the links between crop choice and groundwater depletion are made explicit, farmers can act cooperatively to address groundwater issues (Meinzen-Dick et al., 2016).

Overall, there is a need for more localized policies monitoring groundwater, increasing the adoption of metered tube wells, incentivizing crop choices, and data collection to understand the status of groundwater resources in different parts of the country. Monitoring and data collection and distribution, whether done by government, nongovernmental, or private sector organizations, can help in making informed decisions on groundwater management. There is also a clear need to collect more evidence on business models for irrigation-as-a-service as a means to provide profitable and sustainable access to water for smallholders.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2024.1398822/full#supplementary-material

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