

RESEARCH PAPER

Do Farmers Understand Water Energy Nexus in Agriculture? Evidence from Northern Tamil Nadu

Kiruthika, S.^{1*}, Dinesh Kumar, K.², Srinandhini, M.³, Subashini, S.V.³, Swetha, P.³, DilliBabu, S.³ and Deepak, V.²

¹Department of Agricultural Economics, Adhiparasakthi Horticultural College, G.B nagar, Kalavai, Tamil Nadu, India

²Department of Floriculture, Tamil Nadu Agricultural University, Coimbatore, India

³Hort. Adhiparasakthi Horticultural College, G.B nagar, Kalavai, Tamil Nadu, India

*Corresponding author: kiruageco@gmail.com (ORCID ID: 0000-0002-8491-3987)

Paper No. 1227

Received: 14-09-2025

Revised: 30-11-2025

Accepted: 01-12-2025

ABSTRACT

Increasing agricultural productivity with free and subsidized electricity has made Indian agriculture stuck in complex nexus of groundwater depletion and energy subsidies. The present study conducted in Northern districts of Vellore and Ranipet of Tamil Nadu aims to analyze the groundwater resources of the region and farmers' understanding about the impacts of free electricity on groundwater depletion. Electricity is supplied at free of cost to farmers in Tamil Nadu which is seen as the biggest political agenda in the state. It was evident from the results of the study that majority of farmers use groundwater for irrigation and cultivate water intensive crops like paddy. About 60% of farmers have reported that they are aware of injudicious use of groundwater due to free electricity has caused groundwater depletion and about 62.50% of farmers are willing to pay for electricity.

HIGHLIGHTS

- Injudicious use of groundwater due to free electricity.
- Increased well failure made farmers shift to micro-irrigation and low water intensive crops.
- Farmers willing to pay for good quality electricity.

Keywords: Water Energy nexus, groundwater depletion, WTP, electricity subsidy

Increasing population necessitated increasing food productivity of the country creating higher demand for agricultural inputs. India achieved self sufficiency in food production in 1970s as a result of green revolution through high yielding varieties, higher cropping intensity, mechanization, increased fertilizer usage and irrigation (Mukherji, 2004). The increased cultivation of water intensive crops like paddy and sugarcane increased the demand for irrigation water (Kannan E. 2013). Net area under irrigation increased from 24.66 Mha in 1960 (18.51% of net sown area) to 75.46 Mha in 2021 (53.94% of net sown area) by harnessing groundwater with subsidized and free electricity (GOI, 2022). Consumption of electricity for agricultural purposes

has increased from 17.82 % of total consumption in 1983 to 20.11% in 2022 (GOI, 2022). Thus water, food and energy sectors are interconnected and influence each other.

According to the Statistical Year book of India (2018), out of the total net area sown of 140 million hectares, 46 percent of the area was irrigated with groundwater from tube wells and 17 percent was irrigated with groundwater from other types of wells (Beaton *et al.* 2019). Ground water driven agriculture productivity relies heavily on access

How to cite this article: Kiruthika, S., Dinesh Kumar, K., Srinandhini, M., Subashini, S.V., Swetha, P., DilliBabu, S. and Deepak, V. (2025). Do Farmers Understand Water Energy Nexus in Agriculture? Evidence from Northern Tamil Nadu. *Int. J. Ag. Env. Biotech.*, 18(04): 321-327.

Source of Support: None; **Conflict of Interest:** None



to electricity (Dubash, N.K. 2007). The number of electric tubewells in agriculture increased from less than a million in 1980 to 8 million in 1990 to 14.3 million in 2010 to 21 million by 2022 (Shah *et al.* 2012; Chandra A and Brozović N, 2024). This tremendous growth was the result of subsidized and free electricity policy by the state governments of India.

About 27 states in India including Tamil Nadu, Madhya Pradesh, Andhra Pradesh, Telangana, Punjab and Haryana provide subsidized electricity to agriculture. In Tamil Nadu, agricultural pump sets were charged with unit-based tariffs until 1983 and it is the first state to introduce free electricity to small and marginal farmers in 1984 and tariffs of flat rate at horse power per year to large farmers. From 1990, electricity was supplied free of cost to all the categories of farmers and dairy, sericulture, poultry were added to agriculture for free power in 1991 (Kannan E. 2013).

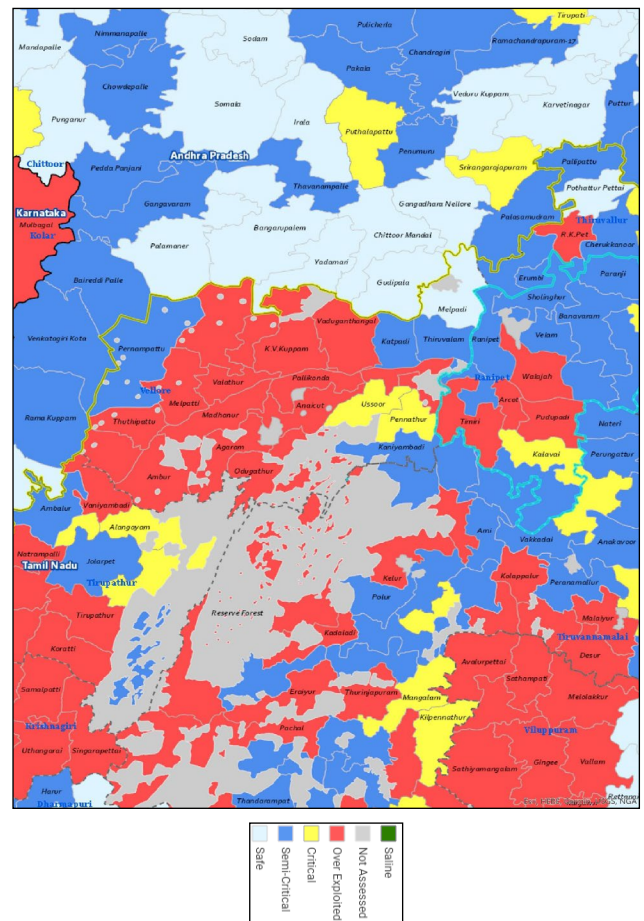
Providing free electricity for irrigation has positive externalities like reduced cost of groundwater extraction, increased irrigated area, increased crop yield and profitability to farmers, lowered food prices, increased demand for labour and exceptionally benefited landless farmers (Modi 2005, Briscoe and Malik 2006, Fosli *et al.* 2021). However, it resulted in negative externalities like overexploitation of groundwater, over pumping, cultivation of water intensive crops, increased number of well failure and inability of state electricity boards to cover power supply cost (Narayanamoorthy 1997; Palanisami and Suresh Kumar 2003, Fosli *et al.* 2021). Various state governments have formulated policies to rationalize the abstraction of groundwater since 2000s but the southern states of Tamil Nadu and Karnataka continued free electricity to farmers due to political reasons (Kannan E. 2013, Mitra *et al.* 2023).

Several studies were conducted to understand the water-energy nexus in agriculture and evaluated different policy options but the empirical evidence from Northern Tamil Nadu is limited. The present study aims to summarize the groundwater resources and irrigation pattern of study area, the effects of free electricity on ground water exploitation and the farmers' perception on implications of increased electricity usage in agriculture on groundwater exploitation and its linkage to public policy formulation. The present study also attempts to

explore electricity pricing strategy for irrigation in Northern Tamil Nadu.

METHODOLOGY

Multi stage random sampling procedure was followed to collect primary data. The study was conducted in northern districts, Vellore and Ranipet of Tamil Nadu as they have more blocks classified as groundwater overexploited region (Fig. 1).



Source: utility.arcgisonline.com

Fig. 1: Ground water resources of Vellore and Ranipet District (2020)

The ratio of net irrigated area to net sown area was 81.44 per cent for Ranipet and 42 per cent for Vellore. The blocks of Walajah and Arcot from Ranipet district and the blocks of Katpadi and K.V. Kuppam from Vellore district were selected in the next stage. Then two villages were selected at random from these blocks and 15 farmers were selected from each village comprising a total of 120 farmers. The survey was conducted by personal interview method using a structured and pre tested interview schedule from September 2023

to December 2023. Information related to land holding details, cropping pattern, area irrigated with groundwater, electricity usage and farmers' perception on depleting groundwater resources due to undue use of free electricity were also recorded.

Irrigation and Groundwater Resources of Study Area

The net sown area of Tamil Nadu is 4.83 Mha and the gross cropped area is 6.42 Mha and the net irrigated area is 2.92 Mha wherein 62.67 percent (1.83 Mha) is under ground water irrigation followed by 23.39 percent and 13.70 percent of net irrigated area under canal irrigation and tank irrigation respectively (GOTN, 2023).

The net sown area of Ranipet district is 52970.33 ha and 47714 ha for Vellore district. The Gross irrigated area of Ranipet is 58079 ha and for Vellore it is 28966 ha. The net irrigated area for the districts Ranipet and Vellore are 43,140 ha and 20040 ha respectively wherein 94.42 percent and 100 per cent of net irrigated area are under groundwater in the respective districts which shows that groundwater is the predominant source of irrigation in the study area (GOTN, 2020; GOTN, 2023).

In Tamil Nadu, a total of 435 blocks are categorized as over exploited with respect to groundwater resource. The annual extractable groundwater resource for Tamil Nadu is 19.51 bcm and the groundwater draft is 14.42 bcm of which 93.48 per cent is extracted for irrigation (GOI, 2023). From the total assessed units of groundwater recharge, 79.39 per cent of area in Vellore and 14.34 per cent of area in Ranipet are categorized as over exploited (GOI, 2023). The details of ground water resources of the two districts and their respective blocks selected for the study are given in Table 1.

The stage of groundwater development is the ratio of total groundwater extracted to the total groundwater availability. From Table 1, it is evident that Vellore district has higher percentage (more than 100%) indicating over use of groundwater resource which is also observed in 16 blocks of Vellore district and 4 blocks of Ranipet district (GOI, 2023).

Land Holding Pattern and Irrigation Sources

The details of land used for cultivation and irrigation by different farmer category are given in Table 2. It can be observed that 99 percent of the total land owned is used for cultivation in which 96.46 percent of area is irrigated. Only 5.95 percent of net sown area is under dry land cultivation due to less and untimely rainfall in the area. The cropping intensity and irrigation intensity is higher across all farmer categories due to groundwater availability and energized pump sets.

About 1.27 percent of area to total net irrigated area is irrigated by tanks and canals in Ranipet district whereas it is 2.06 percent for Vellore district (GOTN, 2024). The sample farmers from the selected blocks in the present study did not have access to canal or tank irrigation hence the only source of irrigation is groundwater. It can be seen from Table 3 that about 90.20 percent of area is irrigated using bore well and only 18.04 percent of area is irrigated using open well. This clearly indicates the shift from open well to dug well due to well failure and decrease in ground water table in the study area. Dubash, N.K. (2007) and Shah *et al.* (2012) indicated availability of free electricity led to increased groundwater demand and depleted aquifers.

Table 1: Groundwater Resources of the study area (in ham)

| Sl. No. | District | Block | Annual Replenishable Groundwater Resources | Net Groundwater Availability | Irrigation Draft | Stage of Groundwater Development (%) |
|---------|----------|------------|--|------------------------------|------------------|--------------------------------------|
| 1 | Vellore | | 1930.30* | 18631.29* | 18198.45* | 112.50 |
| 2 | | K.V.Kuppam | 454.11 | 408.7 | 702.6 | 180.477 |
| 3 | | Katpadi | 925.71 | 833.14 | 515.1 | 81.681 |
| 4 | Ranipet | | 34369.07* | 31056.83* | 24936.90* | 86.41 |
| 5 | | Walajah | 1711.61 | 1540.45 | 2459.13 | 169.486 |
| 6 | | Arcot | 514.27 | 462.84 | 526.9 | 141.502 |

Source: Central Ground Water Board, India (2023).

Note: * indicates values expressed in the unit billion cubic meters (bcm).

**Table 2:** Land use pattern and Irrigation pattern of sample farmers (in acres)

| Sl. No. | Particulars | Marginal | Small | Large | Total |
|---------|--------------------------|----------------|----------------|----------------|-----------------|
| 1 | Total area owned | 100.40 (26.34) | 190.75 (50.05) | 90.00 (23.61) | 381.15 (100.00) |
| 2 | Net Sown Area | 100.40 (26.59) | 187.25 (49.58) | 90.00 (23.83) | 377.65 (100.00) |
| 3 | Gross cropped area | 249.10 (32.48) | 408.75 (53.30) | 109.00 (14.21) | 766.85 (100.00) |
| 4 | Cropping Intensity (%) | 248.11 | 218.29 | 121.11 | 203.06 |
| 5 | Net Irrigated area | 99.65 (27.37) | 181.50 (49.84) | 83.00 (22.79) | 364.15 (100.00) |
| 6 | Gross Irrigated area | 212.90 (31.30) | 379.25 (55.76) | 88.00 (12.94) | 680.15 (100.00) |
| 7 | Irrigation intensity (%) | 213.65 | 208.95 | 106.02 | 186.78 |

Note: Figures in parenthesis indicates percentage to total value.

Table 3: Area irrigated by different sources

| Sl. No. | Type of well | Type of irrigation | Net area irrigated (in acres) |
|---------------------------------|--------------|--------------------|-------------------------------|
| 1 | Open well | | 65.70 (18.04) |
| 2 | | Flood | 49.70 (13.65) |
| 3 | | Drip | 16 (4.39) |
| 4 | Bore well | | 328.45 (90.20) |
| 5 | | Flood | 274.20 (75.30) |
| 6 | | Drip | 54.25 (14.90) |
| Total Net irrigated area | | | 364.15 (100.00) |

Note: Figures in parenthesis indicates percentage to total value.

Cropping Pattern

The important food crops of the study area are paddy, jowar, sugarcane, bajra and finger millet. The major horticultural crops grown are chilli, brinjal, banana and guava. The cropping pattern of the sample farmers are given in Table 4.

The cropping pattern was dominated by Paddy across all farm sizes followed by brinjal and chilli. Medium farmers had majority of area under paddy, black gram and coconut. Farmers cultivate high water intensive crops due to groundwater availability and free electric supply. Marginal and small farmers allocated higher areas to horticultural crops like brinjal, chilli, guava, Amaranthus and banana in addition to black gram. Farmers who faced problems of lower groundwater table and frequent well failure shifted to low water intensive crops like vegetables. About 29.90% of area under brinjal, 45.73% of chilli, 100% of guava and 40.50% of other horticultural crops are cultivated under drip irrigation method. It clearly indicates that the farmers moved towards water saving technologies to mitigate groundwater depletion.

Table 4: Cropping pattern followed by sample farmers (percentage to total cropped area)

| Sl. No. | Crops | Marginal | Small | Medium | Total |
|---------|------------|----------|-------|--------|--------|
| 1 | Paddy | 16.18 | 21.07 | 9.49 | 46.74 |
| 2 | Brinjal | 10.85 | 9.21 | 0.00 | 20.06 |
| 3 | Chilli | 6.91 | 3.84 | 0.70 | 11.44 |
| 4 | Black gram | 1.12 | 2.93 | 2.79 | 6.84 |
| 5 | Guava | 0.00 | 3.91 | 0.00 | 3.91 |
| 6 | Banana | 0.56 | 0.84 | 0.56 | 1.95 |
| 7 | Coconut | 0.28 | 0.28 | 1.12 | 1.67 |
| 8 | Amaranthus | 1.51 | 0.00 | 0.00 | 1.51 |
| 9 | Others* | 2.65 | 3.24 | 0.00 | 5.89 |
| 10 | All Crops | 40.05 | 45.30 | 14.65 | 100.00 |

Note: *includes crops like groundnut, onion, tomato, mango, marigold, turmeric, yam, ash gourd and fodder crops.

Electricity Consumption

The percentage share of electricity consumed for agricultural purposes in India increased from 10% in 1970 to 33% in 1990 (GOI, 2002). The rapid increase is due to availability of free and/or subsidized electricity for agriculture. The Government of India has formulated groundwater regulations while many states have initiated their own programs



to reduce the burden of state electricity boards. The percentage share of agriculture in electricity consumption in Tamil Nadu is 14.77% whereas for India it is 21.25% in 2021 (GOI, 2022).

The supply of free electricity to farmers in Tamil Nadu is subsidized by the state government and cross-subsidized by TANGEDCO. In 2019, the Government subsidy for non-metered agricultural consumers was ₹ 3.59/kWh while for metered agricultural consumers it is ₹ 3.23/kWh which resulted in TANGEDCO having to sell power below cost of supply resulting in revenue gaps (Auroville Consulting, 2020).

The average electricity subsidy for sample farmers was calculated to understand magnitude of revenue loss caused by providing free power. It is calculated by multiplying the unit cost of electricity (taken lower than the cost for domestic consumption) with the amount of electricity consumed. The amount of electricity consumed is calculated based on number hours motor is used in a year and its horsepower converted to kWh per acre. There is no recovery cost from the farmers as they are provided with free electricity. The results are given in Table 5.

Table 5: Average Electricity subsidy of study area (In ₹ per acre)

| Sl. No. | Block | Marginal | Small | Medium | All farmers |
|---------|------------------|----------|----------|----------|-------------|
| 1 | Arcot | 11776.67 | 10041.88 | 19801.50 | 11492.62 |
| 2 | Walajah | 13877.77 | 11879.57 | 17262.84 | 13356.31 |
| 3 | Katpadi | 13250.90 | 15468.67 | 8529.88 | 13347.77 |
| 4 | K.V.Kuppam | 10883.53 | 9644.72 | 1764.00 | 9310.88 |
| 5 | Total study area | 12466.11 | 27027.32 | 27118.04 | 12466.11 |

It can be seen from the above table that the average subsidy is higher for small and marginal farmers in the blocks of Katpadi and K.V. Kuppam as the farmers use high-capacity pump set and longer duration of irrigation. In other blocks of the study area small and medium farmers have the higher subsidy as water intensive paddy is a major crop.

Farmers' Awareness on Water-Energy Nexus in Agriculture

As there is no canal or tank irrigation available in the study area, the entire farmer community is

dependent on groundwater for irrigation. Providing free electricity and subsidizing motor pump sets and storage structures for irrigation has helped farmers in increasing area under irrigation. Even though farmers understand the importance of groundwater irrigation they have also reported concerns regarding free electricity which are represented in Table 6.

Table 6: Farmers' awareness on excess electricity usage and groundwater depletion (Percentage of farmers reported)

| Sl. No. | Particulars | Marginal | Small | Medium | Total |
|---------|--|----------|-------|--------|-------|
| 1 | Free electricity increased injudicious use of groundwater | 32.50 | 24.17 | 1.67 | 58.33 |
| 2 | Awareness on environmental impacts due to excess use of free electricity | 30.00 | 29.17 | 1.67 | 60.83 |
| 3 | Rapid fluctuations in ground water table | 28.33 | 22.50 | 2.50 | 53.33 |
| 4 | Increase in maintenance cost of irrigation equipment | 25.00 | 20.00 | 2.50 | 47.50 |
| 5 | Irregular power supply | 25.83 | 9.17 | 8.33 | 43.33 |

It can be seen from the above table that about 53.33 % of farmers reported fluctuations in ground water table. About 75.83% farmers reported that the ground water level has decreased significantly in the last decade while the average change in depth of borewell is 45 feet with a decrease in water level to minimum of 15 feet to a maximum of 200 feet. About 55% of farmers have dug a new bore well in the last decade and 32.50% of farmers have reported well failure when a new bore well is dug. The average cost of digging new bore well is ₹ 1,08,000. Farmers have a clear understanding on the implications of free electricity on groundwater depletion.

To mitigate the loss incurred on new bore well and to save irrigation water few farmers shifted to low water intensive crops and adopted water saving technologies. About 20% of farmers have installed



drip irrigation systems as it is available with 100% subsidy to small and marginal farmers and with 75% subsidy to large farmers. Among these farmers, 58.30% have reported that groundwater overuse is reduced after using drip irrigation.

Willingness to Pay for Electricity

Although farmers are provided with free electricity supply, they are not satisfied with the quality due to voltage fluctuations and hours of supply per day which increased the annual maintenance cost of irrigation equipment. About 62.50 percent of farmers expressed willingness to pay for better quality electricity which is given in Table 7.

Table 7: Farmers' preference of electricity pricing method (Percentage of farmers reported)

| Sl. No. | Particulars | Marginal | Small | Medium | Total |
|---------|---------------------------------|----------|-------|--------|-------|
| 1 | Willing to pay for electricity | 33.33 | 25.00 | 4.17 | 62.50 |
| 2 | Metering* | 0.00 | 0.00 | 6.66 | 6.66 |
| | Less than ₹ 1 per unit | 0.00 | 0.00 | 6.66 | 6.66 |
| | ₹ 1 to ₹ 2 per unit | 0.00 | 0.00 | 0.00 | 0.00 |
| | ₹ 2 to 3 per unit | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | Flat rate (₹ per Hp per year) * | 44.00 | 42.67 | 6.66 | 93.33 |
| | Less than ₹ 250 | 44.00 | 42.67 | 2.67 | 89.33 |
| | ₹ 250 to ₹ 350 | 0.00 | 0.00 | 4.00 | 4.00 |
| | ₹ 350 to ₹ 450 | 0.00 | 0.00 | 0.00 | 0.00 |
| | More than ₹ 450 | 0.00 | 0.00 | 0.00 | 0.00 |

Note: *Percentage out of farmers who are willing to pay for electricity.

Majority of farmers (93.33%) opted for flat rate system of pricing in which 89.33% were willing to pay less than ₹ 250 per Hp per year. The reason for this choice is that farmers can pay only once a year which will be convenient and will not increase the cost of cultivation significantly when they use groundwater judiciously. Only 6.66% of farmers opted for metering less than ₹ 1 per unit. This indicates that farmers understand the effects of free electricity on groundwater and are ready to pay for good quality electricity.

Implementing pricing system for free electricity is not an easy task. In every election, free electricity is used as the main campaign issue as farmers in drought prone areas see it as a lifeline (Fosli *et*

al. 2021; Badiani *et al.* 2018; Baskaran *et al.* 2015; Kondepoti, 2013). However various states are trying to reduce electricity consumption in agriculture by other methods. The PBK scheme introduced in Punjab combined entitlement and cash incentives with daytime power supply achieved reduced pumping hours for irrigation by farmers (Mitra *et al.* 2023). Introducing any one of pricing method alone will not solve the problem of groundwater depletion. Combining per unit power tariff along with metering and providing high quality electricity to create trust among different stakeholders is essential to craft a multifaceted strategy through political process (Dubash, N. K, 2007).

CONCLUSION

The study explored the groundwater resources of Northern Tamil Nadu and cropping pattern followed by sample farmers to understand the farmers perception on implications of free electricity on groundwater depletion. The field survey concluded that majority of farmers are dependent on groundwater for irrigation and the major crops grown are paddy, brinjal and chilli. The study indicated that the farmers have a clear understanding on environmental impacts of free electricity. Decrease in ground water table, frequent well failure and increased maintenance cost of irrigation equipment have motivated few farmers to adopt micro irrigation technologies and to shift to less water intensive crops in the study area. A high proportion of farmers expressed willingness to pay for better quality electricity. Creating awareness among farmers on groundwater conservation, judicious use of electricity and promoting water saving technologies along with minimum pricing for electricity in agriculture might improve the groundwater resources. However, it is a politically tough decision to implement pricing strategy as measure to reduce electricity usage and ground water exploitation.

REFERENCES

- Auroville Consulting, 2020. Assessing the impact of Tamil Nadu's tariff policy on TANGECO's financial performance. Sustainable Energy Transformation Series. Available at: <https://www.aurovilleconsulting.com/assessing-the-impact-of-tamil-nadus-electricitytariff-policy-on-tangedos-financial-performance/>



- Badiani-Magnusson, R. and Jessoe, K. 2018. Electricity prices, groundwater, and agriculture: The environmental and agricultural impacts of electricity subsidies in India. In *Agricultural productivity and producer behavior* (pp. 157-183). University of Chicago Press.
- Baskaran, T., Min, B. and Uppal, Y. 2015. Election cycles and electricity provision: Evidence from a quasi-experiment with Indian special elections. *Journal of Public Economics*, **126**: 64-73.
- Beaton, Christopher, Purva Jain, Mini Govindan, Vibhuti Garg, Rashmi Murali, Dimple Roy, Andrea Bassi, and Georg Pallasko. 2019. *Mapping policy for solar irrigation across the water-energy-food (WEF) nexus in India*. Winnipeg, Manitoba, Canada: International Institute for Sustainable Development.
- Briscoe, John and Mailk, R.P.S. 2006. *India's water economy, bracing for a turbulent future*. New Delhi, India, Oxford University Press.
- Chandra, A. and Brozović, N. 2024. Shifting dynamics and environmental implications of the irrigation pump market in India. *Front. Environ. Sci.*, **12**: 1398822.
- Dubash, N.K. 2007. The Electricity-Groundwater Conundrum: Case for a Political Solution to a Political Problem. *Economic and Political Weekly*, **42**(52): 45-55.
- Fosli, J.K., Reddy, A.A. and Rani, R. 2021. The policy of free electricity to agriculture sector: implications and perspectives of the stakeholders in India. *Journal of Development Policy and Practice*, **6**(2): 252-269.
- GOI, 2023. "National Compilation on Dynamic Ground Water Resources of India, 2023", Central Ground Water Board Department of Water Resources, River Development & Ganga Rejuvenation Ministry of Jal Shakti Government of India, Faridabad.
- GOTN, 2020. Vellore District Statistical Hand book 2019-2020, Vellore Collectorate, Government of Tamil Nadu.
- GOTN, 2023. Season and Crop Report of Tamil Nadu 2021-2022, Department of Economics and Statistics (DES), Chennai, Government of Tamil Nadu.
- GOTN, 2024. Ranipet District Statistical Hand book 2023-2024, Ranipet Collectorate, Government of Tamil Nadu. <https://cdn.s3waas.gov.in/s32723d092b63885e0d7c260cc007e8b9d/uploads/2025/05/2025050513.pdf>
- Government of India, 2002. *Water and Related Statistics*, Central Water Commission, Ministry of Jal Sakthi, India.
- Government of India, 2022. *Agricultural Statistics at a Glance*, Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation & Farmers Welfare Directorate of Economics and Statistics.
- Kannan, E. 2013. Do farmers need free electricity? Implications for groundwater use in south India. *Journal of Social and Economic Development*, **15**(2): 16-28.
- Kondepati, R. 2013. Agricultural groundwater management in Andhra Pradesh, India: A focus on free electricity policy and its reform. In *Asian Perspectives on Water Policy* (pp. 161-172). Routledge.
- Mitra, A., Balasubramanya, S. and Brouwer, R. 2023. Can cash incentives modify groundwater pumping behaviors? Evidence from an experiment in Punjab. *American Journal of Agricultural Economics*, **105**(3): 861-887.
- Modi and Vijay. 2005. *Improving Electricity Services in Rural India*. Working Paper No. 30, Center on Globalization and Sustainable Development.
- Mukherji, A. 2004. Groundwater markets in Ganga-Meghna-Brahmaputra basin: theory and evidence. *Economic and political Weekly*, pp. 3514-3520.
- Narayanamoorthy, A. 1997. "Drip Irrigation: A Viable Option for Future Irrigation Development," *Productivity*, **38**(3): 504-11.
- Palanisami, K. and Suresh Kumar, D. 2003. "Power Pricing, Groundwater Extraction, Use and Management: Comparison of Andhra Pradesh and Tamil Nadu States," *Water, Livelihoods and Environment in India: Frontline Issues in Water and Land Management and Policy*, 27-29 January, Institute of Rural Management Ahmedabad, Gujarat.
- Shah, T., Giordano, M. and Mukherji, A. 2012. Political economy of the energy-groundwater nexus in India: exploring issues and assessing policy options. *Hydrogeology Journal*, **20**(5): 995.

