Can Chhattisgarh Further Equity, Prosperity, and Sustainability Through Solar Pumps?

Indications from a Beneficiaries' Survey

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Image: CREDA

Solar-powered irrigation on the banks of Indravati river, Bastar District

Executive summary

Farmers in India have been increasingly adopting off-grid solar irrigation pumps over the past few years, largely due to incentives under government subsidy schemes. Beyond achieving target deployment numbers, such schemes must also ensure equitable access and economic support to irrigation for the marginalised, as well as promote sustainable use of groundwater. Different states in India have followed varied approaches to meet some of these objectives, with Chhattisgarh recording the highest number of deployments. Home to about 2.8 per cent of India's farmers (NABARD 2016), the state boasts more than 30 per cent of India's solar pump deployments, due to the success of the *Saur Sujala Yojana* (SSY) scheme. SSY provides about 90–95 per cent subsidy on solar pumps, which is available to any farmer with more than one acre of land ownership. Under SSY, more than 80,000 pumps have been installed in the last five years.

Using administrative data on all beneficiaries, and a sample survey of 773 beneficiaries of SSY's latest phase (conducted in 2020), we present a brief analysis of the beneficiaries' profiles, practices, and perspectives. Conducted just before the commissioning of the solar pumps, the survey provides details on farmers' profiles, their irrigation options and incomes before the installation of the solar pumps. **The insights can help various states learn from Chhattisgarh's experience with regard to furthering social equity, economic prosperity, and environmental sustainability by promoting solar pumps**.

Social equity: who is benefiting from solar pumps?

We found that SSY has helped further irrigation access among the marginalised. As much as 58 per cent of installations were by members of Scheduled Tribe communities. This is striking given that their share in the state's population is just 30 per cent. Two aspects of the state policy led to this success: (i) a differentiated subsidy based on social category, and (ii) geographical targeting of tribal majority areas.

The state also seems to have done reasonably well in targeting farmers without affordable irrigation option for the scheme. Prior to solar pump deployment, about 72 per cent of beneficiaries either did not have any irrigation options or depended on costly diesel pumping. However, about 23 per cent of the total allocation went to farmers with subsidised electric connections that they used to irrigate a different patch of land. We recommend that the state involve discoms in the pump allocation process to avoid this double support.

Small and marginal farmers are major beneficiaries of SSY. Ninety per cent of them cultivated less than five acres of land in the past year. However, landless farmers, or those without at least one acre of land, remain deprived. The state should consider including low-capacity mobile pumps, for such farmers. Further, only 23 out of the 773 individuals surveyed were women who owned connections, indicating that the structural bias against women in agriculture asset ownership has continued in solar pump schemes. Reserving a quota for women beneficiaries could help address this to some extent.

Economic prosperity: what are farmers' considerations?

We assessed the potential impact of solar pumps based on the beneficiaries' prevailing irrigation and cultivation

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> Irrigation access also plays a significant role in potentially increasing crop yield for vegetables and grams, especially in non-Kharif seasons.

patterns. India typically has three season of cropping. In rainfed areas, the cultivation is mostly confined to Kharif season. We found that access to irrigation is a clear determinant of cultivating in the second or Rabi season. However, summer cultivation is not prevalent even among farmers who owned a diesel or electric pump. It would be interesting to see whether solar pumps increase cropping intensity beyond two the two traditional cultivation seasons and leads to summer cultivation as well. We found that irrigation access also plays a significant role in potentially increasing crop yield for vegetables and grams, especially in non-Kharif seasons.

Consequently, targeting farmers who cultivate less water-intensive crops, such as vegetables, can help increase their economic returns. In addition to increasing cropping intensity and yield, solar pumps could also help improve farm incomes by expanding the cultivated area. The survey showed more than 63 per cent of farmers without irrigation access expected to expand their cultivated area once their solar pumps were installed.

To understand the potential utilisation of solar pumps, we looked at the current electric pump users in the sample, as they also experience zero marginal cost of operation. We found their median pump usage to be only 74 days a year. The government should promote other productive uses during non-irrigation days to improve asset utilisation. Thirty-six per cent of pump owners mentioned that they use their pumps for non-irrigation purposes. The state should capitalise on prevailing farmer behaviours to encourage the use of the asset to run other machinery such as those used for chaff cutting, grain milling, food processing, etc. Twenty-nine per cent of the beneficiaries have installed solar pumps on lands adjoining their homestead, making it easy to include such other productive uses. The study found that the cost of irrigation for diesel pumps was about INR 2,000 (USD 27) at the time of survey (Mar 2020) per acre. The cost now (Aug 2021) is likely to be 30 per cent higher, given the sharp rise in the retail price of diesel since the survey. But the cost of irrigation for electric pumps does not change significantly with an increase in the cultivated area, perhaps due to the flat rate tariff structure. At the current 90–95 per cent subsidy, the farmer's contribution for solar pumps is about 2–6 times the average seasonal irrigation cost – indicating a payback period of fewer than three years for an asset with a potential lifespan of 20 years. We propose that there is room to reduce the state subsidy per pump in the coming years if the state could enable financing in tandem with increasing the farmer's contribution. The cost of irrigation constitutes typically 5–15 per cent of the total input cost. This share is higher for small landholders, indicating that they will gain the most from subsidised solar pumps. This should thus be the focus of the state schemes.

Environmental sustainability: what could be the implication on groundwater?

Groundwater is the primary source of irrigation for most beneficiaries. Presently, the water table depth is adequate for most installations that are dependent on groundwater. But we found indications of groundwater depletion driving farmers to opt for higher capacity pumps. On average, survey respondents from districts with lower water tables reported having higher capacity pumps for the same landholding sizes. As the state contemplates increasing maximum capacity of solar pump offered under the scheme, it should be cognizant of these risks.

> Survey respondents from districts with lower water tables reported having higher capacity pumps for the same landholding sizes.

1. Introduction

Solar-powered irrigation systems (SPIS), generally called solar pumps for irrigation, are rapidly proliferating in India, largely due to government-supported capital subsidies. The Indian government launched the *Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan* PM-KUSUM scheme in 2019, with the aim of deploying 3.5 million solar pumps in three years (MNRE 2019; PTI 2020). SPIS have many inherent advantages, making them a convincing alternative to diesel and electric pumps. But as with any new technology, the social, economic, and environmental impacts must be assessed to ensure that policies promoting SPIS are sustainable in the long term. (Agrawal and Jain 2019). Particularly, the policies need to consider how the schemes promoting SPIS can:

- **Enable equitable access to irrigation**
- **Ensure an adequate economic case for farmers to adopt the technology**
- **Ensure that groundwater depletion concerns are adequately accounted for**

In this study, we examine one such state-level scheme promoting solar pumps for irrigation — *Saur Sujala Yojana* (SSY) in Chhattisgarh. The state has the largest number of solar pumps in India, most of which were installed under SSY since 2016. SSY is an ongoing scheme and its target is fixed annually. We studied the profiles of the beneficiaries of the 2019–20 financial year (SSY Phase IV), using the baseline survey data collected by the Chhattisgarh Renewable Energy Development Agency (CREDA), the nodal agency for the scheme. The Council assisted CREDA in institutionalising the impact evaluation framework through baseline and periodic surveys. Here, we present a preliminary analysis from the baseline survey data. We also used metadata on the survey beneficiaries made available to us by CREDA to contextualise the findings.

1.1 Saur Sujala Yojana

SSY provides a subsidy of about 90–95 per cent of the solar pump's total cost and is available to any farmer who owns more than one acre of land. The agricultural department identifies beneficiaries on a first-come-first-serve basis. CREDA sanctions the pump after evaluating the technical feasibility of installing a solar pump on that particular plot of land. According to CREDA officials, they have deployed more than 20,000 pumps in SSY Phase IV and more than 80,00 pumps since 2016.

1.2 The survey

District officials from CREDA carried out the (baseline) survey when solar pumps were being commissioned under SSY Phase IV between May–September 2020. The survey captured information on irrigation options and farm incomes prior to the installation of the solar pump. It had a sample size of 773 beneficiaries out of about 12,000 pumps deployed at the time of the survey. It covered 24 of the 27 districts in the state,[1] with more than 20 respondents from most districts, and is fairly representative of the scheme beneficiaries.

1.3 Objectives of the study

The purpose of this study is to evaluate SSY for its effectiveness in furthering equitable access and economic and environmental sustainability. Correspondingly, the specific research questions we address are the following:

- Has Chhattisgarh been able to ensure equitable distribution of SSY benefits? Can the identification and targeting of beneficiaries under SSY be improved?
- Does the scheme make an adequate economic case for farmers? Can the state make a better economic case for farmers to adopt solar pumps?
- Is solar pumping suitable for Chhattisgarh's agro-economic conditions? What measures are needed to improve environmental sustainability?

2. Who is supported under the scheme?

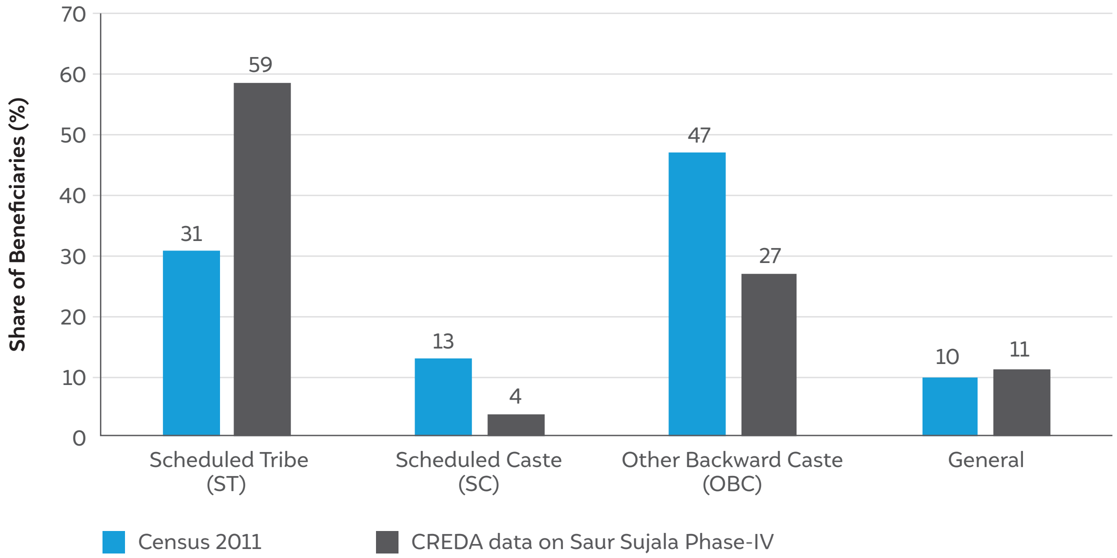
Conventional irrigation promotion strategies have been instrumental in driving agricultural growth, but they have often been highly inequitable and benefit only a small number of farmers (Jain 2006; Howes and Murgai 2003). Policies promoting solar pumps should allow us to enhance irrigation access more equitably.

2.1 Social caste category of the beneficiaries

The survey sample indicated that a significantly higher proportion of beneficiaries were from Scheduled Tribe communities compared to their representation in the state population (Figure 1). The state prioritised tribal communities under the scheme, and it appears to have done well in reaching this population, who so far had the lowest level of irrigation access. It adopted several strategies to target tribal communities:

- The scheme offers different subsidy rates for various social groups, with a higher subsidy rate for marginalised (Scheduled Caste and Scheduled Tribe) communities.
- The scheme's annual targets set quotas at different administrative levels — from the district to the village level. While all districts benefit from the scheme, the state prioritises tribal populated districts in this quota allocation system.

Figure 1 Chhattisgarh has been remarkably successful in targeting Scheduled Tribe (ST) communities for the solar pump scheme



Source: Authors' adaptation from data provided by CREDA

1. The survey was conducted before the establishment of the 28th district, Guerela-Pendra-Marwahi.

However, the same strategies did not ensure sufficient targeting of beneficiaries from the Scheduled Caste category. In terms of geographical distribution, land ownership, and occupational patterns, Scheduled Caste communities differ significantly from Scheduled Tribes. Hence, geographical targeting is not sufficient to reach beneficiaries belonging to Scheduled Castes. The state must explore alternative strategies to reach them.

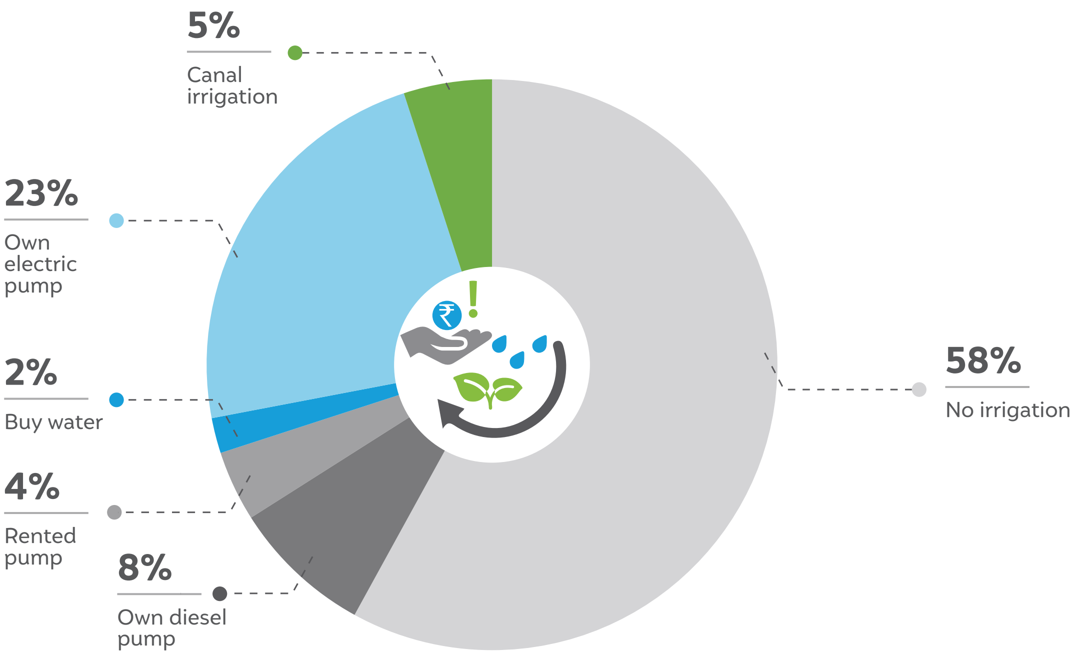
2.2 Prior access to irrigation among beneficiaries

Sixty per cent of Indian farmers rely on rain-fed agriculture. Prioritising such farmers, particularly in areas with good water table, could help further equitable irrigation access. We found that SSY has done reasonably well in furthering irrigation access among the deprived. The survey reveals that 58 per cent of beneficiaries did not have any irrigation option before getting a solar pump (Figure 2). A further 14 per cent of the beneficiaries depended on options like buying water, or using a diesel or kerosene pump (owned or rented), which is one of the costliest ways for farmers to access irrigation.[2] Essentially, about 72 per cent of the beneficiaries were well targeted to further affordable irrigation access.

However, about 23 per cent of the beneficiaries already owned an electric pump. As per the *Fifth Minor Irrigation Census* (2013–14), only 7.4 per cent of operational land holdings in Chhattisgarh had access to electric pumps (Ministry of Water Resources 2017). The state also provides reliable daytime power to these connections at a highly subsidised rate. Providing a heavily subsidised solar pump to an existing electric pump owner means that the beneficiary receives double support, whereas the resources could have been used to further irrigation access to a more needy farmer.

From our interactions with officials at CREDA, two possible reasons emerged for the mistargeting. Firstly, as part of the application process, CREDA only checks whether that particular landholding has been sanctioned an electricity connection. The applicant might have an electricity connection in another land parcel. Secondly, some of these electricity connections are temporary. There is currently no verification or information exchange with the state discom during the approval process. The state should consider receiving validation/verification data from the discom at the approval stage to improve equitable access under the SSY.

Figure 2 **About 72 per cent of the beneficiaries targeted under SSY Phase IV currently do not have access to affordable irrigation access**



Source: Authors' analysis of the survey data

2. In the visualisation, kerosene pumps have been clubbed with diesel pumps, since they are few in number and are very similar to diesel pumps in their characteristics.

2.3 Land ownership of beneficiaries

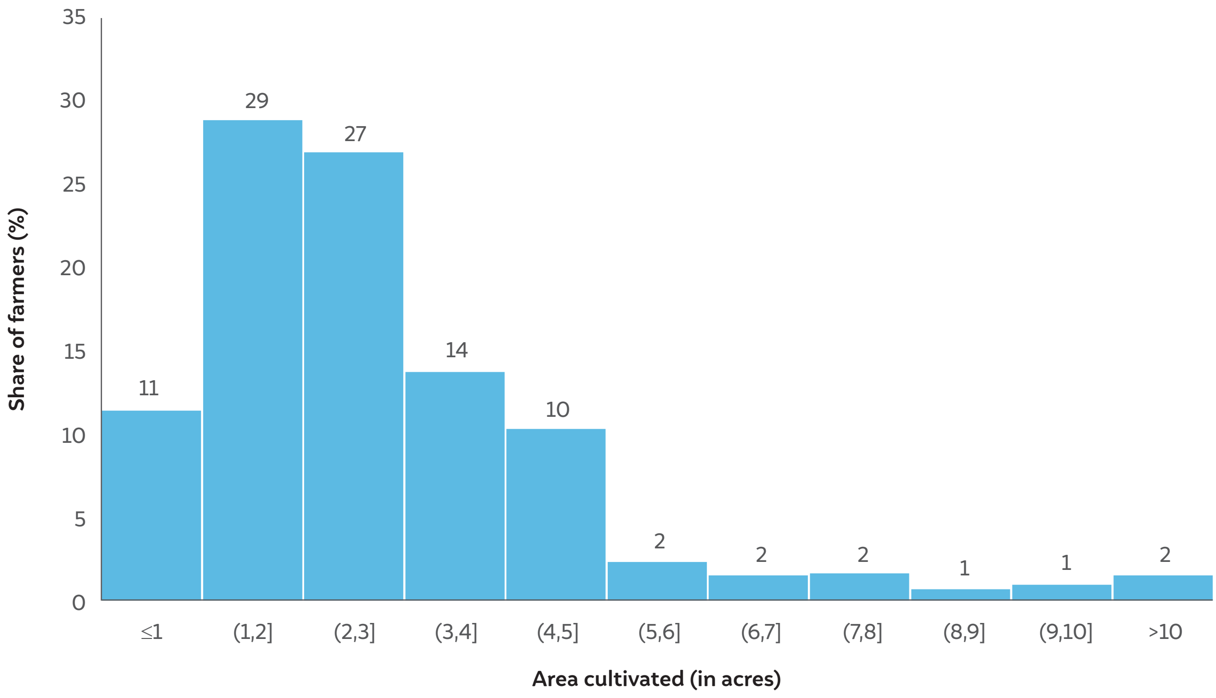
The beneficiary must own at least one acre of land to be eligible under SSY. Solar pumps are long-term investments, and beyond a certain capacity (typically 1 hp), they need to be permanently fixed on the ground, making land ownership an essential condition for such pumps. However, SSY currently does not offer any provision or support for farmers with very small or no holdings. The state should consider including micro-pumps (typically with less than 1 hp capacity and mobile) under the ambit of the scheme.

The survey includes details on the area cultivated by beneficiaries in the last year (2019) for each season. While the actual land ownership may differ compared to the land cultivated in each season, it can give a good sense of land ownership among the beneficiaries. The median area cultivated by the survey respondents in the previous cropping cycle (2019-20) was 3 acres[3] (Figure 3), while the average landholding size in Chhattisgarh is 3.08 acres (Ministry of Agriculture 2020). Only 10 per cent of the beneficiaries cultivated more than 5 acres last year. This indicates that the state has achieved reasonable success in targeting small landholders.

2.4 Beneficiaries' gender

The survey respondent was the person making key decisions regarding farming activities in the beneficiary household. Accordingly, in many cases, the respondent may have been different from the person against whose name the pump was allotted. Out of 773 respondents, only 33 were women. Of these, only 23 (3 per cent of the sample) had been directly allocated pumps. The impact of women's lack of asset ownership on the visibility of the female workforce in agriculture has been widely recognised. Schemes for solar pump promotion should strive to address this gender imbalance to the extent possible. The state should consider policies for gender inclusion such as a quota for women beneficiaries, women self-help group (SHG) owned models, and small pumps for kitchen gardens for women beneficiaries.

Figure 3 A majority of solar pump beneficiaries cultivated less than the average landholding size in the state



Source: Authors' analysis of the survey data

3. For estimating the median value, the maximum area cultivated in all of the three seasons by each beneficiary is considered.

3. Farmers' perspective and irrigation practices

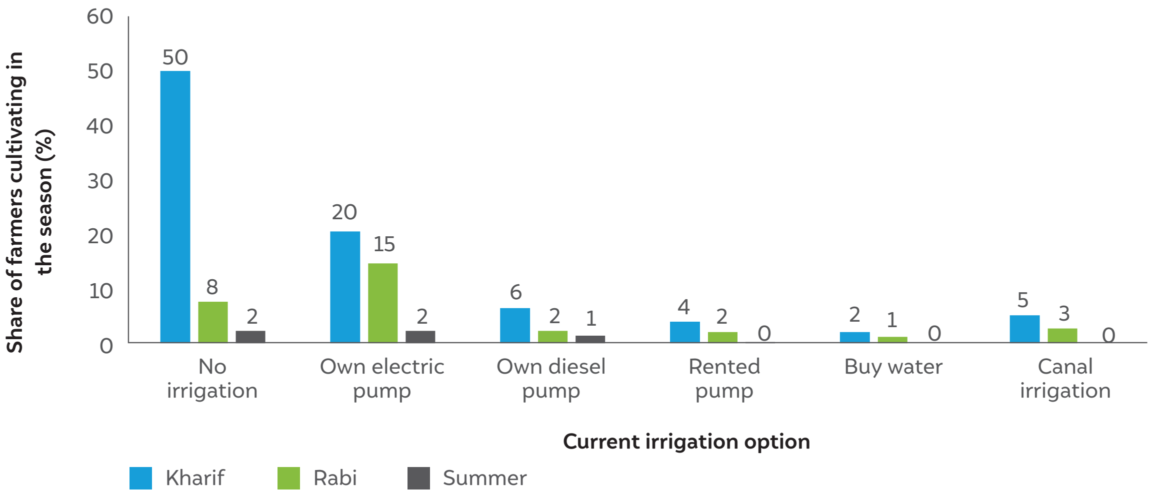
The long-term sustainability of SPIS depends on their ability to compete with other irrigation options in terms of utility and cost. As the survey respondents were farmers with diverse irrigation options, it generated relevant insights regarding the potential impact of solar pumps.

3.1 Cropping intensity and crop yield

First, we examine the impact of irrigation access on cropping intensity and crop yield — the two principal utilities of irrigation. Among the farmers who owned a pump, 64 per cent cultivated crops during at least two seasons in the last year (2019-20). In stark contrast, only 14 per cent of the irrigation-access-deprived farmers cultivated crops during more than one season in the same year (Figure 4). Agriculture is not practised in the summer months even by farmers with irrigation access. In future impact assessments of solar pumps in the state, it would be worth assessing if use of solar pumps would increase cropping intensity beyond two cultivation cycles a year.

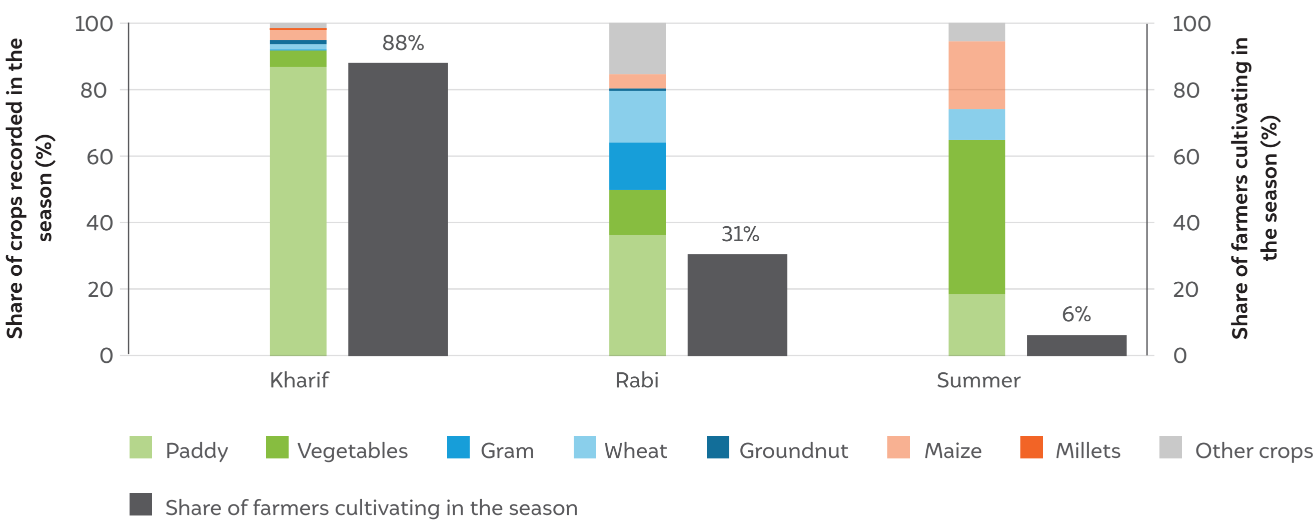
Paddy is the most cultivated Kharif crop in the state (Figure 5). It enjoys historic popularity among farmers as well as consistent market demand due to government procurement . The state has good crop diversity as well, as wheat, maize, gram, vegetables, and sesame are cultivated in the Rabi and summer seasons.

Figure 4 Even among farmers with irrigation access, summer cultivation is not prevalent



Source: Authors' analysis of the survey data

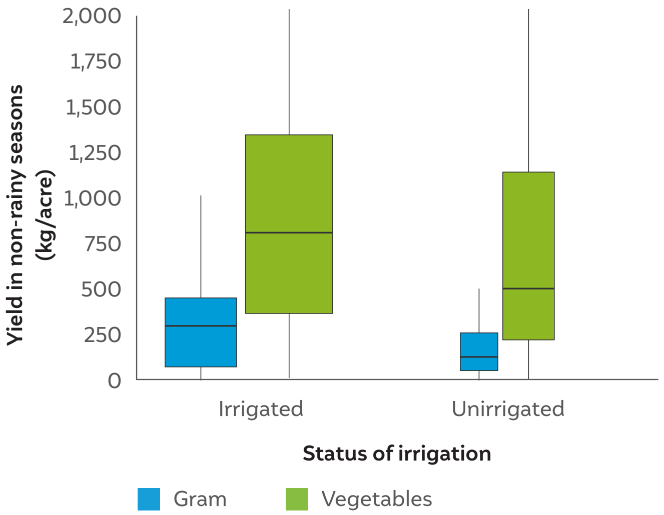
Figure 5 Paddy dominates the crop basket in Kharif season



Source: Authors' analysis of the survey data

The impact of irrigation access on yield varies across crops and seasons. In Kharif 2019 (the recall period for the survey), the monsoons resulted in average rainfall in all except one district in Chhattisgarh. Consequently, we did not observe a correlation between irrigation access and yields, suggesting that irrigation options are likely used as protective/supplementary support in the Kharif season. However, the impact of irrigation access on crops in other seasons (especially for less water-intensive crops) is significant (Figure 6). It indicates that if used adequately, solar pumps may unlock additional farm income for farmers previously deprived of affordable irrigation access, especially in the non-Kharif seasons. The state should explore strategies that seek to complement the deployment of solar pumps with the promotion of high-value and less water-intensive crops. The state's agriculture and horticulture departments can take the lead here and coordinate with CREDA to target and support SSY beneficiaries.

Figure 6 Access to irrigation has significant impact on yields of less water-intensive crops



Source: Authors' analysis of the survey data

3.2 Irrigation needs

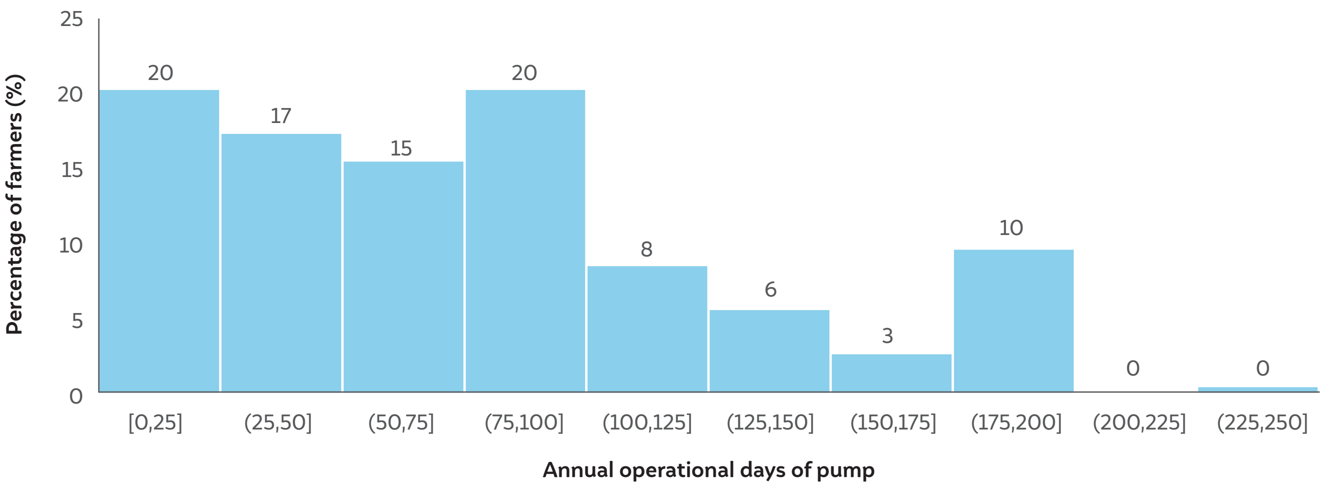
Among the respondents having access to an existing pump (owned or rented), 84 per cent, 58 per cent and 13 per cent of them used it for irrigation in the last Kharif, Rabi, and summer seasons, respectively. However, usage varied significantly between the types of pumps. While almost all farmers cultivated in the Kharif season, only 32 per cent of farmers with diesel pumps cultivated in the Rabi season, compared with 66 per cent of farmers with electric pumps (Figure 4). The high cost of diesel pumping could be the reason why farmers do not find it profitable to cultivate using diesel pumps in non-Kharif seasons. The use of pumps depends on the size and type of pump, the area to be irrigated, crop, depth of water table, and local agro-climatic factors.

The median use of all pumps is about 65 days (Figure 7), while that of electric pumps is 74 days a year. Considering the low marginal cost of running an electric or solar pump, we may see a similar utilisation level for solar pumps — below 100–150 days annually, even when farmers undertake three cultivation cycles. In case they undertake two cultivation cycles, the utilisation may remain well below 100 days a year. The remaining 200–250 days of solar power may go to waste. To improve asset utilisation, the state should consider promoting its use for other productive purposes.

3.3 Potential for non-irrigation productive uses

About 36 per cent of existing pump owners mentioned that they also use it for non-irrigation purposes,

Figure 7 Most farmers use the pump for less than 100 days a year



Source: Authors' analysis of the survey data including livestock rearing. About 29 per cent of respondents stated that the solar pump has been installed on lands adjoining their homestead, potentially enabling the pumping of water for household needs. To further improve asset utilisation, the state can promote equipment such as rice milling machines, chaff cutters, flour mills, or even convert the generation unit into a charging station for electric two or three wheelers. Promoting solar pumps with universal solar pump controllers would allow for such uses beyond pumping. In addition, CREDA should coordinate with other concerned departments like the agriculture/horticulture department and the *Chhattisgarh State Rural Livelihood Mission* (BIHAN) to enable the use of the solar asset for allied income generation activities.

3.4 Expectations from the solar pump

The survey also asked respondents how much land area they expected to irrigate with the solar pump. About 90 per cent of them stated that they expected to irrigate less than 5 acres, with the median value being 2–3 acres for all the districts. We also found that about 63 per cent of the farmers who indicated a higher expectation than their current cultivated area did not have irrigation access prior to getting the solar pump. This suggests that access to solar pumps would not only improve yields and cropping intensity, but it would also increase the cultivated area for such deprived farmers, adding another pathway to improve their incomes.

3.5 Cost considerations for irrigation

3.5.1 Pump maintenance cost

The cost incurred by farmers for the maintenance of their pumps shows wide variations. Both diesel and electric pump owners incur high maintenance costs. The average annual maintenance cost for diesel pumps is about INR 3,000 (USD 40), which is slightly higher than that of electric pumps, which range between INR 2,000–3,000 (USD 27-40), depending on the pump's size. A substantial number of respondents reported a maintenance cost of about INR 10,000 (USD 135), likely due to pump burnouts. Studies have repeatedly shown that frequent pump burnouts due to voltage fluctuations present significant expenditure for farmers.

SPIS have the advantage of better durability as they are designed to manage voltage fluctuations. Considering how massive the maintenance cost is, the five-year maintenance guarantee provided under the scheme is likely to be one reason for the scheme's popularity – provided such guaranteed maintenance services are adequately provided. Policymakers should explore if the maintenance guarantee can be leveraged to gradually reduce subsidies for the scheme. The state can think of extending the maintenance warranty beyond five years through an annual maintenance warranty based on a fixed user fee. Considering that there are enough solar pumps in all districts in Chhattisgarh, this would be a self-sustainable model and will help further the benefits of solar pumps.

3.5.2 Cost of irrigation

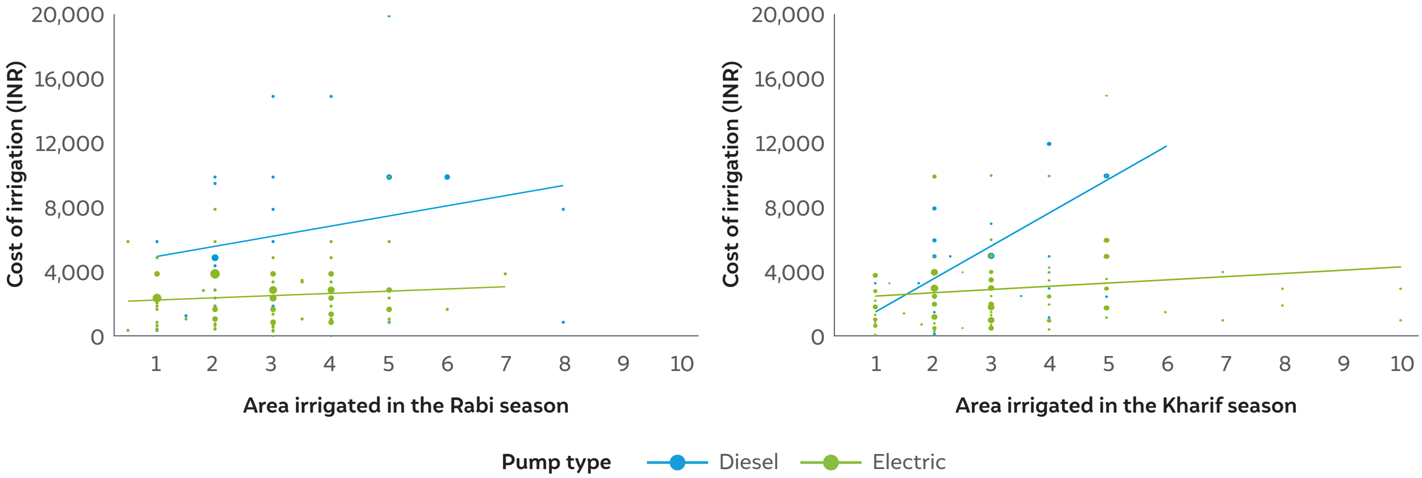
The cost of irrigation, incurred as the amount spent on fuel/electricity per area, exhibits completely different patterns for diesel and electric pumps (Figure 8). For the Kharif season, diesel pump users spent about INR 2,000 per acre on irrigation or about INR 6,000 for the typical landholding of 3 acres. Considering the significant (~30 per cent) increase in the price of diesel since the time of the survey (between 2020 and 2021), this cost would be about INR 8,000 in present day. On the other hand, electric pump users spend between INR 2,500–5,000 for the season, with only a marginally increasing outlay for larger landholdings. This is likely due to the flat rate tariff structure of agricultural connections.[4] Considering these outlays, the current upfront contribution for solar pumps would be approximately 2–6 times the average seasonal irrigation costs for existing users.

Consequently, there is room for reducing the state subsidy per pump in the coming years. However, the initial contribution (~ INR 10,000–20,000) is still unaffordable for many poor farmers. Thus, there is a need to promote affordable financing through partnerships with financial institutions.

> **63% of the farmers surveyed, who indicated they expected to irrigate a larger area than the current cultivated area, did not have irrigation access prior to getting solar pumps.**

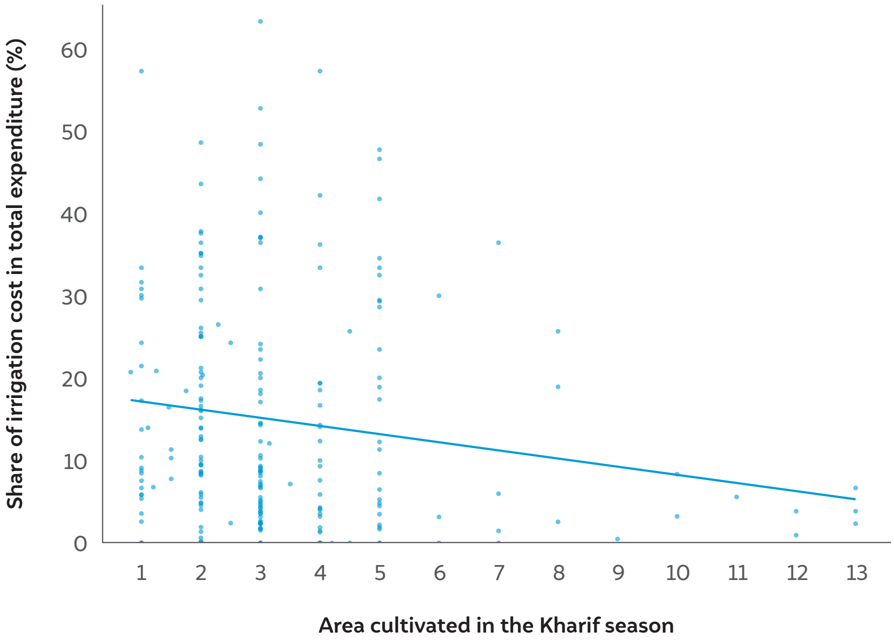
4. The flat rate tariff for agricultural consumers in Chhattisgarh is INR 80/month/hp (CSERC 2019).

Figure 8 The cost of diesel irrigation is proportional to land area, but the cost of electric pumps is more or less constant



Source: Authors' analysis of the survey data

Figure 9 Irrigation as a share of total inputs is higher for small landholdings



Source: Authors' analysis of the survey data

Note: The blue line represents the trendline

The cost of irrigation constituted about 7.5 per cent of the total input costs on average. However, it is worth noting that the share of expenditure on irrigation progressively increased for smaller landholdings (Figure 9). This suggests that targeting small landholders with solar pumps would yield a higher income per beneficiary.

4. What is the implication of promoting solar pumps on the groundwater in the state?

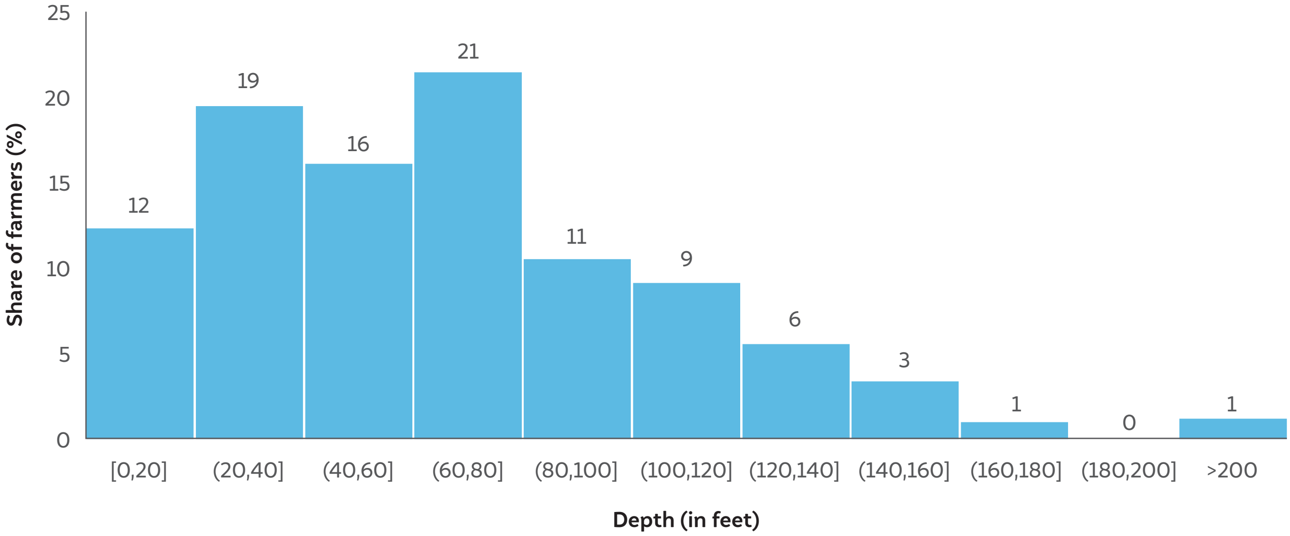
Groundwater is the primary source of irrigation in the state. More than three-quarters of beneficiaries use borewells as the primary water source for their newly installed solar pump. Even among beneficiaries having canal water facilities, the borewell is cited as the primary water source.

Figure 10 shows the groundwater level distribution among surveyed farmers in the last cropping cycle, as recalled by the respondent.[5] The median depth of water was observed to be about 65 feet below ground level. About 79 per cent of beneficiaries mentioned water levels within 100 feet of depth. While the groundwater depth is currently sufficient for most installations dependent on it, indiscriminate deployment of solar pumps could lead to water sustainability challenges in these areas over time.

Presently, the maximum size of pumps offered under SSY is 5 hp. However, as the state contemplates increasing the capacity of the pumps it offers under the scheme, it should note that groundwater depletion is already driving farmers to buy higher capacity pumps.

On average, survey respondents from districts with lower water tables reported having higher capacity pumps, even after controlling for landholding sizes. Continuing policies that incentivise large withdrawals of water will only lead to a 'race to the bottom', as witnessed in states like Punjab and Haryana. Therefore, the state needs to look at its policies holistically and promote less water-intensive crops, water-efficient irrigation practices, and smaller solar pumps for sustainable agricultural growth.

Figure 10 **The groundwater level is reasonably good for a majority of beneficiaries**



Source: Authors' analysis of the survey data

5. Mean value of pre- and post-monsoon groundwater levels.

5. Conclusion

India is massively increasing the deployment of solar pumps for irrigation. The technology is 'green', but it is equally important to consider how it is being promoted and for whom. Recent literature has tried to answer the 'how' through comparative analyses of deployment models and case studies and pilots of various innovative approaches. However, there has been limited examination of who the beneficiaries of state-subsidised solar pumps are. Given that farmers are not a homogeneous group in India, it is important to understand beneficiaries' profiles better, to assess whether public funds are adequately furthering equity, prosperity, and sustainability among farmers.

In this brief, we examined the solar pump programme of Chhattisgarh to understand the profiles of the beneficiaries of the state subsidy programme. Based on the findings, we recommend:

- Geographic measures to target communities at the district and block level are necessary, but they are not sufficient to reach all communities. States should consider more inclusive criteria to target various marginalised communities.
- Better coordination between the implementation agency and other state departments, such as the state agriculture department and discom, can help improve targeting further and limit the number of beneficiaries with existing state support for irrigation.
- Promoting less water-intensive crops (and horticulture in particular) among farmers using solar pumps could help improve economic returns for farmers without impacting groundwater sustainability.
- The prevailing subsidy levels of up to 90 per cent can be reduced to reach a larger number of beneficiaries despite fiscal constraints, provided the farmer's contribution can be financed – otherwise marginal farmers would not be able to adopt the pumps. Asset utilisation for a typical off-grid solar pump may remain as low as less than 100 days a year. Thus, states should consider promoting non-irrigation use of the asset to power other farm-related livelihoods such as post-harvest processing, etc.
- Allocation of high-capacity pumps should be strictly restricted in areas with depleting water tables to avoid long-term challenges.

Image: Agriculture Department, Chhattisgarh

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