TO STUDY THE SOCIO-ECONOMIC IMPACT OF SOLAR BASED IRRIGATION SYSTEM: FOCUS ON DANG DISTRICT GUJARAT. (IT MAY INCLUDE MIGRATION, EMPOWERMENT (GROUP DECISION-MAKING), GROUP MANAGEMENT, FARM PRODUCTIVITY, CROP YIELD, AND FARM INCOME)

Dissertation Submitted to

The IIHMR University, Jaipur

for the partial fulfilment for the award of the degree of

Master of Business Administration (MBA)

in

Development Management

By

Keshav Laxman Gabhale

Under the Supervision and Guidance of

Dr. Ratna Verma

2024

AGA KHAN RURAL SUPPORT PROGRAMME (INDIA)

AKRSPI/DNG/ADM/13/2024 Date: 2nd July 2024

INTERNSHIP CERTIFICATE

This is to certify that **Mr. Keshav Gabhale** from **IIHMR University, Jaipur** has successfully completed 80 Days of Rural Internship with Aga Khan Rural Support Programme (India) in The Dangs district of Gujarat during 1st April 2024 to 20th June 2024.

The internship undertaken by him was on " **To Study the Socio-Economic impact of Solar Based Irrigation System and Regenerative Agriculture in Dang district**." I hereby certify that the work conducted by him was good to the best of my knowledge.

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DECLARATION BY STUDENT

I hereby declare that this dissertation titled "To study the Socio-Economic Impact of Solar Based Irrigation System: Focus on Dang District Gujarat" is the bonafide record of my original research work. I declare that it has not been submitted to any other university or institution for the award of any degree or diploma. Information derived from the published or unpublished work of others has been duly acknowledged in the text.

Signature

Keshav Gabhale

Date: 05/07/2024

CERTIFICATE

This is to certify that the dissertation titled ***"To study the Socio-Economic Impact of Solar Based Irrigation System: Focus on Dang District Gujarat"*** is a record of the research work undertaken by **Keshav Gabhale** in partial fulfillment of the requirements for the award of the degree of MBA Development Management from the IIHMR University, Jaipur under my guidance and supervision and his/her approach to the research study has been sincere, scientific, and analytical.

Faculty Guide: Dr. Ratna Verma

IIHMR University, Jaipur

Date: 05/07/2024

School Dean: Dr. Himadri Sinha

IIHMR University, Jaipur

Date: 05/07/2024

To study the Socio-Economic Impact of Solar Based Irrigation System: Focus on Dang District, Gujarat. (It may include migration, empowerment (group decision-making), group management, farm productivity, crop yield, and farm income)

Dissertation Submitted to

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Master of Business Administration (MBA)

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Development Management

By

Keshav Laxman Gabhale

Under the Supervision and Guidance of

Dr. Ratna Verma

Appendix D: Declaration by Student

DECLARATION BY STUDENT

I hereby declare that this dissertation titled ……is the bonafide record of my original research work. I declare that it has not been submitted to any other university or institution for the award of any degree or diploma. Information derived from the published or unpublished work of others has been duly acknowledged in the text.

(Signature)

Keshav Gabhale

Date:

Completion certificate

AGA KHAN RURAL SUPPORT PROGRAMME (INDIA)

AKRSPI/DNG/ADM/13/2024

Date: 2nd July 2024

INTERNSHIP CERTIFICATE

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Appendix F: Certificate from Faculty Guide and School Dean

CERTIFICATE

This is to certify that the dissertation titled..is a record of the research work undertaken by (Name of Student) in partial fulfillment of the requirements for the award of the degree of MBA (Hospital and Health Management)/MBA (Pharmaceutical Management)/MBA (Development Management) from the IIHMR University, Jaipur under my guidance and supervision and his/her approach to the research study has been sincere, scientific, and analytical.

Faculty Guide	School Dean
IIHMR University, Jaipur	IIHMR University, Jaipur
Date:	Date:

Abstract:

This paper assesses the socio-economic returns of solar-based irrigation interventions undertaken by AKRSPI under different projects at two taluks, Ahwa and Subir of Dang district, Gujarat. The situation in Dang district is – this hilly area is covered with forests, and the entire watershed of the region is drained by the Gira, Purna, Khapri, and Ambika rivers along with their tributaries. Agriculture and crop production here are rain-fed rather than irrigated and the area lacks other alternative irrigation facilities, lack of electricity, and uncertainty. To some extent, farming is done using diesel machines during rabbi season, but the cost of diesel and the overall cost is not affordable. These challenges force many people to migrate for 4-8 months to places like Maharashtra, and Gujarat for seasonal farming (Kharif) and other times. So, they are socio-economically underdeveloped and backward. Consequently, the objectives of the research are as follows: migration, empowerment of farmers, women, and widows (active participation in meetings and decision-making processes of solar pump user groups), SUG management (bank linkage, meetings, participation, water tariff charges), crop diversification, farm productivity and financial to determine the effect of solar irrigation on yield.

According to the 2011 census, Dang district has a population of 2,26,769 out of which the majority (more than 94%) are STs, and most of the population is still below the poverty line. Most of the people are engaged in agriculture and as agriculture is mainly rain-dependent, farming is done for 4 months during Kharif. Seasonal migration cases have arisen every year due to various reasons such as lack of water for agriculture during the rabbi and summer seasons as well as lack of irrigation facilities. These problems can be solved by introducing new technology in the form of solar-based irrigation systems.

According to research findings significant reduction in migration, previously 68.25% and now 19.04%, post-intervention credit for the use of solar pumps in the provision of sustainable agricultural sources of income. Increased social inclusion and participation for empowerment by including women especially widows along with male farmers in the meeting and decision-making process of solar pump user groups. These groups have developed financial inclusion, participation, and proper management through scheduled meetings, and opening of group accounts. At the same time, the sustainable use and future maintenance of the solar pump are well planned by managing the structured water rate.

This intervention greatly improved crop diversity, with particular emphasis on Okra tomatoes and carrots. It focused on diversification of production which increased food supply and household income. Production and income of crops like okra, groundnut, and brinjal increased, thus providing an economic approach to support the solar-based irrigation concept. Farmers have started farming in the rabbi and summer seasons as well.

Thus, this study demonstrates the benefits of solar irrigation systems for socio-economic development in many isolated, tribal areas as well as areas with a background such as Dang. Which provides long-term sustainability by avoiding the additional cost of irrigation. These are also important to further assess the constraints, benefits, and feasibility of such interventions to inform further agricultural and rural development projects.

Acknowledgements:

I would like to express my sincere gratitude to all those who supported and contributed to the successful completion of this research project. First, I would like to thank my mentor Dr. Ratna Verma for her guidance, encouragement, and valuable insights throughout the research process. Her expertise, feedback, and support have been instrumental in shaping our research and achieving our goals.

I would like to express my gratitude to the institution, and the colleagues concerned, for their hard work and support for allowing me to do research at AKRSPI. I would like to thank the community for their cooperation in sharing their knowledge, experiences, problems, collaborations, and partnerships.

Additionally, I would like to thank my Mentor, Research associate, and other colleagues at AKRSPI for their thoughtful feedback and discussions which have been invaluable in shaping my thinking. Special thanks to the thematic experts and field team for their perspective and for mitigating my language barrier problem. I would also like to thank the participants of this study, whose time and effort, whose willingness to share their experiences and insights made this research possible, is greatly appreciated.

Once again allowed to do research, provided necessary facilities, guided, and helped from time to time. We would like to thank AKRSPI and all the team members for their hard work support for Guidance and help in the work.

Table of Contents

List of Figures

List of Tables

Abbreviations:

AKRSPI: Aga Khan Rural Support Program India

SUG: solar user group

BPL: Below Poverty Line

ST: Scheduled Tribes

PV: Photovoltaic

AKDN: The agencies that comprise the Aga Khan Development Network

SUG: Solar User Group

HEIS: High-Efficiency Irrigation Systems

CO2: Carbon Dioxide

SIP: Solar-run Irrigation Pumps

ROI: Return on Investment

SBIS: Solar-Based Irrigation Systems

ICAR-AICRP: Indian Council of Agricultural Research - All India Coordinated Research Project <Organization uncertainties>

Cobo: Cobo Tools (a software platform for data collection)

USD: United States Dollar

NGO: Non-Governmental Organization

GDP: Gross Domestic Product

Ha: Hectare

Chapter Scheme

Chapter 1: Introduction

Sustainable agriculture is essential for achieving many sustainable development goals such as poverty alleviation, food security, inclusive economic growth, and sustainable production methods. In India, 56.4 % population is involved in the agriculture sector. Currently, agricultural production is becoming more challenging due to the increasing global population, climate change, increasing demand for food and shrinking agricultural land area, water scarcity, and lack of technology. These challenges give rise to many problems such as rural-to-urban migration of large populations, crowded urbanization, unemployment, social instability, and poverty. To address these issues, various sustainable production methods such as precision agriculture, conservation, organic farming, agroforestry, Agriculture technology, and integrated Agro-agricultural systems are being practiced worldwide.

A complex set of factors including global warming, competitive land use, and lack of basic infrastructure are creating new challenges for India's vast agrarian population. The ever-increasing mismatch between energy demand and supply in general, and electricity in particular, is posing challenges to farmers in remote areas and making them vulnerable to risks, especially small and marginal farmers. In India, even today electricity has not reached some remote areas for irrigation, and even though there are exceptions for some remote areas, many problems such as electricity uncertainty, and unaffordable electricity bill costs arise in rural areas with mountainous and remote areas. In such areas, farmers must depend on alternative irrigation equipment like diesel engines. About 12 percent of India's total diesel consumption, i.e. more than 4 billion liters, is diesel. In this, the cost of diesel is greater than the production, and the damage to the environment is huge. Hence, solar-powered pumps are emerging as an alternative solution to those powered by electricity and diesel. Diesel and electric pumps have lower capital costs, but their operation depends on the availability of diesel fuel or a reliable supply of electricity.

1.1 Demographic profile of Dang:

Dang district, the study area, lies parallel to the meridian of 200 33' and 210 5' latitude and 730 27' and 730 57' longitude. It is bordered by Surat and Dhule Districts of Maharashtra State to the North, Nashik District to the East, and Valsad District to the West. The area of the district is 1,764 sq. km. The district is essentially a hilly area covered with thick forests. The entire watershed of this region is drained by the Gira, Purna, Khapri, and Ambika rivers along with their tributaries.

This district has a historical and cultural background. Dandakaranya in the Ramayana was none other than the Dang district of Gujarat state. The historical district is the only district in the state with dense forest. A total of 311 villages are included in Dang, where 75% of the population still lives below the poverty line and 98% of the population belongs to Scheduled Tribes,

According to the 2011 census, the population of Dang district is 2,26,769. About 94% of the population of the district is tribal. About 73.84% of the total population falls under the BPL category. Around 30,000 people migrate every year in September for employment in sugarcane cutting and vineyards.

1.2 Study background:

Dang is one of the most backward districts in Gujarat. Most of the rural population in the district is 89.19 percent while the urban population is 10.81 percent. Due to the hilly terrain in Dang, people have limited livelihood options such as limited agriculture, and forest-based livelihoods. Agriculture is mainly rain-fed and due to limited irrigation facilities, there are limited opportunities for Dangs. Major crops like paddy, nagli, varai, ground nut, etc. are grown in rainwater. In Rabbi, gram, cowpea, and wheat crops are grown in small quantities. Due to the remoteness of the area, farmers are dependent on traditional irrigation methods and some areas lack resources for irrigation. Due to the lack of electricity due to dense forests, diesel engines are used for farming. Unlimited expenditure on diesel, relatively low income, and all this is unaffordable to farmers, resulting in mass migration of people. An average of more than 30000 people migrate to Nashik in Maharashtra, Surat in Gujarat, and Vadodara for work every year. A region's socio-economic development is closely linked to its agricultural productivity, making agricultural and irrigation progress critical to the well-being of local communities as well as environmental sustainability and increasing agricultural productivity.

1.3 About AKRSPI Organization:

The Aga Khan Rural Support Program (India) is a non-governmental organization dedicated to improving the lives of rural communities in India. Founded in 1984, AKRSP(I) functions under the Aga Khan Development Network (AKDN), a group of development organizations founded by the Aga Khan. AKRSP(I) is active in more than 3255 villages in Gujarat, Madhya Pradesh, Bihar, and Maharashtra as a catalyst for the improvement of rural communities by directly supporting local communities. The organization undertakes a multi-pronged approach to rural development by focusing on several key areas including agriculture and natural resource management, livelihood development, women's empowerment, education and health, climate change, and environment.

The organization has been actively working in the Dang district since 2010. It is intervening through solar-powered irrigation systems under various projects in Subir and Ahwa talukas of the district. These initiatives aim to address the problem of migration from the district by increasing local employment and income opportunities in agriculture and allied activities. It stops migration and boosts local economic development.

1.4 Purpose of research:

Solar Irrigation System interventions by AKRSPI organization under various projects are now prominent in agricultural areas in remote areas of Subir and Ahwa talukas. Due to irrigation problems in the region, the high cost of diesel compared to production, unavailability of electricity connection or uncertainty of power supply, solar irrigation systems will have a positive impact on the development of farmers. However, the knowledge of the effects of solar-based irrigation model on migration, empowerment (group decision-making), management, farm productivity, crop yield, farm income, and economic viability in Ahwa and Subir talukas of Dang district is still limited in the context of Dang district. Therefore, the objective of this paper is to assess the impact of irrigation systems on the Ahwa and Subir blocks in the Dang district. Along with this, it helps to understand the social acceptability, desirability, and sustainability of the solar model.

1.5 Study objective:

The objective of this study is to evaluate the socio-economic impact of solar-based irrigation pump intervention in Ahwa and Subir talukas of Dang district under different projects by the AKRSPI organization.

- In this, to study the social impact of solar-based irrigation pumps on farmers' migration, farmer empowerment (group decision making), and farmers integration (group formation, its management).

- Studying crop diversity, farm productivity, crop yield and farm income in economic impact.
- Identify potential benefits and challenges of solar-based photovoltaic (PV) pumps.

1.6 Research problem:

Although solar based irrigation model has positive effects on "farm productivity, crop yield, farm income, economic viability, and environment" from national, international as well as different levels of research, still there is limited information about the effect on farmers in remote areas like Dang in Gujarat. Migration was the main problem in this area due to low income in specialty agriculture, uncertainty of electricity, cost of diesel, lack of irrigation facilities, and rain-fed agriculture. Due to this, the integration of solar-based irrigation pumps by AKRSPI in this area has gained special importance.

This study highlights the impact of solar-based irrigation pumps on crop diversity, farm productivity, crop production, and farm income, the economic viability of solar-based irrigation pumps, its benefits, and challenges as well as farm migration, farmer empowerment (Group formation, decision making, and its management). It also provides useful insights into understanding the socioeconomic impacts of solar-based irrigation pumps in the context of Dang district and the challenges, benefits, and implications of these will provide valuable insights into the future design of such interventions.

Chapter 2: Review of Literature:

Several studies have been conducted from time to time at national and international levels to explore the social and economic impact of solar-based irrigation systems or solar pumps on farmers. Several studies have highlighted the positive socio-economic impact of solar-based irrigation systems. The results of previous research have opened doors for further research and study. It has reviewed several academic as well as empirical studies. By evaluating the previous literature, this chapter attempts to present an overview of the many features and issues of the subject.

1. Bangladesh is an Agriculturally based country and optimization of this sector is hindered by the shortage of electricity and high cost of diesel fuel. As an alternative option to overcome this crisis, a 3KW solar irrigation system has been installed at a remote location near Mymensingh, about 120 km from the capital. An economic analysis and life cycle cost analysis of this system have been carried out and compared with its conventional counterpart diesel-powered irrigation system**,** showing that a solar-based irrigation system is an economically viable option for long-term investment. *Tasneem, Zaima and Annie, Saila and Salim, Khosru. (2015). Economic analysis of a 3KW solar-based irrigation system and comparison with its diesel-based counterpart. 10.1109/WIECON ECE.2015.7443939.*

2. As an alternative clean and climate-friendly energy source, renewable energy has gained more importance in government policies. Not only do solar irrigation systems facilitate adequate water supply and reduce production costs, but they also significantly increase agricultural yields. Overall, the adoption of SIP (solar-run irrigation pumps) ensures the reliability of water supply (i.e. water adequacy) in addition to availability and affordability, leading to long-term implications for farmers' welfare. *Hossain, Monzur, & Karim, Azreen. (2020). Does renewable energy increase farmers' well-being? Evidence from solar irrigation interventions in Bangladesh. ADBI Working Paper Series, No. 1096, Asian Development Bank Institute*

3. This paper presents the results of a field study conducted across Punjab, Pakistan to evaluate the socio-economic and climate impact of photovoltaic-driven high-efficiency irrigation systems (HEIS), that is, drip and sprinkle irrigation systems. Farmers' dependence on fossil fuels for the operation of irrigation systems has increased rapidly, resulting in higher costs of agricultural production. The results of this study show that the

installation of PV systems has increased the adoption of high-efficiency irrigation systems, reducing the high operating costs of older diesel-driven pumping systems (with annual savings of 6.6). Million liters of diesel), a 100% increase in farmers' income, 17,622 tones of CO_2 emissions reduction per year, and 41% water savings. The unit cost of the PV-powered HEIS was found to be 0.1219 USD/kWh**,** which was 4% and 66% lower than the subsidized electricity cost and diesel cost, respectively. *Raza, Fakhar and Tamur, Muhammad and Meeran, Sajjad and Amjad, Waseem and Hussain, Muhammad and Lee, Gwi-Hyun. (2022). Socio-Economic Impact of Using Photovoltaic (PV) Energy for High-Efficiency Irrigation Systems: A Case Study. Energy. 15. 1-21. 10.3390/en15031198.*

4. The results showed that the use of SBIS is recent (4.5 years), mainly through (77%) donor-funded projects constructed mainly for domestic water use and livestock (88%). In terms of irrigation, vegetable production was the major water use (60%) enabling rural farm households to generate more than 40% additional household income during the dry season. The results further showed that 4,274 km2 (22%) of the total land area for the Bogouni district and 1,722 km2 (18%) of the Kautilala district are suitable for solar-based irrigation. The affordability of solar panels in many locations makes SBIS an emerging climate-smart technology for the largely rural Malian population. *Zemadim, Birhanu & Sanogo, Karamoko & Traore, Souleymane S. & Minh, Thai & Kiziito, Fred. (2023). Solar-Based Irrigation Systems as a Game Changer for Improving Agricultural Practices in Sub-Saharan Africa: A Case Study from Mali. Frontiers in Sustainable Food Systems. 7 - 2023. 10.3389/fsufs.2023.1085335***.**

5. Solar power pumps are one of the viable options. From rural electrification and collective water sources to irrigation and livestock water supply, they have been implemented in many remote areas. It is renewable because it does not emit carbon dioxide, is non-messy runs low, and is available for sustainable economic development with conservation costs. *Neetu Sharma 1st, Dr. Oum Kumari R 2nd, Research Scholar of 1st, Assistant Professor 2nd Department of Economics Manipal University Jaipur, Jaipur Rajasthan, India. 2020 JETIR December 2020, Volume 7, Issue 12.*

6. Socio-economic Impact of a Solar Water Pumping System in a Rural Community in Indonesia. Journal of Sustainable Development of Energy, Water and Environment Systems. *Sita Rahmani*1, Takehiko Murayama2, Shigeo Nishikizawa3.2022.*

7. Decentralized renewable energy projects, such as solar photovoltaic water pumping, have been deployed to provide water in rural areas with strong local community participation. The results showed that the ability of the local management team and satisfaction with saving money were considered the most significant outcomes. However, the economic benefit of economic savings did not translate into welfare improvements. These findings provide insights that show that (1) rural community members gain knowledge about renewable energy technologies through project deployment and (2) building support mechanisms with project deployment is critical to achieving greater development opportunities in the context of rural poverty alleviation.

8. This study was conducted to find out the socioeconomic and environmental impact of solar-powered automatic drip irrigation systems on drip owners in the Faisalabad division. The study found that most solar drip owners agreed to change their social status and self-reliance by 39.58% and 72.92% respectively. 79.17% of farmers improve the quality of their produce by using a solar drip system. *Tamur, Muhammad and Zakaullah, Paris and Mobeen, Mehwish and Zaka, Muhammad. (2021). Solar Powered Automated Irrigation Systems in Rural Areas and their Socio-Economic and Environmental Impacts. 10. 17-28. 10.18488/journal.13.2021.101.17.28.*

9. found that SIF (Solar irrigation facilities) adoption significantly increased ROI (return on investment) by 20% to 30% and reduced irrigation costs by 21% to 30%. *(Farooq As Sunny. 2023)*

10. Before installing the solar system, the area of gram, sesame, and pearl was only 19.5 ha, while the limited area of wheat, mustard, and chickpea was 5.0 ha due to rainfall. The effect on yield of the gram, sesame, and pearl millet increased by 39 to 92% and wheat, mustard, and chickpea by 10 to 108% respectively compared to a pre-solar irrigation system. The net income from crops was only Rs. 6165/year/family before irrigation intervention, while it was Rs. 32,440/year/household improved crop intensity and productivity. The total net income of 62 families in the group was Rs. 3,82,265/year before the intervention and after the establishment of the system, it was increased to Rs. 20,11,329/year from crops. Similarly, the total benefit-cost ratio of crops was 1.8 before establishment and 2.9 after establishment, cropping intensity was also increased from 101 to 205% respectively. The system also generated 2248 man-days/year of employment, compared to 1161 man-days/year from crops before the installation of solar irrigation

systems that reduced migration to nearby towns. *ICAR-AICRP-Irrigation Water Management, Moren, Madhya Pradesh.*

11. The findings of the study show that PV pumping systems have lower total cost and energy consumption compared to diesel pumping systems despite higher initial investment. (*Raut, B. R., Nakarmi, A. M., & Singh, S. (2017).*

12. The capacity of the local management team and satisfaction in saving money were perceived as the most significant impacts of solar water pumping in Indonesia. *Rahmani, S., Murayama, T., & Nishikizawa, S. (2022). Socio-economic impact of a solar water pumping system in a rural community in Indonesia. Journal of Sustainable Development of Energy, Water and Environment Systems, 10(3), 1-18.*

13. The installation of PV systems has resulted in the increased adoption of high-efficiency irrigation systems. *Raza, F., Tamoor, M., Miran, S., Arif, W., Kiren, T., Amjad, W., ... & Lee, G. H. (2022). The socio-economic impact of using Photovoltaic (PV) energy for high-efficiency irrigation systems: A case study. Energies, 15(3), 1198.*

14. The installation of PV systems has resulted in the increased adoption of high-efficiency irrigation systems. A reduction in the high operational costs incurred on account of old diesel-powered pumping systems (with an annual saving of 6.6 million liters of diesel), a 100% increase in farmer's income, a reduction of 17,622 tons of CO_2 emissions per annum, and 41% savings in water. The unit cost of PV-powered HEIS was found to be 0.1219 USD/kWh, which was 4% and 66% less than the subsidized electricity cost and diesel cost, respectively. *Raza, F., Tamoor, M., Miran, S., Arif, W., Kiren, T., Amjad, W., ... & Lee, G. H. (2022). The socio-economic impact of using Photovoltaic (PV) energy for high-efficiency irrigation systems: A case study. Energies, 15(3), 1198.*

15. Day to day rise in the cost of operating diesel pumps as well as an insufficient and irregular supply of electricity for electric pumps leads the end user to shift from traditional ways of supplying water to solar water pumping systems for irrigation. The use of similar farming patterns will increase the demand for solar-based pumping systems in other tribal regions of India. *More, A., Bhalerao, S., & Auti, K. (2019). Solar Based Irrigation System for Tribal Belt of India. Techno-Societal 2018.*

Chapter 3: Methodology

3.1 Key research questions:

1. What is the impact of solar-based irrigation systems on farm productivity, crop diversity, crop yield, and farm income compared to conventional irrigation methods?
2. How effective are solar-based irrigation systems for farmer empowerment (group decision-making) and farmer mobilization (group formation, its management)?
3. What are the potential benefits and challenges of solar-based photovoltaic (PV) pumps?

3.2 research design

Descriptive research was conducted using qualitative and quantitative methods. A descriptive cross-sectional study was conducted using a post-test-only design to measure potential factors. Both primary and secondary data were collected for research purposes. The primary research was conducted in two block villages of Dang district, Ahwa and Subir. Primary data has been collected through a questionnaire survey, a meeting with the farmer of the solar group, and a personal interview with him. Solar group members were the main target for whom this study was conducted. Secondary data was collected from the organization's annual report, baseline data other research journals, and official government websites.

3.3 study setting

This study explores the socio-economic outcomes of farmers adopting solar-based irrigation in two taluks, Ahwa and Subir, of the Dang district. The diverse agricultural landscape and hilly terrain of this district in the southeastern part of the state of Gujarat provide a unique backdrop for the use of renewable energy (solar-based irrigation systems). Dang district is a hilly remote area with 94% tribal population and 73.84% of people belong to the BPL category. Agriculture, the mainstay of the economy, is done using traditional irrigation methods on rainwater. Erratic rainfall and water scarcity during critical periods pose significant challenges. The use of diesel pumps is common but economically and environmentally unsustainable. Generally, four months of agriculture and 6-8 months of migration are seen in this area.

3.4 Study population:

- Inclusion criteria: The study covers farmers and agricultural stakeholders in Dang district who have adopted solar-based irrigation systems. Inclusion criteria are defined based on active participation in agricultural practices and the use of solar energy irrigation technology.

- Exclusion Criteria: Individuals or communities not actively involved in agriculture or not adopting solar-based irrigation systems will be excluded from the study. This exclusion criterion ensures focused analysis on specific populations directly affected by the intervention.

3.5 Duration of study: 15th March 2024 to 16 Jun 2024 (3 months)

3.6 sample size: 30% of the total 74 solar based irrigation pump user groups i.e. 21 solar

based irrigation pump user groups and 3,4 from each group actively participating and adopting solar based irrigation system were considered as a sample of 63 farmers.

3.7 Sampling technique: A study would use of the technique of Simple Random

Sample in research.

3.8 Data collection procedure: Data were collected by conducting surveys and

interviews using structured questionnaires. In selected areas, meeting with solar group farmers, in-depth interviews, and observations provided qualitative insights into the local context.

3.9 Study instruments:

The survey was conducted using a structured questionnaire which consisted of both quantitative and qualitative questions. The survey was mainly done using Cobo tools.

3.10 Operational definition:

Solar-based irrigation system: A solar-based irrigation system is a sustainable method of using the power of the sun to irrigate crops. It uses photovoltaic (PV) solar panels to convert sunlight into electricity. Using this electricity, an electric motor pump then draws water from a source such as a well or reservoir and distributes it to agricultural fields through pipes and sprinklers (or other irrigation methods).

Migration: Migration is the movement of people from one place to another, permanently or temporarily, intending to settle in a new place. Ahwa and Subir talukas of Dang district witness seasonal migration of people. Seasonal migration is the temporary movement of people between two or more locations based on seasonal variations. This type of migration is often cyclical, with people returning to their place of origin after a certain period.

Farmer empowerment: Farmer empowerment is a process that allows farmers to make independent decisions and take action to improve their lives. It involves participation and leadership and is a lifelong learning activity. It includes farmer specialty women's, widows' decision-making ability, and active participation in the group.

Farmer integration: Farmer integration refers to the process by which individual farmers or farm organizations combine their resources, efforts, and operations to achieve common goals and increase overall efficiency and productivity. Here integration means group/cooperative organization and partnership and its proper management integrated leaves to face common challenges, optimize the use of resources, and maximize profits.

3.11 Ethical considerations:

Ethical approval and consent were obtained from the "AKRSPI" organization to use their confidential data for research without compromising their privacy and confidentiality. Also, during the survey, the informants explained the purpose of the research and other information and after getting their consent the survey was conducted.

Chapter 4: Results

The Planning Commission (2003) ranks Dang as the most backward district among the 447 districts of India. Dang is a tribal district with 13 different tribes living here. Along with the Bhil Konkani, the Kotwalia Kathodi and Kocha tribal tribes belong to the PVTG group. Dang receives an average annual rainfall of 2491 mm (annual rainfall from 1991 to 2012). Agriculture has been the lifeline of the Dang district for decades. However, agriculture is practiced here based on a traditional rain-fed irrigation system. The main sources of irrigation are wells and group wells, suction irrigation, pump sets, and only 6% runoff irrigation. Dependence on diesel/electricity for irrigation and challenges like low income, water scarcity, and hence migration. Every year around 30,000 people migrate to places like Surat, Maharashtra after September and October for employment in sugarcane cutting and vineyards.

However, since 2010 AKRSPI has been working in the Dang district of Gujarat. Solar-powered irrigation pumps were installed under various projects to stop large-scale migration here and develop agriculture-based livelihoods. AKRSPI has commissioned a total of 78 solar-based irrigation projects in four states of Gujarat, Maharashtra, Bihar, and Madhya Pradesh by 2022, benefiting 826 farmers and bringing 731 hectares of land under irrigation. These initiatives use solar energy for irrigation systems, reduce dependence on fossil fuels, and promote sustainable water management in agriculture. Through these initiatives, AKRSP(I) has enabled farmers to increase their productivity and make effective use of water resources by reducing operational costs.

In the background of the Dang district, solar-based irrigation pumps were also installed in Ahwa and Subir talukas under various projects. The main objective of this was to promote agriculture-based livelihoods by reducing migration. Migration, farmer empowerment (group decision making), farmer integration (group formation, its management), crop diversity, farm productivity, crop yield and farm income, and solar-based irrigation to conduct a social study on the socio-economic impact of solar-based irrigation pumps on pigs. The parameter was taken as the economic feasibility of the pumps. Based on these parameters the entire analysis process of this research has been done and here are the parameters.

Age group-wise respondent distribution:

A graphical representation of the survey results is given below: -

The graph above displays the respondent data by age group, who actively participated in the survey for the research study. Here the X-axis represents the age group of the respondents (20-29, 30-39, 40-49, 50-50, and 60+) and the Y-axis represents the percentage (number) of the respondents in each age group.

The data indicates that out of 63 responses, most of the respondents fall into the younger age group (40-49 and 50-59 years old), collectively at 50.8%. Also, the (30-39) age group is significantly under-represented at 17.5% i.e. 11, the (60-69) age group at 12.7% i.e. 8, and the (20-29) age group at 3.2% i.e. 2.

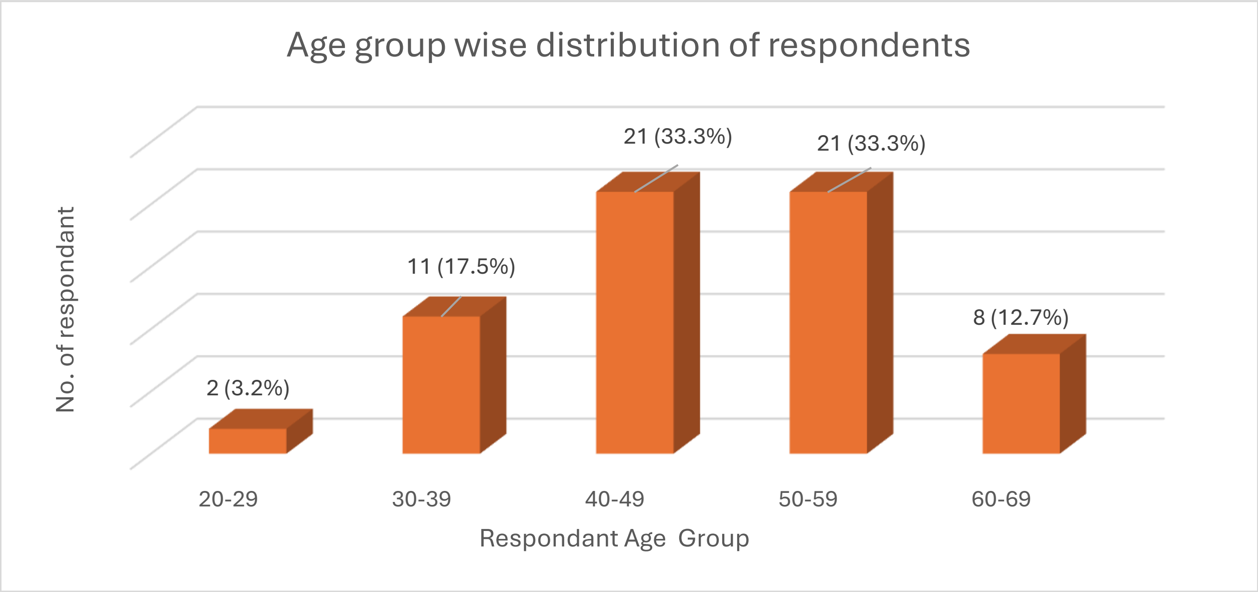


FIG. 4.1 AGE GROUP DISTRIBUTION OF RESPONDENTS

- House types:

The above bar graph shows the type of household of the respondent and its distribution. This helps us to understand the situation in that area. There are a total of 63 respondents out of which 58.7% people i.e. 37 people live in kacha (mud) houses. While below that 34.9% i.e. 22 respondents have "pakka " houses built with brick cement or concrete. The remaining 6.3%, I.e. 4 respondents, said semi-kachha houses are constructed using both raw and reinforced materials. This distribution clearly shows that a large part of the population lives in kachha houses that are built using stone and mud.

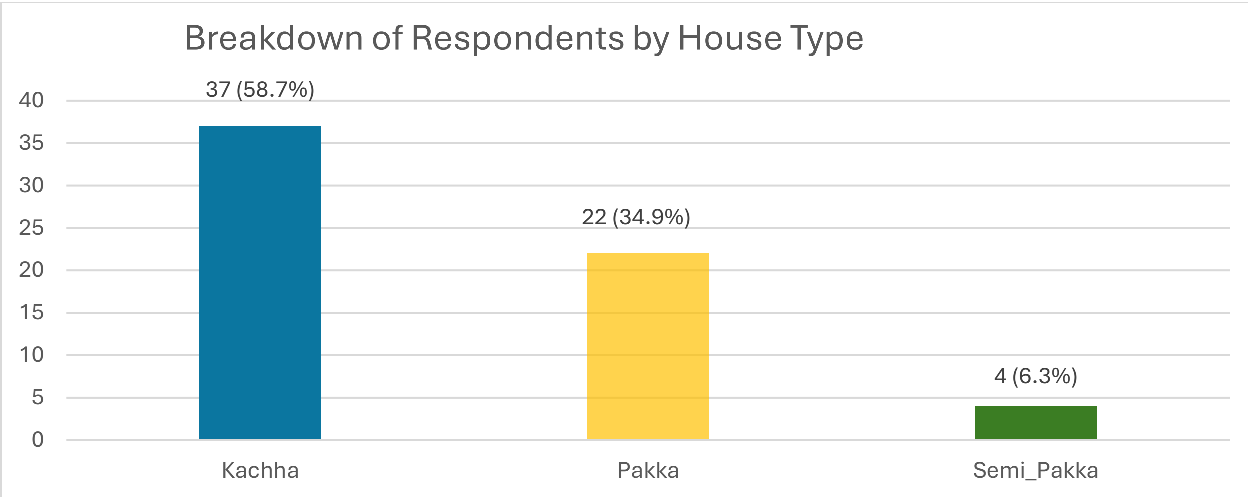


FIG. 4.2 RESPONDENT BY HOUSE TYPES

- Poverty status:

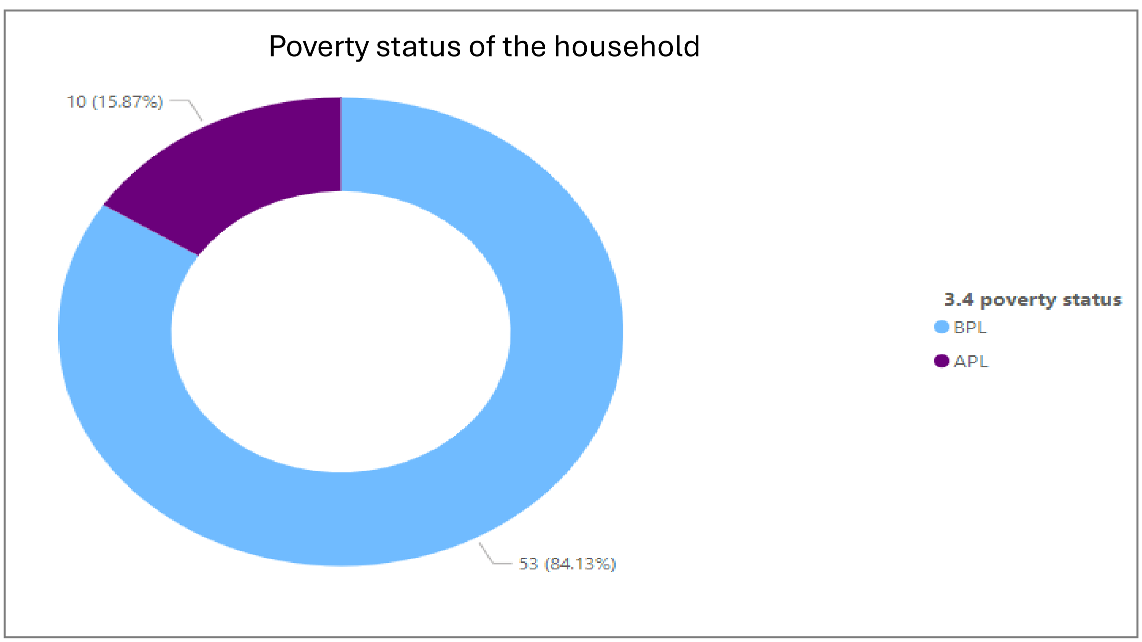


FIG. 4.3 POVERTY STATUS BY RESPONDENT

The above graph analyzes the poverty status of the 63 respondents. The graph showing the below-poverty line (BPL) and above-poverty line (APL) categories is divided into two sections. Out of the total respondents, 53 persons, or 84.13% fall under the BPL category. This indicates that a significant portion of the surveyed population is living below the poverty line, suggesting economic challenges and the need for targeted interventions to improve their living conditions.

The remaining 10 respondents, totaling 15.87%, are categorized as APL. This small segment represents the people above the poverty line, which shows relatively better financial stability compared to the BPL group.

- ## Cast group of households:

Dang district is a tribal district, and many primitive caste tribes live here. This graph shows the caste-wise classification of responses. Out of the total 63 responses surveyed, 68% participation is from the Bhil community. 26% Konkani while other Kunbi and Warli are 4% and 2% each. Among them, Bhil, Warli, and Konkani belong to the particular-vulnerable tribe group (PVTG).

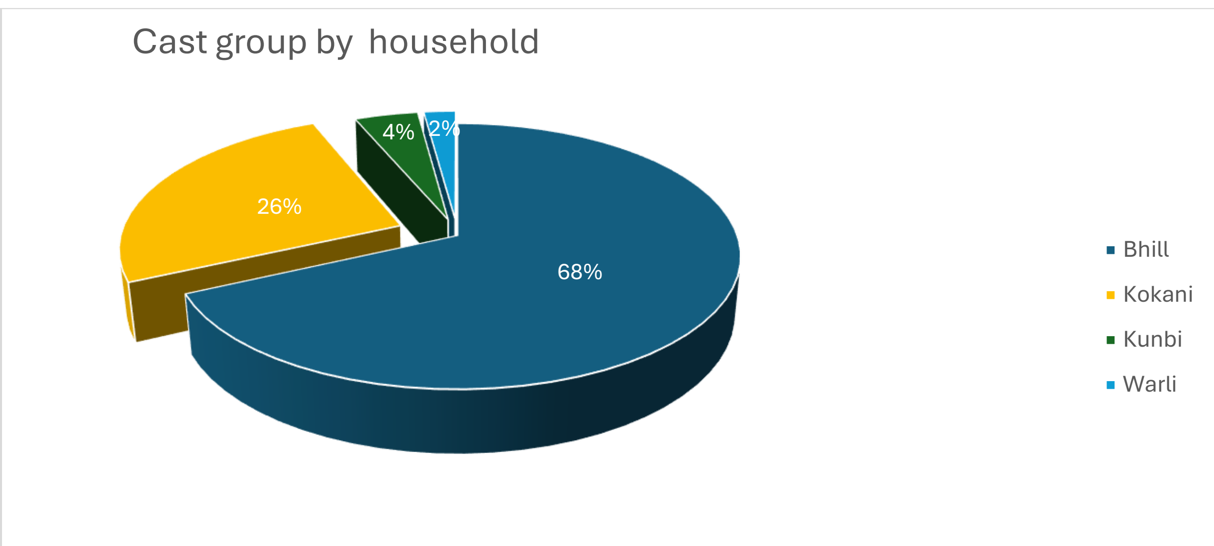


FIG 4.4 CAST GROUP BY HOUSEHOLD

- Gender of solar pump user group

The pie graph above shows the gender distribution of solar user group members. Out of the total of 63 solar user group members, 19 i.e. 30.16% are male. Whereas a large part of the population (44 persons) represents 69.84% female participation. Which is important in terms of advancing and empowering women.

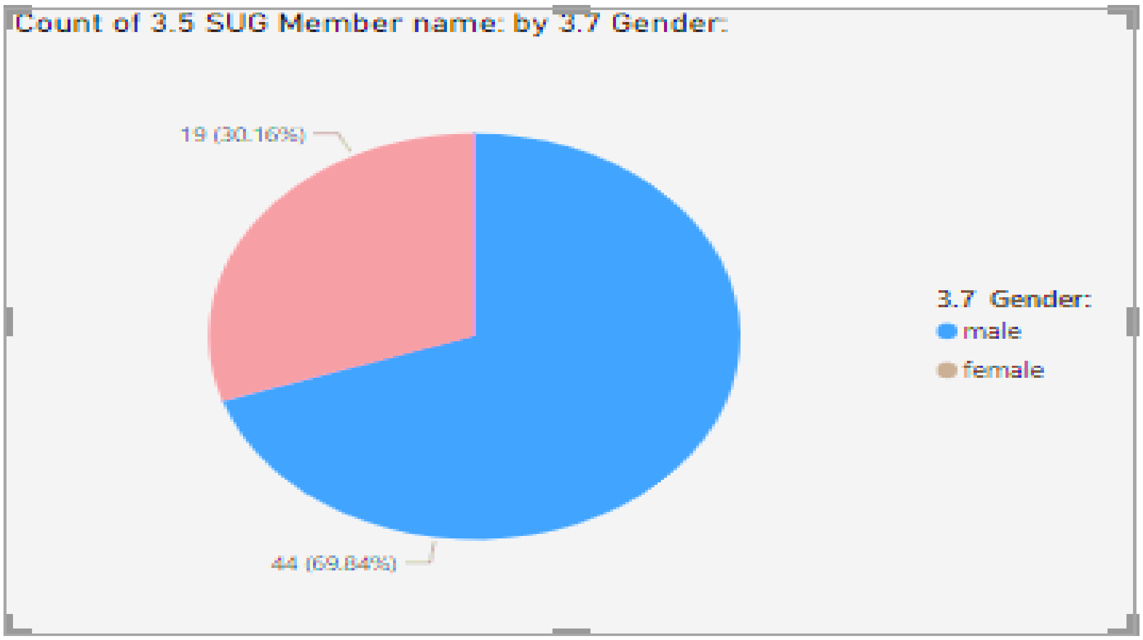


FIG. 4.5 GENDER BY SOLAR USER GROUP MEMBER

- Marital status of SUG member:

The above doughnut graph shows the marital status of solar user group members. It shows that out of a total of 63 solar user group members, 84% i.e. 53 people are married. The remaining 16%, i.e. 10 persons reported being widowed. Importantly, 16% are widowed women who are represented in Solar Group.

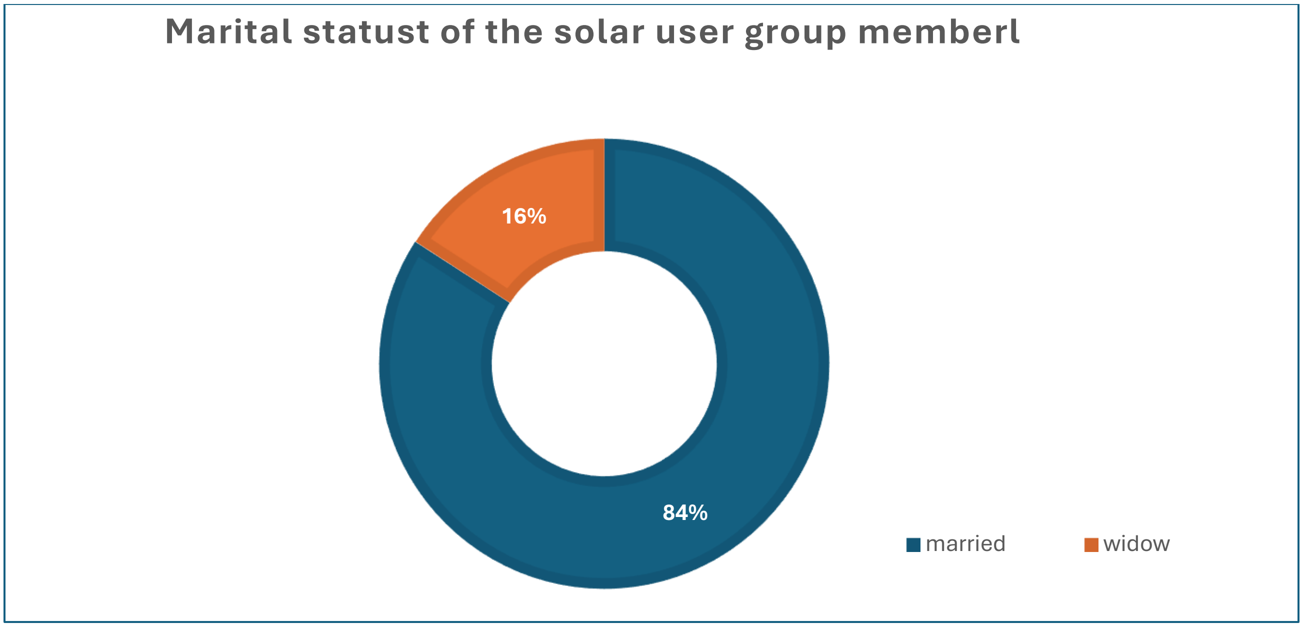


FIG. 4.6 MARITAL STATUS OF SUG MEMBER

- Challenges before intervention.

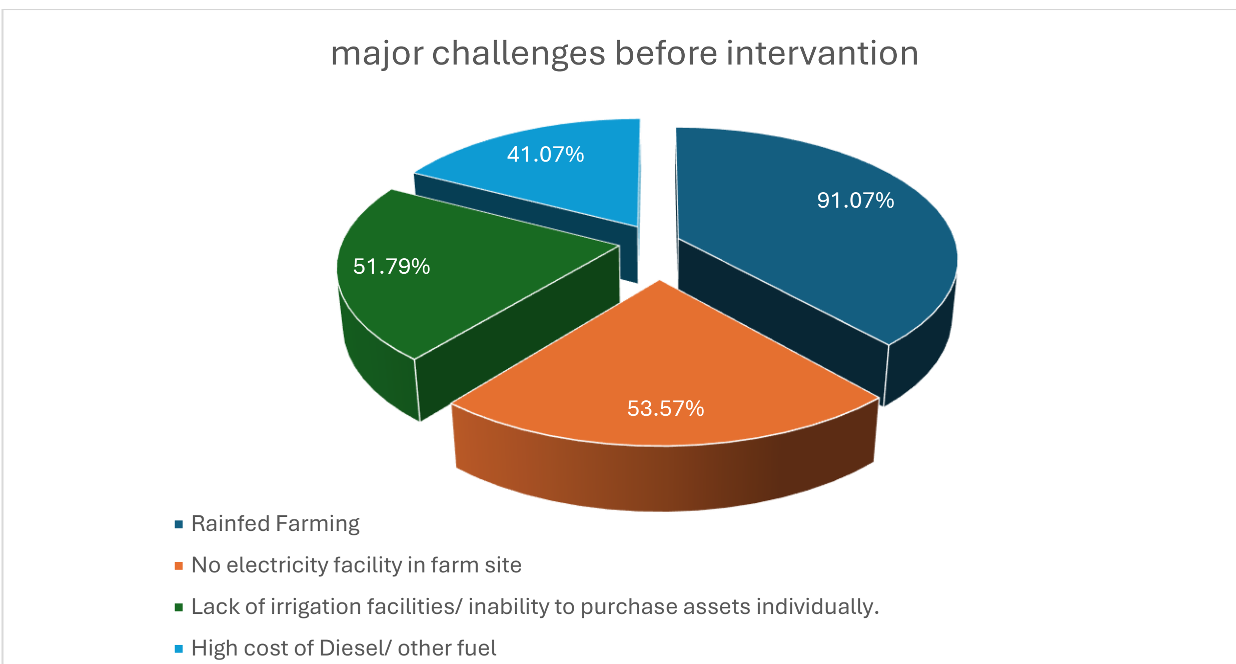


FIG. 4.7 MAJOR CHALLENGES BEFORE INTERVENTION

The above pie graph shows the challenges facing agriculture in Dang district. Rainfed Agriculture (91.07%). There is no electricity capacity on farmland (51.79%). Lack of irrigation facilities/ inability to purchase property individually (53.57%). There is no electricity capacity on farmland (51.79%). Major Challenges to Intervention (41.07%). The total value is more than 100% due to the high cost of diesel/other fuel (24%).

Where respondents are allowed to select more than one challenge. The above challenges indicate that agriculture here is mainly dependent on rainwater, and farming during the Rabbi season faces another challenge.

- Land pattern:

The bar graph shown provides an insight into the land distribution and utilization of farmers. Three distinct classes are shown in the graph including average total land owned, average total land under agricultural activity, and average total land under irrigation after implementation of solar interventions. On average, farmers own a total of 4.58 acres of land including fallow land and agricultural land. Out of this total, an average of about 2.35 acres of land is used for agriculture, which is rain-fed. Whereas the green bar highlights that an average of 1.09 acres of land was brought under irrigation after the solar pump intervention. Even if the area under irrigation is less, it is beneficial for sustainable development in the future.

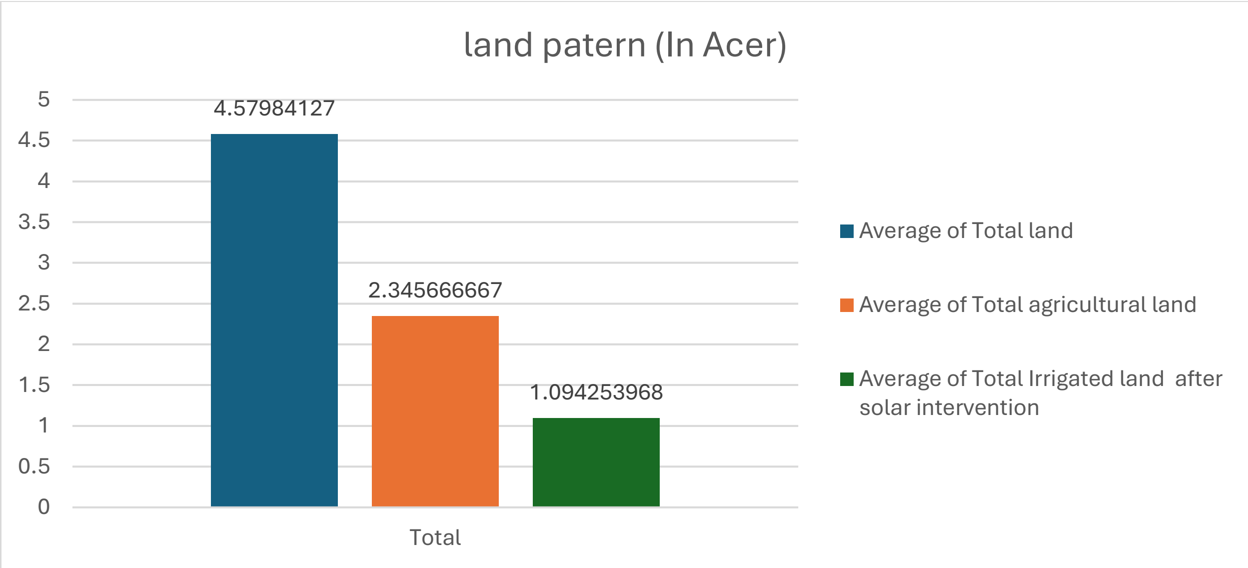
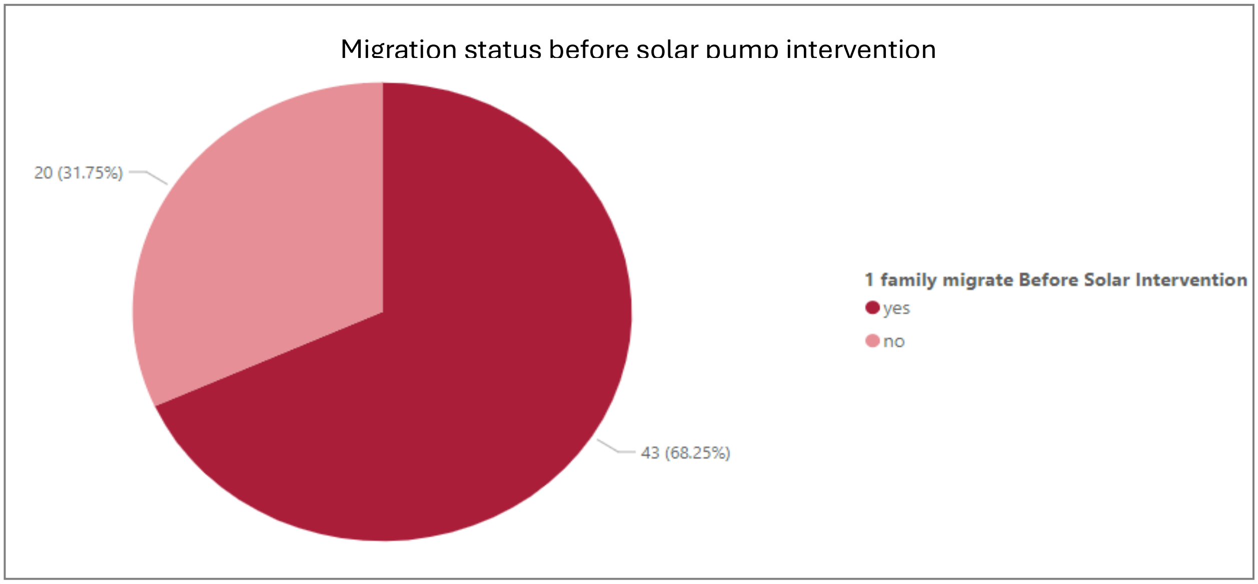


FIG. 4.8 LAND PATTERN

- Social impact: 1. Migration

The above pie graph shows the "migration status before solar pump intervention". It shows that before solar pump intervention, a significant majority of 68.25% of households (43) had to migrate for livelihood after 4 months of monsoon. On the other hand, 31.75% (20) of households reported not migrating. This graph shows that the families in this area are migrating in large numbers.



- Migration status after solar pump intervention

A pie chart titled "Migration status after solar pump intervention" illustrates the impact of solar pumps on household migration. A total of 63 families were surveyed. The graph above shows that a significant majority, 81% of households (51) reported not migrating. While the remaining 919% (12 families) appear to be still migrating. The data after the solar pump intervention and the pre-intervention data show a significant change. The availability of sustainable means of irrigation (solar irrigation pumps) after the intervention allowed families to switch to agriculture and helped reduce migration.

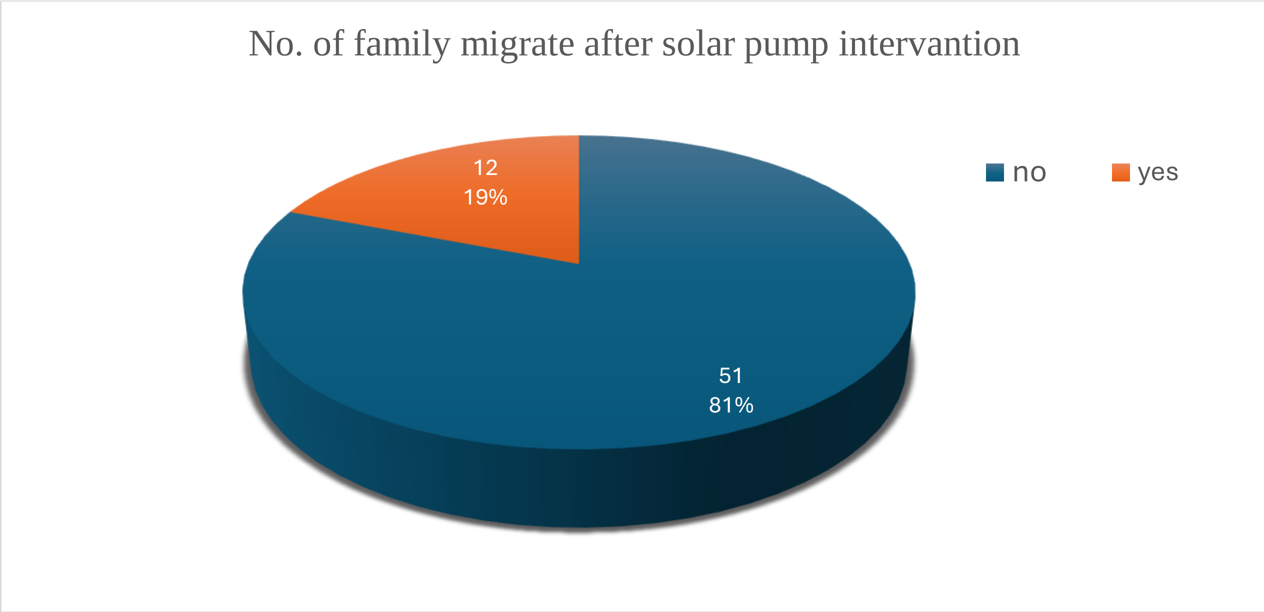


FIG 4.10 MIGRATION STATUS AFTER SOLAR PUMP INTERVENTION

2. Empowerment

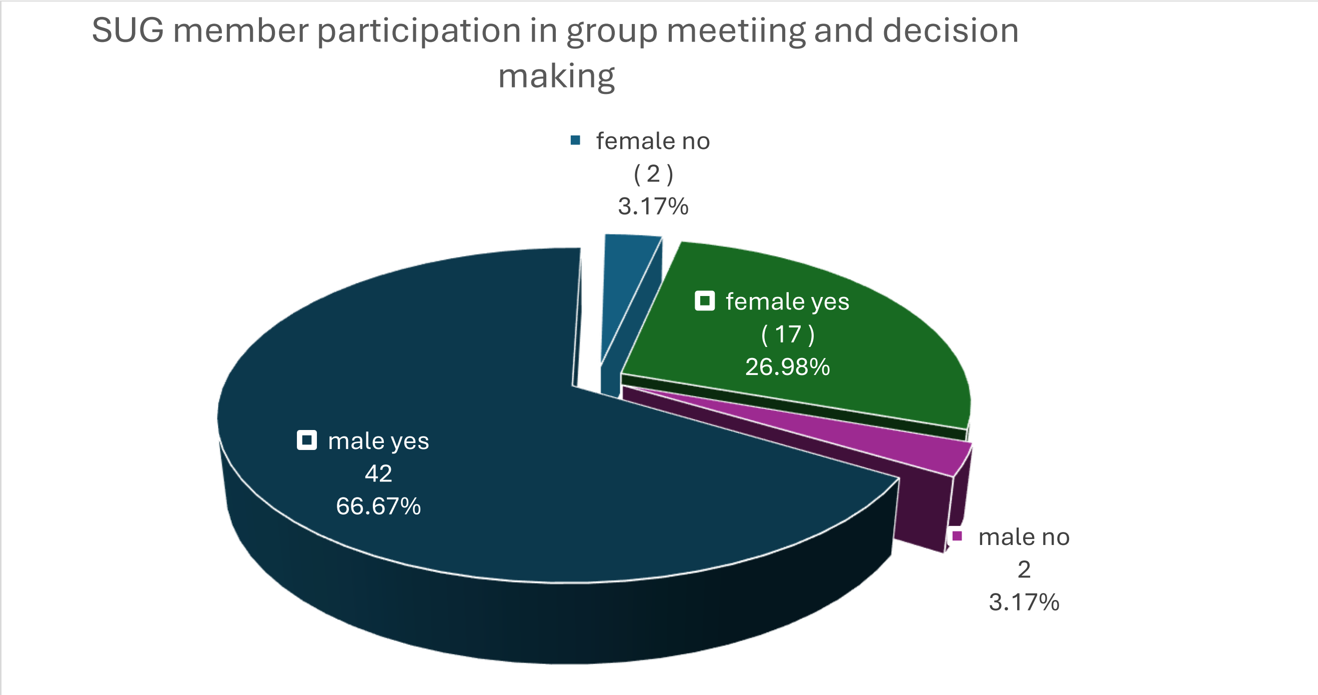


FIG 4.11 EMPOWERMENT (PARTICIPATION IN GROUP MEETING AND DECISION MAKING)

The pie graph above depicts the participation of members of a solar pump user group in group meetings and decision-making processes. The graph breaks down the data by gender. The larger portion of the graph 66.67 (42) represents the male who participates in group meetings and decision-making. While the smaller portion 26.98 (17) represents women participating in group meetings and decision-making processes. The remaining two equal parts 3.17% each, did not participate in the group meetings and decision-making process.

- Marital status and gender-wise participation

A pie chart shows marital status and gender-wise participation in group meetings and decision-making. The data revealed that most of the participants were married men, with a total of 66.66% (42 individuals). Female widows constitute 15.87% (10 persons), followed by married women at 11.12% (7 persons). This distribution shows a significant dominance of married men in group meetings and decision-making processes, while also indicating the inclusion of widows, a marginalized section of the community. Who represents a very small percentage of the group, 3.17%, who are women and do not participate in group meetings and decision-making.

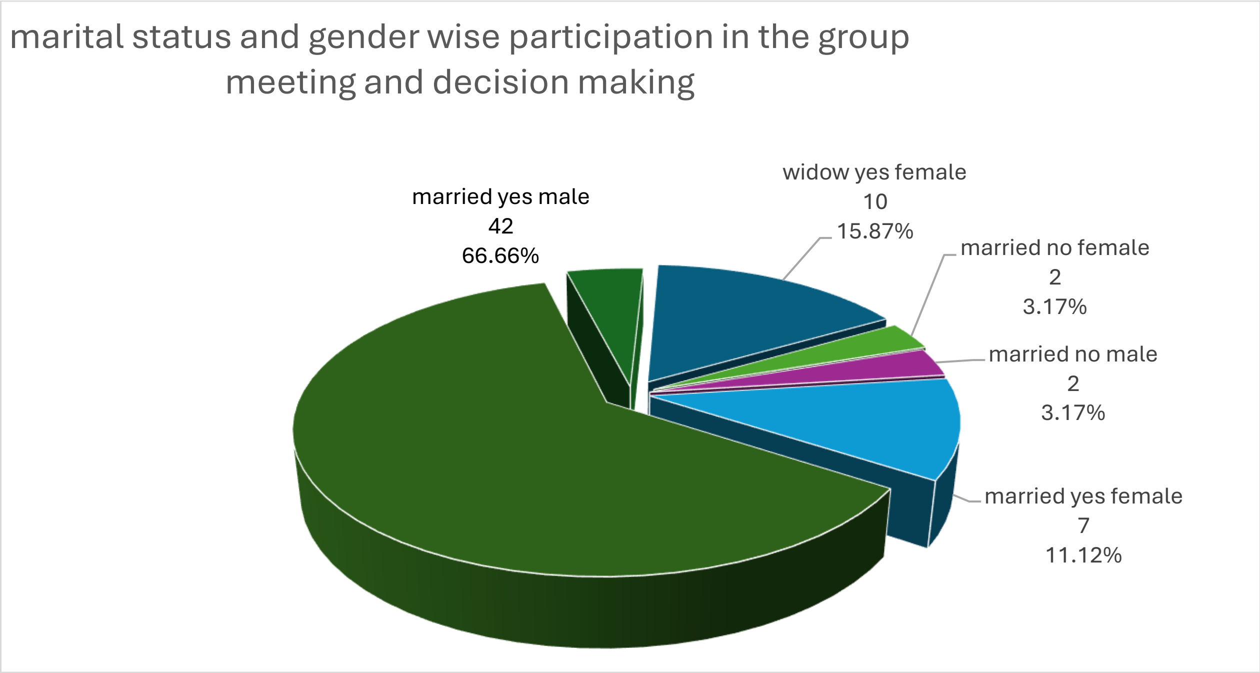


FIG 4.12 MARITAL STATUS AND GENDER-WISE PARTICIPATION IN GROUP MEETINGS AND DECISION MAKING

3. Group management: bank account status of SUG

A bar chart displays the bank account status of a solar pump user group. According to the table, 13 solar user groups are showing bank accounts while 8 solar pump user groups are said not to have bank accounts. This indicates that most solar pump user groups (61.90%) are connected to the bank. Which can facilitate better financial management and access to financial services.

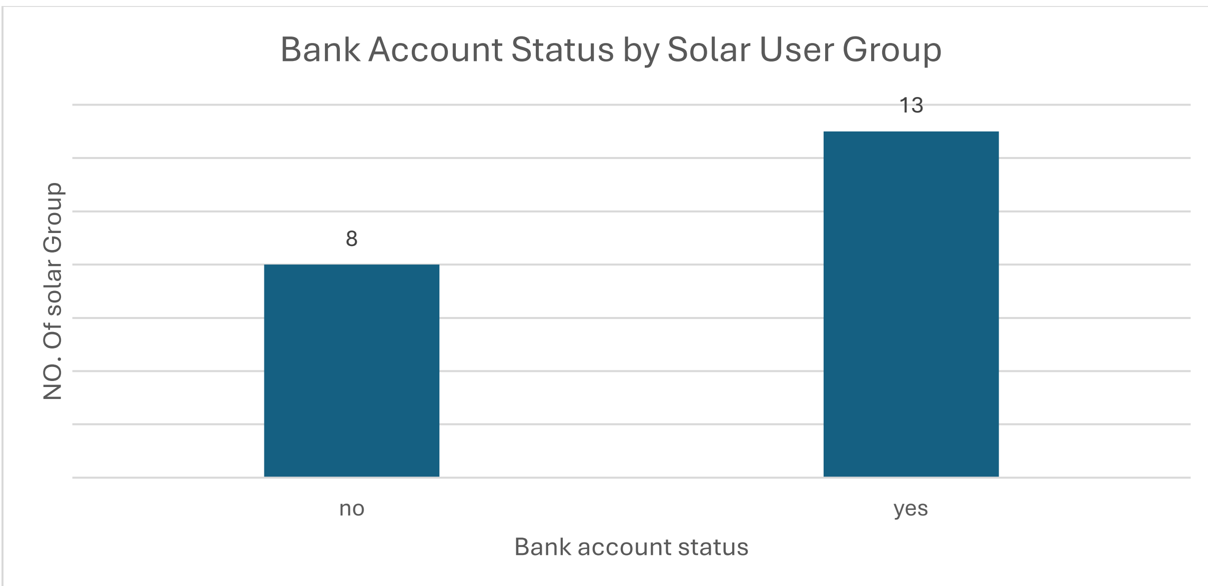


FIG. 4.13 BANK ACCOUNT STATUS BY SOLAR USER GROUP

- SUG meeting status

The bar graph above shows the status of regular meetings of the Solar Pump User Group. As shown, there are a total of 21 solar pump user groups out of which 19 groups have regular meetings every month, which is 90.47% of the total. There are 2 groups which do not have regular meetings. Regular group meetings are necessary for transparency and planning, which helps the group to survive.

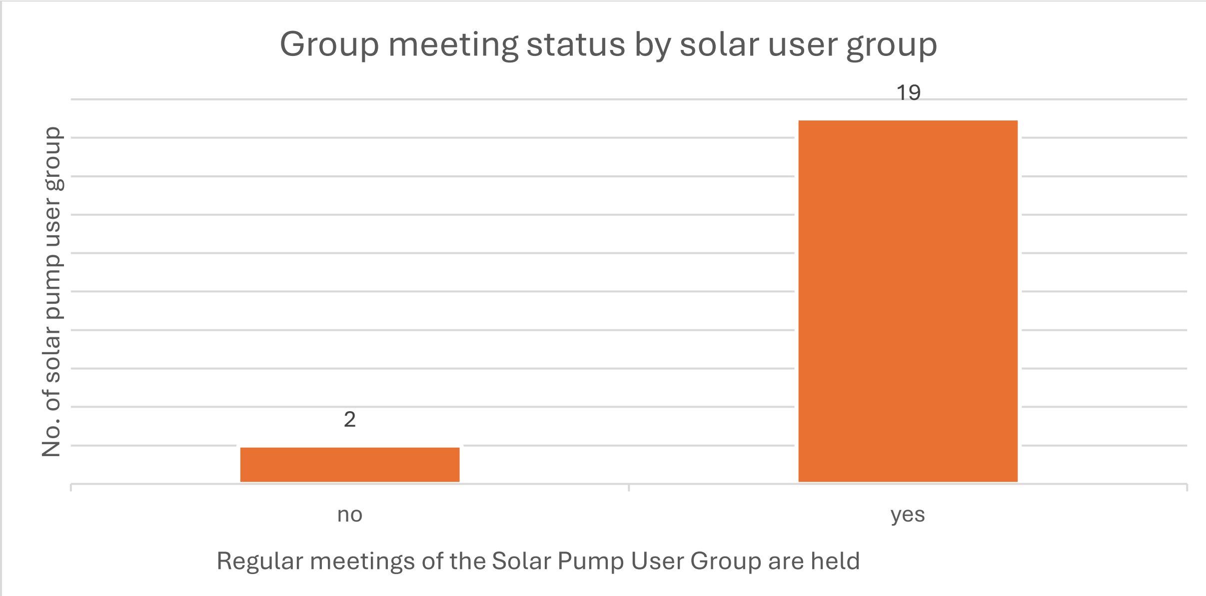


FIG. 4.14 GROUP MEETING STATUS BY SOLAR USER GROUP

- Water tariff charge

A bar chart displays the status of the Water tariff charge by the solar pump user group. As shown in the graph, there are 16 solar pump user groups that have fixed water tariff charges and collect them regularly. In the remaining 5 solar pump user groups no water tariff charge is fixed so they do not collect any kind of fee from the farmers in the group. So, there is a question mark on how such groups will handle future solar pump maintenance, and other costs, etc.

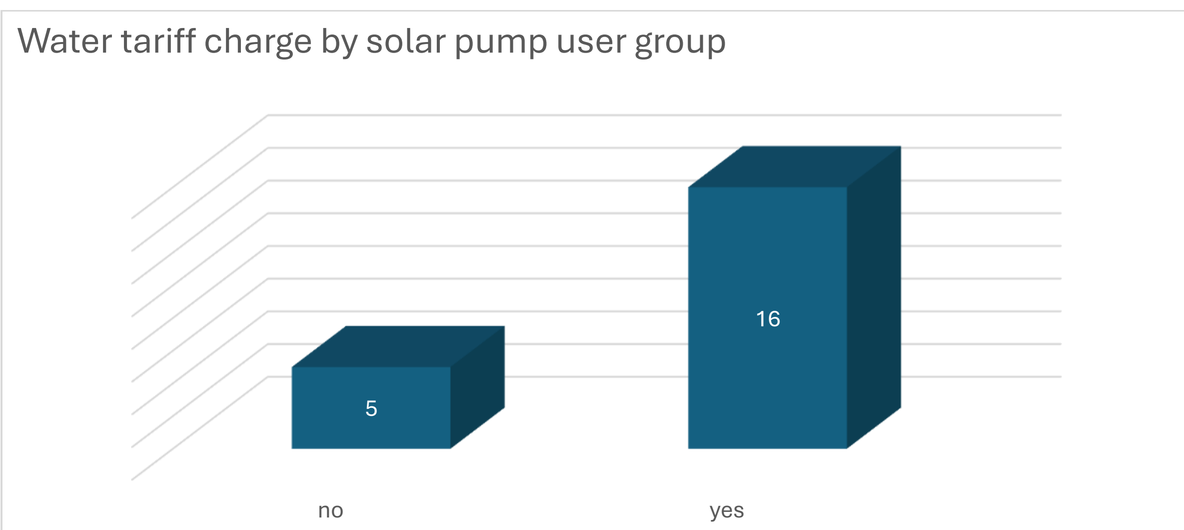


FIG. 4.15 WATER TARIFF CHARGE BY SOLAR PUMP USER GROUP

- Water tariff charge and its amount:

The above bar chart shows the water tariff charge and its amount within and outside the solar pump user group. Accordingly, there are a total of 16 solar pump user groups in which water tariff charge is taken. In these groups, a water tariff charge of Rs.51.01 is levied from agriculture. Among these, 5 groups are such that they also supply water to farmers outside the group and charge an average water tariff charge of 94.73 in return. The average fee charged is credited to the group's bank account to cover future expenses and maintenance of the solar pump.

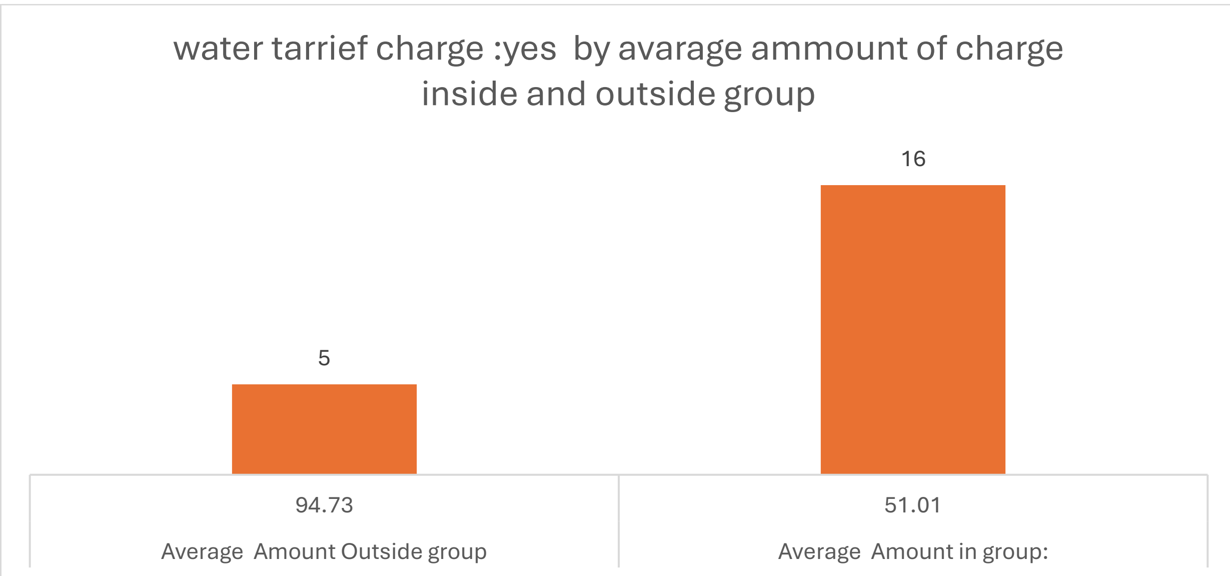


FIG 4.16 WATER TARIFF CHARGE: YES, BY AVERAGE AMOUNT OF CHARGE INSIDE AND OUTSIDE THE GROUP

- Economic indicator: cropping season

The graph above shows the household-wise cropping season before the intervention of the solar irrigation pump. This graph illustrates that all (63) 100% of respondents said that before the intervention of solar irrigation pump, the entire farm was dependent on rainwater (Kharif season) while 20 (31.74%) of these farmers were farming in the Rabbi season also.

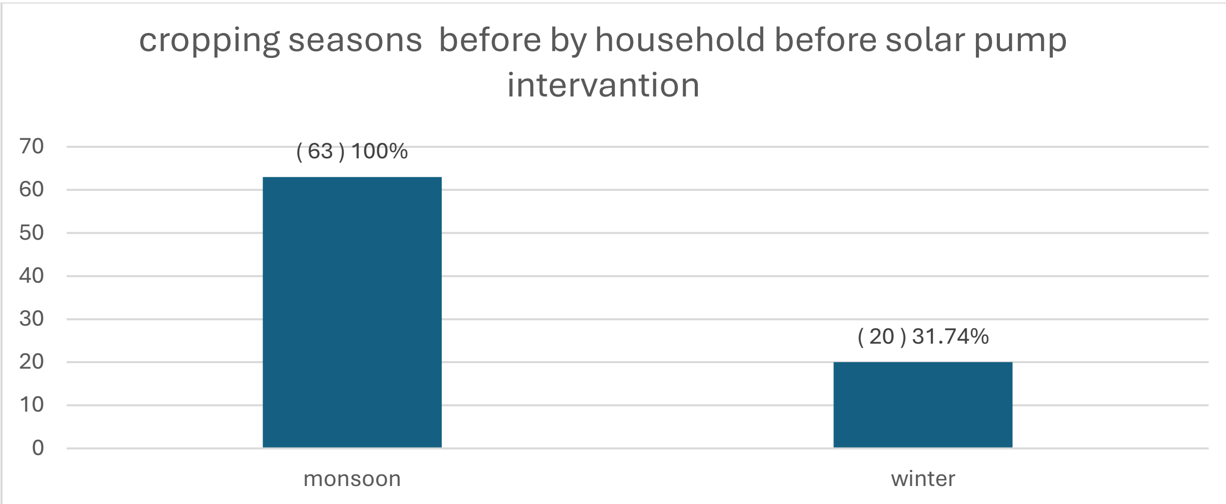


FIG. 4.17 CROPPING SEASONS BEFORE BY HOUSEHOLD BEFORE SOLAR PUMP INTERVENTION

- Cropping season after intervention:

The bar graph above shows the household-wise cropping season after the solar irrigation pump intervention. All (63) 100% of respondents said that the entire farm was dependent on rainwater (Kharif season) before the intervention of the solar irrigation pump. The graph shows that after the intervention of the solar irrigation pump, there is a significant increase in the amount of cultivation in the rabbi and summer season. Among these 54 (85.71%) farmers are also cultivating in the Rabbi season while 12 (19.04%) farmers are cultivating in the summer season. This shows that the number of people migrating after the Kharif season is getting involved in agriculture during the Rabbi and Summer seasons and looking at it as a sustainable livelihood.

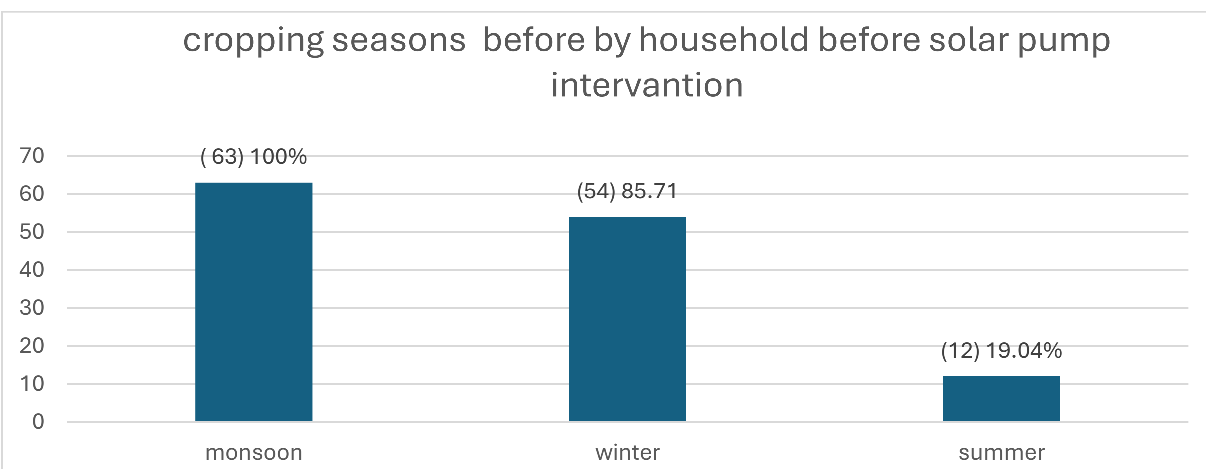


FIG 4.18 CROPPING SEASONS BEFORE BY HOUSEHOLD BEFORE SOLAR PUMP INTERVENTION

- Farming types before solar pump:

The chart titled "Types of Farming Before Solar Pumps" illustrates the distribution of farming practices among households before the implementation of solar pumps. According to the table, most of the households 92.06% (58 households) were engaged in arable farming. In contrast, 7.93% (5 Households) were engaged in vegetable farming. This distribution highlights the community's heavy reliance on arable farming, indicating that before the introduction of solar pumps, very little vegetable farming was practiced due to limited resources, additional costs, and reduced electricity consumption.

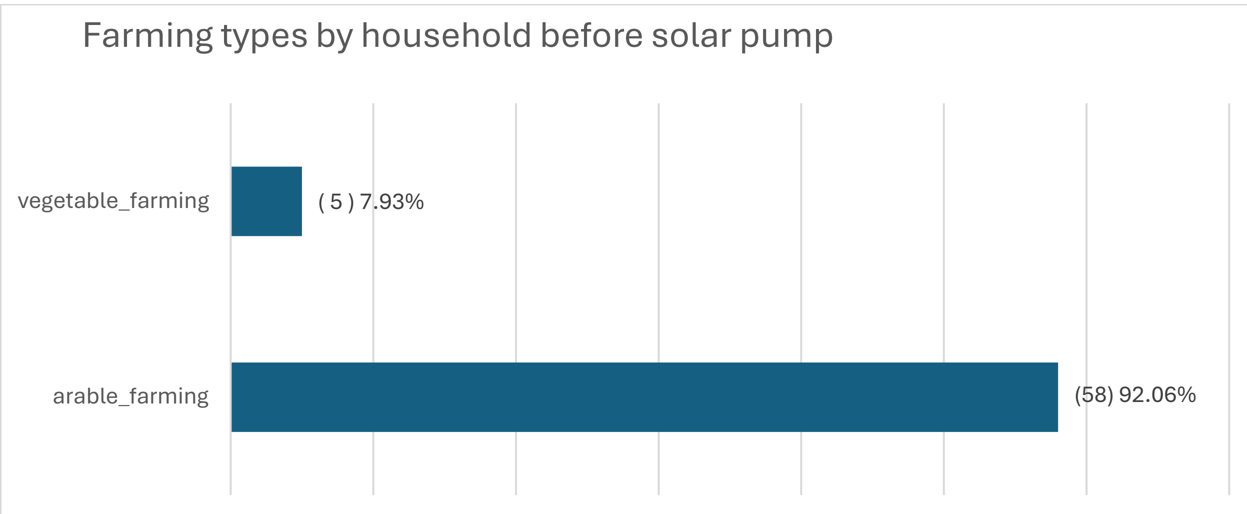


FIG. 4.19 FARMING TYPES BY HOUSEHOLD BEFORE SOLAR PUMP

- Farming types after solar pump intervention:

The above graph shows the type of farming after solar pumps and the changes in farming practices after the intervention of solar pumps. Arable farming remains significant in this; In fact, 63 out of 63 (100%) are engaged in this type of farming. The rest of the vegetable farming and horticulture have seen a significant change after the intervention of solar pumps. Vegetable farming is increasing and now 62 families (92.06%) are engaged in this farming. Also, horticulture is shown to include 26 (41.26%) families. Horticulture mainly includes mango wadi and other fruit trees. These are important in terms of sustainable and diversified agriculture.

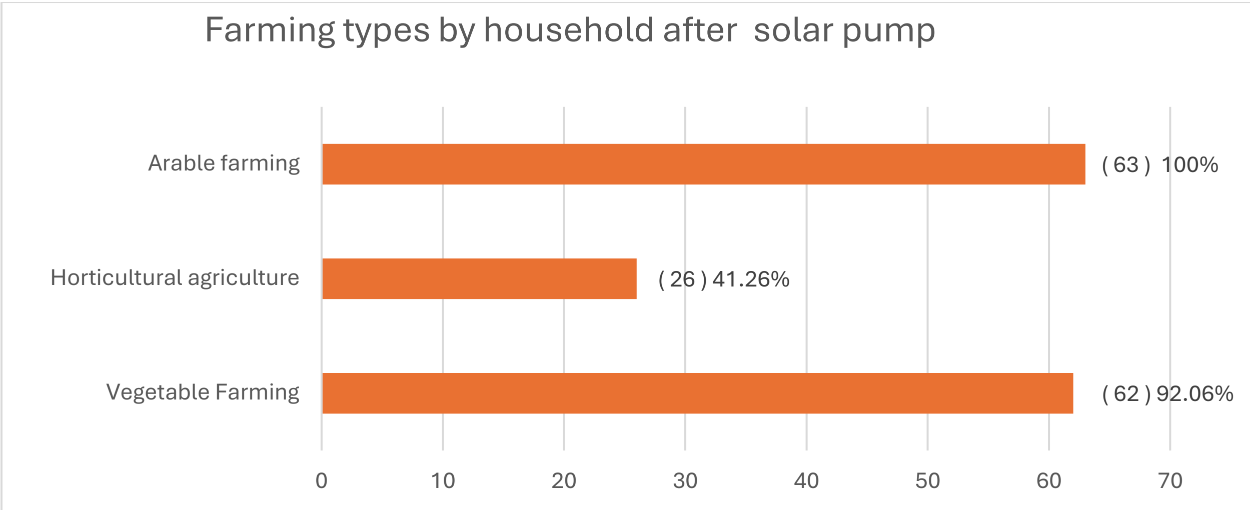


FIG.4.20 FARMING TYPES BY HOUSEHOLD AFTER SOLAR PUMP

- Irrigation tools used before solar pump intervention

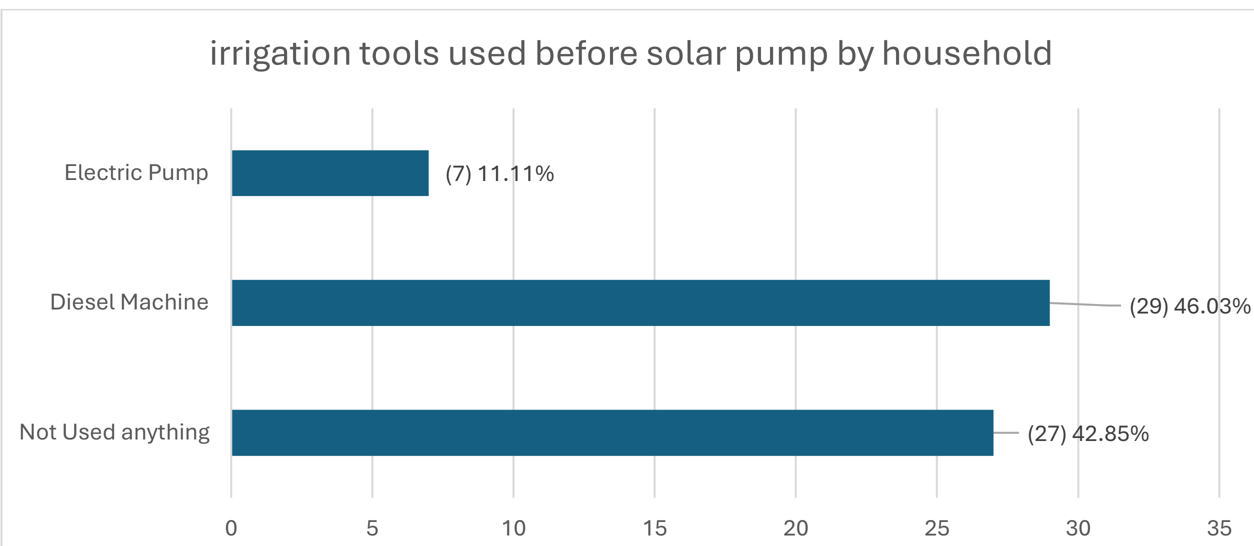


FIG 4.21 IRRIGATION TOOLS USED BEFORE SOLAR PUMP BY HOUSEHOLD

This is a graph showing irrigation equipment used before the intervention of solar pumps. This shows that 46.03% of households, i.e. 29 households, were using diesel machines for irrigation in agriculture before solar pump intervention. However, 42.85% (27 households) of farmers did not use any type of irrigation equipment in their farming i.e. they were farming on full leaf rainwater. The remaining 11.11% or 7 households used electric pumps for irrigation in agriculture. This distribution shows that many farmers depended on diesel machines and many farms had no irrigation equipment. Low utilization of electric pumps is also due to geographical location, cost of electricity, access, and availability. Such findings call for the adoption of other means of irrigation distribution such as solar pumps to improve agricultural productivity and food security in the absence of inadequate irrigation facilities.

- Irrigation tools used after solar pump intervention:

The bar graph above shows the irrigation equipment used by the pigs (family) after the intervention of the solar pump. 92. 06% (58 households) of farmers used solar pumps for irrigation after solar pump intervention while only 7. 93% (5 households) reported still using diesel machines for irrigation.

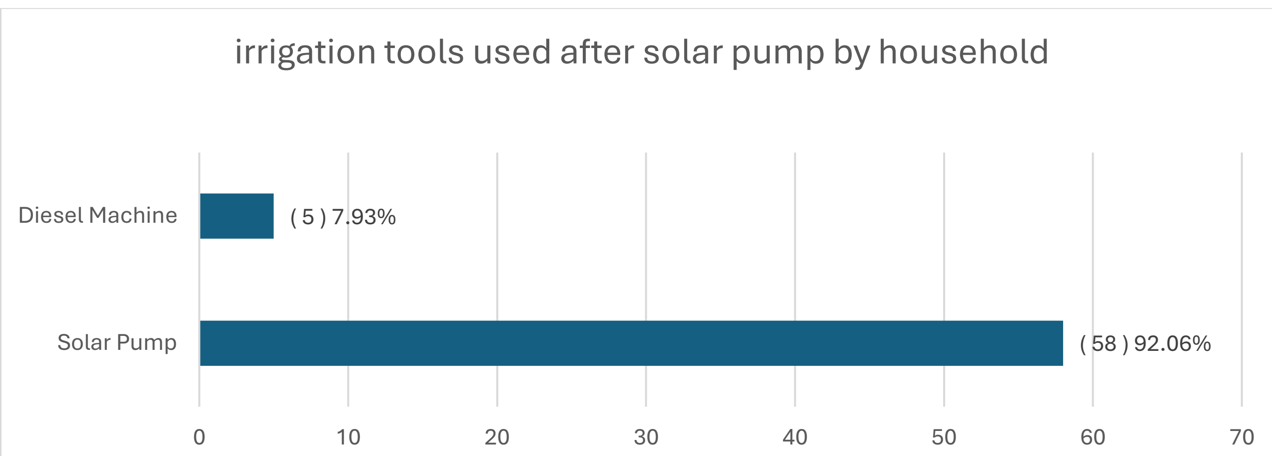


FIG. 4.22 IRRIGATION TOOLS USED AFTER SOLAR PUMP BY HOUSEHOLD

- Crop-wise farm productivity, crop yield, and farm income before solar pump intervention

Crop diversity, average total farm productivity, and average income before the intervention of solar-based irrigation pumps were analyzed for Rabbi season by taking a sample of 63 households, a total of 27 farmers out of 63 were farming in Rabbi season using other irrigation tools even before solar pumps. Crop diversification focuses on four crops: commonly gram (chickpea), cowpea, groundnut, and maize. Chana is grown by 19 families on 0.3490 acres where the average yield is recorded at 0.707 quintals per acre and the average marketing is 0.0789 quintals. Thus, the average price per quintal came to Rs.1000 and thus the average gross income for these households was calculated as Rs.342.1. Cowpea was cultivated on 0.2063 acre by 6 families and yielded 0.525 quintal per acre. As cowpeas are produced in small quantities, no sale is recorded. Among all the households surveyed, only one household earned a gross sales income of 3000 from groundnut farming on 0.29 acres with high productivity of 3 quintals per acre and a total output of 1000 per quintal. Similarly, a family seems to have planted 0.15 acres of land with maize which is mainly used as char while for sale in very small quantities, showing zero productivity per acre of maize but fetching a significant income of 2500 by selling 10 per no. This analysis highlights the variation in Rabbi season crop cultivation, productivity, and household income before the intervention of solar-based irrigation pumps.

Total Household = 63							
Season Name	Crop name	No. Of household	The area under crop (Acer)	Average productivity (quantal)	Average sales	Average price/ Quantal	Average total income
Rabbi	Chana	19	0.349	0.707	0.0789	1000	342.1
	Cowpea	6	0.2063	0.525	0	0	0
	Groundnut	1	0.29	3	3	1000	3000
	Maize	1	0.15	0	10/pice	10/pice	2500

Table 1: crop wise farm productivity, crop yield, and farm income before solar pump intervention

- Crop-wise Average farm productivity, average crop yield, and average farm income after solar pump intervention

Data were collected from a sample of 63 households for analysis during the Rabbi season, to the average productivity and average crop yield of the farmer's farm after the intervention of solar pumps, and average gross income. The findings show significant differences in crop diversity, average farm productivity, average crop yield, and average gross income. After the intervention of solar pumps, almost all the farmers are showing more than one crop from agriculture during the Rabbi season. Okra grown by 12 families on an average of 0.426 acres gave the highest yield of 5.741 quintal/acre and earned a total average gross income of 28,741.67 from an average price of 5,300/quintal. Groundnut planted by 15 families on 0.507 acres showed an average yield of 2.053 quintals per acre and an average sale of 51.4 quintals yielding an average income of 13,500.

Chana with a total of 25 families out of which only 0.285 acres are under cultivation, but its productivity was 2.786 quintals per acre. Still, its sale value was low, and the yield was only 0.085 quintals sold at an average price of 576 and a total yield of 492.48. Two households planted an average of 0.137 acres of tomatoes; Their productivity was 1.1 quintal per acre and above, yielding 2880 at the rate of 3100 per quintal from the sale of produce.

Pulses planted on an average of 0.5 acres of land by a family recorded a high yield of 25.71 quintals/acre and a good yield of 89,985 = 3,500 per quintal. Sunflowers planted on 0.2 acres per household produced 0.5 quintals per acre and 2,000 yield 4,000 per quintal. Among the nine households cultivating brinjal on an average of 0.2605 acres of land, the productivity was 1.744 quintals per acre for which the income was 4,027.77 and the selling price was 3,000 per quintal.

A few other crops such as sesame, Nagli (ragi), groundnut, cowpea, moong, onion, maize, and urad yielded comparatively less, though the sales value reported was negligible as the corresponding sales volume was nil. The productivity of tur grown by five families on 0.282 acres is 476; quintal acre but like the other three none of the five households reported any income from sales indicating their productivity was zero.

Many crops have benefited from the intervention of solar pumps, it seems that people have shifted to agriculture after the intervention and started farming on a large scale during the Rabbi season and this has also led to an increase in agricultural production, although the increase is negligible in some crops. Gross farm income, however, showed mixed results, which were attributed to factors such as market access and crop selection.

Similarly, it highlights the remarkable effects of solar pump intervention on crop diversity, average productivity, and average income of 63 farmers during the summer season. Post-intervention farming is not limited to the Rabbi season but also to the summer season. As shown above, among the crops planted on an average of 0.107 acres by the three families, tomato has a relatively high average productivity of 23.17 quintals, and its sale yielded an average income of

3333 copies per quintal: Rs.80,451/-. On an average of 0.21 acre, six households grew bitter guard showing high productivity of 16.83 quintals per acre with an average yield of 31,783.33 as against 5,691.66 per quintal.

Three families cultivated brinjal on an average of 0.0243 acres with a total productivity of 62 quintals per acre yielding an income of Rs.6, 640/- at a rate of Rs.800 per quintal. Whereas on average 0.074 acres per acre of chilli cultivated by a family yielded 0.5 quintals per acre and at 20000 per .5 quintals yielded Rs.10000 per acre. On average .14 acres of mung bean grown by a family produced 1 quintal per acre and yielded an income of 50,000 at the rate of 5,000 per quintal.

12 families cultivated cowpeas on an average of 0. 222 acres, its productivity was 0.361 quintals per acre out of which 0.0041 quintals were sold and the average yield was 12. 5 at the rate of 250 per quintal. The productivity of gram cultivated by the four sample households on an average of 0. 191 acres was 0. 31 quintals per acre and yielded an average yield of 412 per quintal at a rate of 1,650.

Like other crops, the total productivity of the maize crop cultivated by 2 families on an average of 0.1625 acre was not given, but 7000 was returned at Rs.10 per piece. Whereas a family planted Ridged guard on an average of 0.29 acres got an income of 0.90 per quintal and from it got an income of Rs.3500 per quintal equal to Rs.3150. Apart from this, each family cultivated groundnut 0.74-acre, onion .15-acre, pea 0.15-acre, sesame 0.15 productivity 0.1 quintal, but these crops are important in terms of livelihood, although there is no financial benefit.

In areas where farming is almost impossible during the Rabbi season, families are expected to migrate in large numbers, this intervention is accelerating agriculture-based livelihoods in these areas. This shows that solar pump intervention affects productivity.

Total Household = 63							
Season Name	Crop name	No. Of household	The area under crop (Acer)	Average productivity (quantal)	Average sales	Average price/ quintal	Average total income
Rabbi	Okra	12	0.426	5.741	5.508	5300	28741.67
	Groundnut	15	0.507	2.053	51.4	4937.33	13500
	Chana	25	0.285	2.786	0.085	576	492.48
	tomato	2	0.137	1.1	0.9	3100	2880
	Ridged guard	1	0.5	25.71	25.71	3500	89985
	Sunflower	1	0.2	0.5	0.5	4000	2000
	Brinjal	9	0.2605	1.744	1.388	3000	4027.77
	Sesame/mole	1	0.074	0.15	0	0	0
	Nagali (Ragi)	1	0.0496	0.2	0	0	0
	peanut	12	0.1944	0.405	0	0	0
	cowpea	29	0.291	1.958	0	0	0
	mung bean	3	229	0.4	0	0	0
	Onion	1	0.15	3	0	0	0
	Maize	0.3221	0.8	0	0	0	0
	Udad	15	0.2546	0.5433	0	0	0
	Tuur	5	0.282	476	0	0	0
Summer	Cowpea	12	0.222	0.361	0.0041	250	12.5
	Chana	4	0.191	0.31	0.0625	1650	412
	Tomato	3	0.107	23.17	23.17	3333.33	80451.67
	Maize	2	0.1625	0	10/pice	10/pice	7000
	Brinjal	3	0.0243	0.62	0.5533	800	6640
	bitter guard	6	0.21	16.83	78.66	5691.66	31783.33
	Chili	1	0.074	0.5	50 kg	20000	10000
	mung bean	1	0.14	1	1	5000	50000
	Ridged guard	1	0.29	0.90	0.90	3500	3150
	Groundnut	1	0.74	2	0	0	0
	Onion	1	0.15	2	0	0	0
	Peanut	1	0.15	0.2	0	0	0
	Sesame/mole	1	0.15	0.1	0	0	0

Table 2. Crop-wise Average farm productivity, average crop yield, and average farm income after solar pump intervention

Chapter 5: Discussion

In two Block of Dang district, Ahwa, and Subir in Gujarat, AKRSPI, a non-profit organization, knowing the various problems there, implemented several interventions to promote agriculture and agro-based livelihoods, one of which was the "Solar Based Irrigation Pump". Based on the results presented from the study on the socio-economic impact of the farmers there, several key observations and implications can be discussed.

Dang district is a tribal region in the state of Gujarat and is surrounded by hilly terrain and forests. Bhil, Konkani, Kunbi, and Warli have been living in this area for many years. Most of the population of this developmentally backward region 53 (84.13%) still lives below the poverty line. Although the main occupation here is agriculture, it is seen that there were problems such as low income, and rain-fed agriculture. 91.08% of agriculture is rainfed, 53.27% of farmers reported problems with electricity for irrigation, and 51.79% of farmers said that they do not have any means of irrigation. 41.07% of the farmers who were farming during the rabbi season reported spending more money on diesel. It was clear that there were not enough tools for farming, and the income was less than the expenditure. Although the land holding capacity of the farmer is higher (4.57 acres) on average, the amount of cultivable land is less (2.34 acres). So, many people used to migrate after the Kharif season. From the findings, the significant and positive socio-economic effects of the intervention of solar pumps on the farmers were seen. Social impact here includes migration, and farmer empowerment (especially women, and widows) as well as solar user group management. (Here empowerment means participation in group meetings and the decision-making process and group management means knowing about regular group meetings, participation, bank account, water tariff charge, etc.) The economic results include crop diversity, farm productivity, crop yield, and farm income

5.1 Reduce migration:

Lack of irrigation facilities, and a shortage of water, have led to mass migration after the kharif season as most households have adopted the use of solar-powered irrigation pumps. Analysis of the results revealed that in the absence of intervention, 68.25% of the households studied migrated during the post-monsoon period. After the intervention process, it was significantly brought down to 19.04%, which means that it is a good and affordable option to practice sustainable agriculture-based livelihood. It also suggests that increased agricultural activity during the Rabbi and summer seasons provides a sustainable livelihood option, reducing dependence on seasonal labor migration.

5.2 Empowerment and Participation:

Male participation in meetings and decision-making processes of the solar pump users' group is relatively high, which is 66. 67% although female participation is a relatively low percentage of 26. 98%, it has to be appreciated that women are not excluded. The significant participation of widows (15.87%) in this is a positive step towards social empowerment. Active participation in the decision-making process helps to increase the cohesion of the workforce and communities and ensures the sustainability and development of the group.

5.3 Solar user group management:

The characteristics of management practices of groups of solar pump users are evidenced by the following data. Thus, 61. 90% (13) of the solar pump user groups have their bank accounts, which will improve the financial status of these groups and manage some form of financial services. 90.47% of the group has regular monthly meetings. These meetings are important for group transparency and the planning process which strengthens the sustainability of the group, increases transparency, and increases the life of the group. Moreover, 76.19% (16) groups are those who have fixed water tariff charges and collect fixed charges from regular farmers. It will no doubt help them in future maintenance and other expenses of the solar pump. The total water tariff charge average water tariff charge in the fixed group is Rs. 51.01 while 5 groups charge an average of 94.73 in return for providing water to farmers other than their group. This amount helps with their future expenses and maintenance costs.

5.4 Crop Diversification:

This intervention has led to significant changes in crop diversity. Before the intervention, agriculture was completely rain-fed and only 7.93% of vegetables were cultivated during the Rabbi season. Before the intervention, 4 crops Kever gram, maize, groundnut, and cowpea were grown. Before the intervention, most of the households (100%) depended solely on rain for cultivation during the kharif season. After the intervention, there was a significant increase in cultivation during the rabbi and summer seasons. (85.7% and 19.04% of farmers respectively do agriculture). While most of the households (100%) are engaged in arable farming, vegetable farming (92.06%) and horticulture (41.26%) are also practiced. There has been a significant increase in the cultivation of high-value crops like okra, tomato, and carrot, which fetch good prices in the market. Apart from this, growth was seen in other crops like okra, sesame, sunflower, brinjal, onions, peas, and chillis. This diversification not only increases food security but also increases household income, as evidenced by the significant increase in average farm income across crops.

5.5 Improved productivity and income:

The study reported an increase in average farm productivity for various crops like okra, groundnut, brinjal, and chili after solar pump intervention. Farmers said that their income has increased from the sale of these crops. For example, okra cultivation yielded the highest average gross income (₹28,741.67). Even though the productivity of crops like cowpea and moong is low, it is important for food security.

5.6 Challenges:

- Despite the positive results, challenges remain, such as proper markets, transportation facilities, water scarcity, etc.
- In addition, ongoing support and training are required to optimize pump use crop management, and water management practices ensuring long-term benefits.
- Certain groups of solar pump users have adopted new farming practices like drip irrigation, and mulching, and other farmers are deprived of these, so proper planning is necessary when water is a problem.
- Some solar pump user groups do not have bank accounts, do not hold meetings on time, and do not charge any water usage charges, although these groups may close in the future.
- Water scarcity: Most of the solar pumps are installed on check dams but some of the check dams are filled with earth and do not stop the water so maintenance is required.
- As the market for the purchase and sale of agricultural inputs is far away, local traders benefit and due to this, agricultural activities do not get fair prices.
- Some of the poor farmers do not have the money to cultivate the farm, so the group needs to take appropriate steps for them while they still migrate.

Chapter 7: Conclusion

In conclusion, the solar pump intervention in the Dang district by AKRSPI has revived the socio-economic scenario for farmers. Solar-based water pumps are coming in handy in hilly terrain like Ahwa and Subir talukas of Dang district to alleviate the lack of irrigation facilities. These interventions have significantly reduced large-scale seasonal displacement of people and have led to increased livelihoods and more stable living standards.

Greater participation of farmers, especially women and widows in solar pump user group meetings and decision-making processes is helping to empower them through social inclusion.

Strong management practices, including solar pump user group meetings, bank linkages, and water rate structures, ensure the long-term sustainability of the intervention.

Most notably, crop diversity increased. Farmers cultivate high-value vegetables and horticultural crops, which increase farm productivity and income. This model is very useful for promoting sustainable agriculture and for long-term sustainable agriculture as it is affordable for longer periods in exchange for a lack of irrigation facilities or expensive irrigation equipment.

7.1 Recommendation:

- Water is a major problem here despite abundant rainfall. Since water is the main basis of agriculture, there is a need to pay attention to maximum water retention. Since the check dam is the basis of solar pump irrigation in this area, it needs to be maintained.
- As the people have newly started farming in the rabbi and summer season, they need to be trained in different farming methods, practices, water planning, drip irrigation, and other methods that will save water, and get more crop yield at lower cost.
- In this area, even though the crops of okra and kale earn more money, the poor and small farmers cannot afford it because of the lack of transport and high input costs. For this, it is necessary to make efforts like group buying and selling, and group crop planning.
- Solar pump user groups should be linked with farmer producer companies for buying and selling their agricultural produce to eliminate middlemen and benefit farmers.
- Interventions like integrated agricultural equipment centers and seed banks will be useful for small and medium farmers who do not have agricultural implements or have to hire them.

7.2 Consent:

This research project examines the social and economic impact of farmers' adoption of an intervention "Solar Powered Irrigation System" by AKRSPI in Dang district, Gujarat. The goal is to understand how these systems affect factors such as migration patterns, group decision-making, irrigation management, farm productivity, crop yields, farm income, livelihoods, and economic viability of solar technologies. Your participation in this research is completely voluntary. You have the right to withdraw from the study without explanation or penalty. All information collected during this study will be kept confidential. Your name and other identifying details will not be linked to any data used in reports or publications. We believe this research will provide valuable knowledge about solar irrigation pumps' social and economic impacts.

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Chapter 8: Annexure – 1

survey of solar-based irrigation system

Organization: AKRSP(I) Block: Ahwa District: Dang, Gujarat

Section A: Demographic profile

Village:	GP:
Block:	Cluster:
District: Dang	State: Gujarat
	Date:

Section B: Respondent profile:

Respondent name:	Age:
Gender:	Contact no.
Relation of household:	

Section C: Profile of the Solar User

Household name:	Category: SC / ST / OBC/ PVTG
SUG Member name:	Age:
Gender:	Education level:
Types of houses: Kachha/ Pakka/ Semi Pakka	Marital Status:
Total Income Before Intervention (Rs):	After Intervention:
Primary activity engaged.	Secondary Activity.
Total land:	Total agricultural land:
Name of Solar User Group:	Total members of SUG:

When the solar unit was installed (Mention Year):
Did it cost you to join the group? Yes/ no (If Yes) How Much:
Do you participate in group meetings and decision-making? Yes/ no
Who participates in the group meetings/decision-making process? Yes/ no
Did you participate in any training on water budgeting and crop planning? Yes/ no
Did you participate in any exposure to Solar maintenance and its function? Yes/ no
Have you received any training on water use, farming practices, etc? Yes/ no

Section D: Major Challenges before the intervention:

a) No electricity facility on the farm site.
b) Lack of irrigation facilities/ inability to purchase assets individually.
c) High cost of Diesel/ other fuel
d) Rainfed Farming
e) Specify others.

Section E: Land Pattern

	Before Solar intervention	**After Solar intervention**
Types of Agriculture	▪ Horticultural agriculture ▪ Arable farming ▪ **Vegetable Farming** ▪ Shifting cultivation	▪ Horticultural agriculture ▪ Arable farming ▪ **Vegetable Farming** ▪ Shifting cultivation
Total Irrigated land **(Acer)**		

Section F: Irrigation Pattern

Source of Irrigation: 1) River (Dahad). 2) Well. 3) Pond. 4) Borewell. 5) Depend upon Monsoon.

Till when water is available for irrigation…………

	Before Solar intervention	**After Solar intervention**

Irrigation tools used	▪ Diesel Machine ▪ Electric Pump ▪ Other	• Diesel Machine • Electric Pump • Other • Solar Pump
What method of irrigation do you use	▪ Drip irrigation. ▪ Sprinkler irrigation ▪ Flood Irrigation ▪ (वाफा) Farrow ▪ Other	▪ Drip irrigation. ▪ Sprinkler irrigation ▪ Flood Irrigation ▪ Farrow ▪ Other

Section G: Input Cost in Irrigation

	Before Solar Interventions	**After Solar intervention**
Do you use a diesel engine or an electric pump	1. Yes 2. No	1. Yes 2. No
Diesel engine (In Rs.) (HIGHER CHARGE / OWN)		
Overall Cost Diesel (In Rs.)		
Electric pump		
Overall cost light bill of electric pump (In Rs.)		
Water tariff charged in solar-based irrigation per hour (In Rs.).		
Has the solar irrigation system changed the working hours/Schedule in the field?	1. Yes 2. No	1. Yes 2. No
Irrigation time in hours		

Agriculture input cost: (in RS)	**Before Solar Interventions**			**After Solar intervention**		
	monsoon	**winter**	**summer**	**monsoon**	**winter**	**Summer**
Seed						
Fertilizer						
Insecticide						
labor cost						

Cultivation						

Section H: Agriculture Tools and Equipment		
What are the agriculture tools used?		

Section I: Crop Pattern, Productivity, and Income Details

Have you benefited from solar based irrigation system for farming: a) Yes b) No

What was the benefit (if yes)

- increase agricultural productivity.
- cost saving
- Increased flexibility
- Increases animal production.
- stop migration.
- increases irrigation area.

		Crop Pattern and Productivity: (Before Solar Based Irrigation System)					
Season	**Major Crop**	**Area Under Crop (Guntha/Hectare**	**Productivity (Quintal/Kg)**	**Do you Sell it (Yes/No)**	**How many**	**where**	**Price /Quintal (if yes)**
Kharif							

Rabbi							

		Crop Pattern and Productivity: (After Solar Based Irrigation System)					
Season	**Major Crop**	**Area Under Crop (Guntha/Hectare**	**Productivity (Quintal/Kg)**	**Do you Sell it (Yes/No)**	**How many**	**Where**	**Price /Quintal (if yes)**
Kharif							
Rabbi							
Summer							

Section J: Impact of Solar Intervention in Livestock Development

Do you have livestock: **(Yes/No)**

	Before Solar intervention	**After Solar intervention**
Do you find any increase in livestock	1. Yes 2. No	1. Yes 2. No

Type Of Livestock and their number	1. Cow 2. Buffalo 3. Goat/sheep 4. Ox / Male Buffalo 5. Other	1. Cow 2. Buffalo 3. Goat/sheep 4. Ox / Male Buffalo 5. Other
Did you cultivate fodder for livestock	1. Yes 2. No	1. Yes 2. No
Which type of fodder do you cultivate?		
If Yes, Did You find any increase in the production of Fodder	1. Yes 2. No	1. Yes 2. No
Did the production of fodder increase milk production	1. Yes 2. No	1. Yes 2. No

Section K: Migration Status

	Before Solar Intervention	**After Solar intervention**
Does any member of the family migrate?	1)Yes 2) No	1)Yes 2) No
If Yes, No. If family members migrate		
Purpose of Migration n		
No. of months for which family members migrate		
Location of migration		

Section L: Details about Solar User Group Management

Has Solar Group opened a bank account for Solar Management?	1. Yes 2. No
Do you know about Solar Based Irrigation System and its operation?	1. Yes 2. No
Does the solar-based irrigation group hold regular meetings?	1. Yes 2. No
Do You Deposit Water Charge?	1. Yes 2. No
When? ___________________	Amount: (in group) ______________ (Outside group) ____________
How many meetings are held?	▪ Once a month ▪ Twice a month ▪ Two months later

	▪ When needed.

Section M: Effectiveness of Solar-Based Irrigation System (Rating 1 to 5)

Indicators	**1**	**2**	**3**	**4**	**5**
Has Solar irrigation been able to save on diesel					
Has Solar irrigation been able to save input cost					
Solar pump is convenient to use					
Is Solar Functional full-day					
Solar irrigation reduced the operational costs.					
Solar irrigation has increased the frequency of irrigation.					
Solar-based irrigation systems are effective more than diesel and electric pumps.					