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# Technology for whom? Solar irrigation pumps, women, and smallholders in Nepal

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Agricultural technologies are often promoted as a medium for women's economic empowerment, which can transform unequal gender relations in rural agrarian societies. This paper investigates three solar irrigation pump (SIP) schemes implemented by state and non-state actors and examines their impacts on women and marginal farmers. We utilize a theory of change framework intended to evaluate the effectiveness of livelihood interventions and guide the design of gender transformative interventions. Our analysis relies on 63 qualitative interviews, 9 key informant interviews and 4 telephonic interviews with social mobilisers from the Saptari District in Nepal. The findings shed light on the unequal social and gender relations that have skewed the adoption and benefits of SIP technology. Gender and social inequalities persist, with limited adoption and benefit of SIP among women and smallholders. Women's involvement in strategic decisions related to SIP adoptions, installations and usages is limited. This study underscores the importance of strategic interventions that foster meaningful women's empowerment and ensure equitable distribution and benefits from SIP technology. Assessing the effectiveness of SIPs in empowering women, it is crucial to consider whether the resulting access, ownership, or decision-making opportunities challenge, reinforce, or reproduce unequal gender and social relations.

## KEYWORDS

gender relations, Nepal, solar irrigation pump, technology, women empowerment

## 1. Introduction

Solar Irrigation Pump (SIP) technology has the potential to help achieve a number of important Sustainable Development Goals (SDGs), including food security (SDG2), sustainable water resource management (SDG 6), and climate change adaptation (SDG13) (IRENA, 2016; Shah et al., 2018). SIPs are becoming more popular as a clean, profitable alternative to fossil fuels in the agricultural sector, as they allow for the development of low-carbon irrigation and can reduce reliance on national grid systems in areas with limited electricity infrastructure (IRENA, 2016; Mukherji et al., 2017). Additionally, research has demonstrated that SIPs can increase crop yields and help farmers transition to more profitable commercial crops (IRENA, 2016; Mukherji et al., 2017).

Solar irrigation technologies are often regarded as labor- and time-saving solutions for women farmers, which have the potential to improve health and nutrition within rural households (SDG 5). For instance, in northern Benin, Sehgal (2011) demonstrates that women who utilized solar-powered drip irrigation systems spent 50 per cent less time tending to their

plots compared to traditional methods of hand watering. Consequently, this enabled them to allocate time towards additional income-generating activities such as rabbit farming. Similarly, Upadhyay (2004), in her study on gender and small-irrigation technologies in Nepal, reveals that the adoption of simple irrigation technologies like drip kits helped alleviate the workload for women, increase household income, and yield positive effects on food security and household nutrition. Moreover, similar cases of reduced labor in water-fetching tasks for women following the implementation of solar pumps have been reported in Kenya (Njuki et al., 2014), Zimbabwe (Magrath, 2015), and Ethiopia (Nigussie et al., 2017).

Research indicates that technology has the potential to bridge the gender gap in agriculture and empower women (Huyer, 2016; Mohideen, 2018). In the Upper East Region of Northern Ghana, women engaged in dry season irrigation were highly respected by both the community and their families, leading to an increase in their social standing (Bryan and Garner, 2022). The availability of motor pumps indirectly benefited women by reducing their time commitment, allowing them to focus on more economically favorable activities and explore avenues of empowerment beyond agriculture. Women who utilized irrigation reported direct benefits, including control over the revenue generated from their cultivated plots (Bryan and Garner, 2022). Similar findings highlight that irrigation projects specifically designed for women, such as irrigated home gardens, provide direct advantages such as increased assets, income controlled by women, and enhanced decision-making authority (Njuki et al., 2014; Alaofè et al. 2016; Nigussie et al., 2017; Bryan and Garner, 2020). Additionally, the use of ICT technologies is gaining popularity in reducing the knowledge gap between men and women farmers and improving women's social status (Mittal, 2016; Zhu et al., 2022).

Nevertheless, a lack of attention to intersecting gender and social power relations<sup>1</sup> during the planning and implementation of technologies can lead to disempowerment, low adoption rates, and the failure of pro-poor programs (Doss, 2018; Fischer et al., 2018; Belete and Surafel, 2020). Despite the importance of gender-responsive technology development and deployment, many agriculture and energy-related projects tend to focus narrowly on the technical aspects of adoption, use, and benefit. Existing studies have highlighted the systemic and structural exclusion of women from energy and technology services, with limited access to renewable energy technologies (RET) and a lack of participation in RET planning and decision-making (ADB, 2018; Lieu et al., 2020). High upfront costs can also limit access to energy services for women and disadvantaged groups (DAG). There is evidence to suggest that ownership and access to RET and training and education programs often benefit more advantaged men, while women and DAG have limited access to such programs (Bhatta, 2016; ADB, 2018, 2020).

Discriminatory norms and practices impede women's and excluded groups' access to energy (Dutta et al., 2017; Doss, 2018). Gender stereotypes and perceptions can also discourage women from adopting technology, particularly in fields like irrigation that are traditionally seen as men-dominated (ADB, 2020). Additionally,

the adoption of technology at the household level may not necessarily benefit everyone in the household equally, as household structure and intra-household gender relations can either promote or limit the equitable benefit of technology (Fischer et al., 2018; Theis et al., 2018). Moreover, evidence suggests that as soon as an activity is mechanized and becomes profitable, it is appropriated by men (van Eerdewijk and Danielsen, 2015; Fischer et al., 2018; Theis et al., 2018). Women's reliance on men family members or technicians for even minor repairs of energy technologies can also restrict their control over such technologies (Mahat, 2006). Thus, technology can have both positive and negative impacts on women's empowerment, potentially increasing their decision-making authority over production and income or reproducing existing gender inequalities and unequal labor allocation in new ways (Bryan and Garner, 2022).

SIP have only recently been introduced in Nepal and is a priority in national policies and programs. To encourage SIP adoption, the national government provides a subsidy of up to 60 per cent with investments of up to NPR 2, 000,000 (USD 15358) per system, as outlined in the Renewable Energy Subsidy Policy 2016. Some local governments also provide additional subsidies for SIPs. Under Nepal's new Constitution (2015) and federal governing structure, local governments have also been responsible for overseeing small-scale energy and agriculture projects within their jurisdiction. While there are several SIP initiatives in Nepal being implemented by state and non-state stakeholders, the impact of these interventions on smallholder, women, and disadvantaged farmers has not been well studied. At the time this article was written, there were no scientific studies investigating gender equality and social inclusion (GESI) impact of SIP technology in Nepal. Additionally, there is limited research on how intersecting identities based on caste/ethnicity, class, religion and age can influence the empowering impact of technological interventions on women and marginal farmers. It is important to understand the GESI dimensions of SIPs in Nepal, where there is a high incidence of feminization of labor activities and sharecropping by marginal farmers due to men labor migration (Tamang et al., 2014). Small-scale farming by women and marginal farmers has been crucial in ensuring household food security during the COVID-19 pandemic in Nepal (Leder et al., 2021). However, Nepal's energy policies show limited consideration of GESI. This paper aims to fill this research gap by examining the access to SIP technology among its intended beneficiaries and analyzing the impacts of three SIP technology interventions implemented by state and non-state actors in Saptari District, Nepal.

## 2. Conceptualizing women's empowerment through irrigation technology

Improving livelihood opportunities and the economic status often forms the basic premise behind technological interventions targeting women. Generally, such interventions focus on the welfare approach (e.g., temporary solutions to work burden) or project efficiency (easily observable and measurable indicators, e.g., agriculture productivity) and do not challenge structures that reinforce and reproduce gender inequality (Skutsch, 1998; Tavenner and Todd, 2022). A feminist analysis of technology considers the ways in which technology is developed, used, and impacts gender roles and power dynamics. It recognizes that technology is not neutral and is shaped by the social

<sup>1</sup> The heterogeneity in experiences of exclusion and inclusion, discrimination and privilege based on overlapping multiple identities of an individual is conceptually termed as Intersectionality.

relations of production, and therefore cannot be understood independently from issues of gender (Doss, 2018; Mohideen, 2018).

Empowerment is a contextual and multi-dimensional concept, with women’s experiences varying based on their social positions. This research draws on Kabeer’s (1999, 2018) conceptualization of empowerment and the theory of change framework. According to Kabeer, women’s empowerment involves transforming unequal gender roles and relations enabling agency and making choices for their well-being. This process involves three interrelated dimensions: agency, resources, and achievements (Kabeer, 1999). Agency refers to individual’s ability to define and pursue goals that are meaningful to them. Resources, such as material, human and social, support agency. These resources are acquired through social relationships within various institutional domains, such as the family, community, market, and state. Sen (1985) refers to the combination of resources and agency as capabilities, or the potential for individuals to live the lives they value. While access to resources is a necessary precondition for agency, it does not always lead to agency unless individuals also gain critical consciousness and use their resources to achieve their aspirations. Finally, achievements are measured by individuals’ well-being resulting from the use of their agency (Kabeer, 1999; Kabeer, 2018).

The theory of change framework (Kabeer, 2018) incorporates “structures of constraint,” - intrinsic constraints and extrinsic constraints, that shape men’s and women’s access to resources and opportunities and affect their ability to participate in livelihood activities (Folbre, 1994; Kabeer, 2018). Intrinsic constraints, such as customary norms, define appropriate roles and responsibilities for men and women based on their socially ascribed identities and often value masculine roles, creating a hierarchy of power and agency within families and communities. Extrinsic constraints are shaped by informal norms and values and can take the form of discriminatory laws and practices within formal institutions, such as those related to property inheritance or citizenship, that favor men (Kabeer, 2018). In

addition, intersecting identities, such as caste, ethnicity, religion, class, and age, further shape women’s access to resources, opportunities and their ability to achieve valued outcomes (Valentine, 2007; Kabeer, 2018).

The framework addresses three critical questions throughout intervention phases. The first focuses on beneficiaries’ resource access. The second question explores the impact of resources on women’s capabilities, further subdivided into two sub-questions. The first sub-question assesses the impact of interventions on aspects of women’s agency: Cognitive, subjective, and practical. The second sub-question examines the outcomes resulting from agency impacts, categorized as practical outcomes (e.g., increased income) and strategic outcomes (e.g., challenging power relations and structural change). This framework evaluates intervention effectiveness, and supports the design of gender-transformative interventions. The framework can be helpful to analyze structural constraints and enhance women’s access to and benefit from SIP technologies.

This research investigates the impact of SIP technology on women and smallholders in Nepal. It aims to understand – (i) the extent of SIP technology access among the intended beneficiaries, (ii) the impact of SIP on women’s capabilities, (iii) the outcomes achieved - practical outcomes (e.g., improved water access, crop productivity, income, access to women-friendly technology, land and livelihood opportunities) and strategic outcomes (e.g., disrupting power relations and altering structures of constraint; Kabeer, 2018) (Figure 1).

### 3. Methods

#### 3.1. Study area

The study was conducted in the Saptari district of Province 2, which is located in the Eastern Gangetic Plains (Map 1). This region

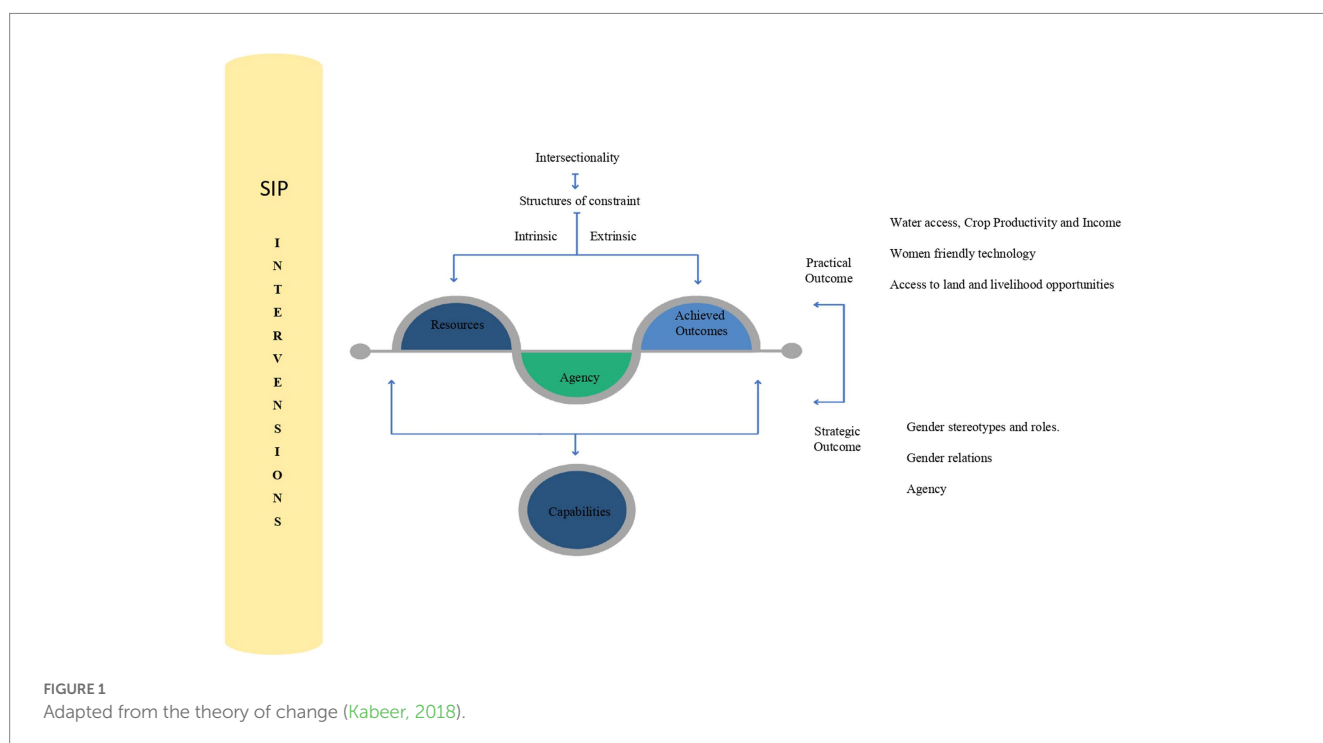
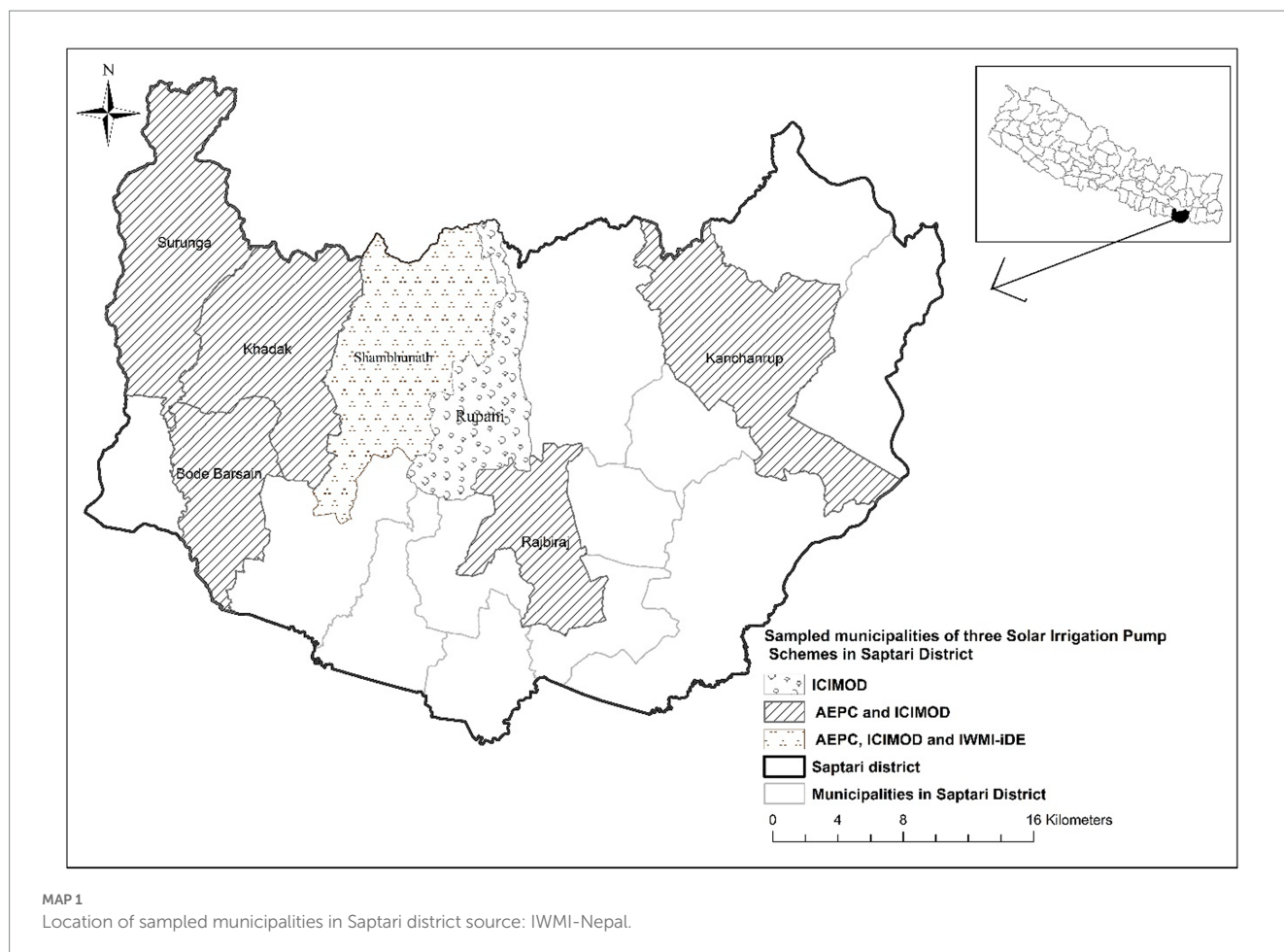


FIGURE 1 Adapted from the theory of change (Kabeer, 2018).



is known for its agriculture, but it also has a high rate of multidimensional poverty and a high rate of men youth migration (CBS, 2014; NRB, 2017). There are significant inequalities in land ownership and gender and caste relations in the province (Sugden, 2017; Leder et al., 2019). Around 87.7 per cent women in the region are landless or have limited land resources, rely on sharecropping as their primary means of farming (ADB, 2020). Additionally, a significant portion of the population are Dalits, who experience significant disadvantage due to caste-based discrimination (ADB, 2020).

The Saptari district was one of the first areas where SIP was implemented. This study focuses on SIP schemes implemented by the International Water Management Institute (IWMI) and International Development Enterprise (iDE), the Integrated Centre for Mountain Development (ICIMOD), and the Alternative Energy Promotion Centre (AEPC), which is a government agency promoting renewable energy. These schemes are described in detail in section 3.3.

### 3.2. Data collection and analysis

The study used a qualitative research method and consisted of two phases of fieldwork. The first phase included semi-structured interviews with 20 men and 20 women farmers, which were conducted over a week in September 2021. The second phase

included 23 (11 men, 12 women) in-depth interviews (IDI) with landless and smallholder farmers, who used SIP water from three different schemes located within the Saptari district. These interviews lasted from 45 min to 1.5 h and took place in November 2021 (Table 1).

In addition, the study conducted a total of nine key informant interviews (KII), consisting of two interviews with researchers, two with local mobilizers, and four with local implementing organizations. Observation as a tool was used to study the gestures and body language of the respondents. Purposive sampling was used to target specific categories of participants, such as single women-headed households, single women with migrant men, Dalit women, and sharecroppers. Disaggregated data from each sample in terms of gender, caste, economic status, age, education, family structure, occupation, migration status, and involvement in community groups were collected. The interview questions focused on awareness of and experience with SIP subsidies, including the benefits, impact on income, cropping patterns, time and labor, risks and violence, gender roles and relations, and decision-making. The study also included 4 brief telephone interactions with quasi-government social mobilizers to understand the deployment process for the SIP interventions. These mobilizers were specifically recruited to reach out to women farmers under the ICIMOD SIP scheme.

Before conducting each interview, the researchers shared the objectives and expectations of the interview with the respondents. The

TABLE 1 Total number of respondents.

Sex/Caste	Religion	AEPC	ICIMOD	IWMI-iDE	Non-SIP Users
Male	Hindu	10	7	8	6
Female	Hindu	8	10	8	6
Dalit	Hindu	1	1	4	-
Tharu	Hindu	1	3	8	7
Muslim	Muslim	1		-	
Madhesi (other Caste) <sup>1</sup>	Hindu	15	8	4	5
Brahmin-Chettri	Hindu	-	4	-	-
Total Sample		18	17	16 members of 4 farmer's groups	12

<sup>1</sup>The Madhesi ethnic community maintain their own version of caste hierarchy. Nepal Social Inclusion Survey (2018) divides the community into three groups – Madhesi Brahmin/Chettri, Madhesi other caste and Madhesi Dalit (Gurung et al., 2022). Tharu are indigenous to the southern plains of Nepal.

TABLE 2 Codes for qualitative analysis.

Code(s)	Description	Themes
Demographic details	Ethnicity/caste, religion, gender, age, education, economic status, migration status, family structure, occupation, location.	Intersectionality
SIP details	SIP ownership, SIP design, size/capacity, cost–benefit, subsidies, risk, subsidy, functionality, information and technology dissemination methods, operation and maintenance, aftersales services, other irrigation technologies, preferences and priorities	Resources
SIP adoption	Land ownership/access, sharecropping arrangements boring ownership, membership in WUA/IUA, cropping patterns, crop productivity, water sharing arrangements, income, livelihood opportunities, knowledge, skills, market.	
Social Capital	Involvement in community groups, access to ICT, number of visit to AKC, meetings/interactions with N/GO staffs and social mobilisers, kinship relations, social support, language, trainings and orientations opportunities.	
Intrahousehold relationships	SIP ownership, operation and maintenance, decision-making, control over technology, control over ICT, income, time, labor, information sharing, mobility, domestic violence, gender norms and expectations, family structure, relations with in-laws, children, husband.	Agency and outcomes
Interhousehold/social relationships	Conflicts/disputes, labor relations, discrimination, reciprocity, trust, safety–security, collective/community work, decision-making spaces, opportunities and constraints, relations with community members, N/GOs, market. Informal norms and values.	

audio recordings of the interviews were transcribed and translated from Maithili/Nepali to English. The transcripts were then coded using NVIVO software. The codes were grouped based on themes and sub-themes that emerged during the coding process (Williams, 2008). Examples of coded themes are presented in Table 2. Supportive interview excerpts were arranged under relevant themes. The transcripts and audio recording were repeatedly revisited to reconfirm and refine theme categorizations. The data were analyzed using inductive interpretation methods (Gilgun, 2001).

### 3.3. SIP schemes and deployment process

#### 3.3.1. Scheme I

The ICIMOD-led SIP scheme was implemented in 2015 as part of a project called “Reviving Springs and Providing Access to Solar-Powered Irrigation Pumps through Community-Based Water Use Planning,” with funding from the Australian Department of Foreign Affairs and Trade and the CGIAR Research Program on Water, Land

and Ecosystems. A total of 23 SIPs were installed in Saptari between 2015 and 2017, three of which were set up on a pilot basis in 2015 for free as part of a field experiment on financing models. The pilot aimed to test the preference of farmers for three different financing models: a subsidy (60% grant), a subsidy and loan (60% grant and a 20% loan at a 5% interest rate), and a rental model (payment based on the usage of a rented SIP). In addition, a 10% additional subsidy was offered to women farmers if they transferred the land on which the SIP was installed to their name. The goal of this incentive was to encourage more women farmers to apply for SIPs. The program was able to communicate the available financing options to 2,659 farmers in Saptari, 24.4% of whom were women.

#### 3.3.2. Scheme II

The AEPC began offering SIP subsidies in 2016/17. According to the Renewable Energy Subsidy Policy (2016), a maximum subsidy of up to 60% of the total cost (not exceeding NPR 2,000,000 or approximately USD 15358 per system) will be provided for SIPs managed by individual farmers, communities, or private companies.

The beneficiary farmers are expected to pay the remaining 40% of the cost. Between 2016 and 2019, the AEPC distributed more than 2,000 subsidized SIPs throughout Nepal, including 109 in the Saptari district (90 men farmers and 19 women farmers). One of the main goals of the AEPC is to improve the livelihoods of disadvantaged households, particularly single women, socio-economically disadvantaged groups, and natural disaster victims, through the efficient delivery of RETs in rural areas. The primary objective of the AEPC's SIP program is to raise awareness about solar irrigation and promote the use of SIPs in an equitable manner throughout the country. The Renewable Energy Subsidy Delivery Mechanism Policy (2016) outlines the process for collecting demand for SIPs, which involves the participation of pre-selected private firms working with local or regional government departments such as Nepal Electricity Authority offices, the irrigation department, or agricultural extension offices. Despite the devolution of powers to local governments for small-scale irrigation under the 2015 Nepal Constitution, the SIP program remains a federal government initiative (Kafle et al., 2022).

### 3.3.3. Scheme III

IWMI-iDE implemented a SIP collective farming model in Saptari as an experiment in 2015 under an ACIAR (Australian Centre for International Agricultural Research) funded research project - Improving water use for dry season agriculture by marginal and

tenant farmers in the Eastern Gangetic Plains (Nepal Tarai, Bihar, and West Bengal regions). The project aimed to improve water use and increase dry season agricultural production by bringing together small landholders, tenants (those who own no land and cultivate only leased land), and marginal and women farmers to pool their land and labor and efficiently manage irrigation equipment. The goal was to increase the bargaining power of these farmers vis-a-vis landlords and enable them to use resources more efficiently. Five voluntary farmer groups were formed in two villages, prioritizing farmers with 0.5 hectares or less of land and tenants and women farmers affected by men outmigration.<sup>2</sup> The farmers were from Tharu, Muslim, and Dalit (Madhesi) communities. The project provided irrigation technology (solar and electric pumps), small huts for storing the pumps and panels, training in efficient water management, and support for dry season vegetable production. The farmers collectively leased a contiguous plot of land and were responsible for their own plots, cooperating for irrigation by taking turns watering their subplots as needed (KII, 2021) (Table 3).

<sup>2</sup> The fifth group faced early project failure due to conflict between Dalit and non-Dalit regarding land leasing.

TABLE 3 Major characteristics of SIP schemes.

SIP Schemes	Scheme II ICIMOD 2015–2018	Scheme I AEPC 2016/17 – ongoing	Scheme III IWMI-iDE 2015–2019
Total SIP in Saptari District	23	109	4 farming groups <sup>1</sup>
Technical specification/Cost	USD 3,800 (1 HP) with solar panels of 1,200 watt-peak and 2,400 watt-peak	USD 3,500 to USD 4,000 (1.7 HP average size).	SIP 80-watt-peak (30 feet suction), 10,000 liters water/day, powered by a photovoltaic panel, and affordable, ultra-low-pressure drip irrigation kits. Free Distribution
Total Subsidy	60 Per cent (men), 70 per cent (women)	60 per cent	Free Distribution
Information dissemination procedure	Radio, local newspapers, pamphlets distribution in 30 local weekly markets ( <i>hattiyas</i> ), and door-to-door campaigns, A two-hour session for 27 days - 33 demonstration and orientation campaigns. Quasi-government social mobilizers invited 1,989 farmers from 93 VDCs (30% women). Additional people were reached through campaigns in rural markets. Monetary incentives for mobilizers to reach out to women farmers. Training - vegetable cultivation, aquaculture, field water management.	National newspapers, radio, television, internet. Pre-selected private vendors/companies help farmers with form-filling, application submission and following up with the AEPC. An NGO supported demand collection (filling forms, online submissions, collecting documentation).	Farmers' group formation guided by bottom-up participatory action research approaches. National census data, household census survey, local experts, focus group discussions, extended community meetings, interest of farmers, merits, drawbacks, and practicalities of collectives of land, labour, and capital. Mobilizers (man/woman) for 3 years. Training- operation and maintenance, planning irrigation schedules, collecting funds for repair and maintenance.
Eligibility Criteria	Availability of boring, pump set, land ownership and other documents.	Farmland lease/ownership document, citizenship, ward recommendation.	No document requirement.

<sup>1</sup>SIP was distributed to two groups. The other two groups were provided electric pumps.

## 4. Findings

### 4.1. Access and adoption of SIP technology

The ICIMOD SIP scheme was the first of its kind to be implemented in the Saptari district. Under this scheme, eligibility for SIP applications was determined by factors such as land ownership, the presence of boreholes, citizenship and ward reference documents.

In our study area, all 23 SIP recipients (5 women, 18 men) were predominantly from the Brahmin-Chettri, Madhesi (other castes) and four from the Tharu community. The respondents owned a minimum of 2 bighas<sup>3</sup> to 30 bighas of land. Half of them have leased land in sharecropping<sup>4</sup> and were educated and well-networked farmers. 50 per cent held salaried jobs; others were active local politicians (19 per cent) and absentee landlords (10 per cent). In the initial phase, social mobilizers were responsible for information dissemination and gathering at least 35 people from one ward and for orientation and demonstration workshops organized at the district Headquarter. Interviews indicate that promotional information was disseminated in and around market spaces.

*[...] The information was known to the market people ... no one went to give information in the village. Man, Madhesi.*

Our interview with four social mobilizers confirms this finding. It was shared that public spaces such as ward offices were chosen for information dissemination. Only one woman social mobilizer reported making an extra effort to reach women farmers – meeting them in the kitchens and the fields. They also reported that 1–2 days was insufficient to reach all farmers. The claim that the orientation and demonstration workshop was able to gather farmers of distinct categories (man, KII) was contradicted by farmer's interviews which suggest an absence of DAG farmers in the orientation workshops. When asked about the number of SIP applicants from the wards of the interviewed social mobilizers, it was indicated that no one had applied for SIP. Given that it was the first-ever SIP scheme in the district, perceived high cost, risk aversion and unawareness about the cost–benefit of available irrigation technologies were some of the reasons for not applying. Social mobilizers also reported that farmers have become more interested in applying for SIP in recent years.

None of the five women interviewed during the first phase of fieldwork had personally processed SIP applications. Despite the provision of an extra 10 per cent subsidy for women farmers who own land or can have it transferred to their name, several men applied for SIPs in the names of women (such as their wives or daughters-in-law). Among the five women interviewed, four were over the age of 60 and had migrant sons and their families settled in developed countries. One woman was the wife of a former member of parliament. All of these households leased their lands to sharecroppers. The women SIP recipients were generally less aware

of the application process, as evidenced by their statements during interviews.

*[...] How did you receive information about the SIP?*

*Respondent (husband): I was at the Municipality and saw the pamphlet on SIP there. I know xxxx who works there. She provided details. She also suggested applying in my wife's name since women will receive a 70% subsidy on SIP. My wife had land in her name, so it was easy. Woman, Madhesi*

*Respondent (wife): I have not gone, but he had participated. I am not interested in such things. Woman, Madhesi*

*[...] Where did you see it? Respondent: I saw at Rajbiraj, even at home, at the village (her husband was speaking in the background, what are you trying to ask? When did she hear first? Tell them through the ward office). I see, yes, I heard from the ward office. Woman, Madhesi.*

Most of the respondents had opted for either the grant-loan model or the grant-pay-as-you-go model. They were able to pay back using their current income sources except for one woman respondent who stated using remittance to make the payments. In addition, except one, all women SIP recipients (and their husbands) had attended training on SIP, including on vegetable and aquaculture farming.

Under the AEPC SIP scheme, 90% of SIP recipients in the sample represent Madhesi men (other castes), except two respondents each from the Muslim and Tharu communities, with an average landholding range from 2 Bigha to 20 Bighas of land. All SIP recipients were educated and socially well-networked. Additionally, some of them had political connections, as they had previously participated in local government elections, and intended to campaign for future elections. Only one woman with a migrant husband and an elderly woman had SIP registered in their name. In all cases, it was the men who were aware of the pump program, either through formal communication with the local NGO responsible for collecting demand or through informal social or familial connections. The men respondents were able to describe the process of obtaining the pump, which typically followed these steps:

*[...] Someone came from an NGO; I knew someone there...., he is from a nearby village.....from Kathmandu someone then came... and they brought all the paperwork...from solar company...they came after we got accepted for solar...they said take this pump from our company... several companies called us... Man, Madhesi.*

Women SIP recipients, on the other hand, had received information about the pump through men relatives (e.g., nephew, uncle, husband), who has also helped them with the application procedure and maintenance activities.

Non-SIP users and women farmers who used the SIP water, on the other hand, had limited information about such schemes, new technologies and training. This is also because communication tools used for such information dissemination are often out of reach for women and marginal farmers. The local Agriculture Knowledge Centre (AKC) noted that they commonly used their websites and written notices to disseminate information about subsidy schemes

<sup>3</sup> 1 Bigha = 0.67ha. 1 Khatta = 3,645 sq. ft.

<sup>4</sup> Existing share cropping arrangements – adhiya/bataiya – by lease or contract system.

(concerning shallow boring, among other schemes). Women were also less likely to carry smartphones or listen/frequently watch to the radio or television. According to a respondent from the NGO who facilitated the process of information dissemination and applying on behalf of farmers, there had been only one woman who had been selected in the two lots of selection, beginning about 4 years ago:

*'One woman has been selected, but no one knew who she was, we went to the village to find her, but no one said it was her... then the people came to install and after they left then, she found out that she had got it (the pump) and came here to inquire... then I called the company, called other places (someone at Itahari)... but they said they would not be able to install it now.[...] People do not know women's names here – if she were born here, then people would have known, but she was a daughter-in-law (not born here), so no one knew her... Man, Madhesi.*

Even getting to the process of being selected as a woman or as a marginal farmer remains difficult because of the eligibility criteria for the subsidy. In addition, as noted by one respondent, farmers also had to show that they already had a boring installed to be able to apply for the pump.

*[...] what were the set standards for getting SIP?*

*Respondent: Photocopy of land ownership certificate, citizenship certificate, recommendation letter from ward .....and photo...*

*Was it hard to get a recommendation letter?*

*Respondent: It was difficult. When I was in the office, the ward chief said he was not free, so I should visit again. Woman, Madhesi.*

With a *per capita* income of USD 1362 (CBS, 2021), even with 60 per cent subsidies, SIP is highly expensive to be adopted by poor farmers. Furthermore, women experience weaker affordability, with an average monthly income of 73. 21 USD less than men (CBS, 2017/18). Interestingly, 100 per cent of our AEPC SIP respondents had received additional support for the installation of SIP from municipalities, bringing the cost of SIP almost to a negligible amount of less than 40 USD. Yet, none of the SIP recipients represented marginal or DAG farmers.

Under IWMI-iDE, members of four collective farming groups – Madhesi Dalit, Tharu and two Madhesi (other castes) were interviewed. In all groups, a majority were marginal farmers with an average land holding ranging from 0 to 8 katthas of land. The first two groups (Madhesi Dalit and Tharu) received small-sized SIP and electric pumps. Two other groups with members of Madhesi (other castes) had received electric pumps. A majority of Tharu and Dalit respondents were from nuclear families. All the members interviewed indicated continuous support for group formation, leasing land and other services from the project staff during the project duration.

*[...] How do you know about SIP?*

*Respondent: xxxx and xxxx came here and explained it. In the beginning, we were not ready to work in a group, and we refused several times [...]. They regularly visited us and formed a group*

*after six months. They said, make a group, we will arrange a land..... we will also manage the irrigation for vegetable farming, install solar, and electric pump, it will be good.... Woman, Dalit.*

Information dissemination, skill training and access to resources such as land under the IWMI-iDE farming group model evolved out of bottom-up participatory processes. Project staff and local mobilizers provided regular support for 3 years with group formation, technical support such as vegetable training, exposure visits to SIP sites in Madhubani, India, demonstration sessions, land leasing and support with information on government subsidies such as irrigation pipes. Access to leased land and irrigation technology (electric and solar pumps) in the collectives has allowed farmers to cultivate cash crops like vegetables. The groups have also received subsidies for irrigation pipes, agriculture meters etc., from the AKC. Though 1 Bigha land could be irrigated at once, members usually irrigated separate plots at their convenience. All respondents had information on the application and benefits of SIP. However, they were less aware of the SIP cost and subsidy scheme by AEPC and ICIMOD.

## 4.2. Practical impacts of SIP

### 4.2.1. Water access, crop productivity and income

The study found that in most cases, SIPs were used in combination with electric and diesel pumps, making it difficult to attribute the positive or negative impacts solely to the SIP. Reasons for the continuation of the electric and diesel pumps were scattered land parcels, breakdown of SIPs, the smaller size of SIPs which did not meet all irrigation needs, and foggy days in winter when SIP water yield is low. Beside unaddressed technical considerations, respondents in all three SIP schemes agreed that compared to electric and diesel pumps, SIPs demonstrated a definite positive impact in terms of easy, cheaper, and reliable water access, increase in crop productivity, and income of households.

*[...] There is a difference.... Even if it is small, we can choose to irrigate whenever we want [...] we have cultivated young paddy (Kanchi dhaan in Nepali) .... Because this paddy ripens fast [...] after harvesting we can plant potatoes and other vegetables.... after potatoes we can again plant vegetables.... There is a benefit.... Woman, Tharu, IWMI-iDE*

*[...] This system is very useful for vegetable farming and aquafarm. The agriculture meter requires payment as per usage per hour. SIP irrigation is free. Woman, Madhesi, ICIMOD*

*[...] After SIP installation, the irrigation facility has increased, and we can grow the crop of our choice.... In comparison to before, our yield has increased. Man, Madhesi, AEPC.*

SIPs were deemed useful, particularly over diesel pumps, in the way they saved time (not having to wait in the fields to irrigate) and money (not having to buy fuel). Compared to electric pumps that ran on subsidized electricity, SIPs were still deemed cheaper. SIP has also improved access to irrigation water for the



sharecroppers. Several SIP recipients with large landholdings have leased their lands and provided water for irrigation to tenant farmers. While, in the case of an absentee landlord, sharecroppers would operate the SIP themselves, in others, we found reluctance of SIP recipients to provide full control of the operation to sharecroppers, which meant they wait for the owners to operate the SIP.

[...] We have invested a huge amount on SIP; how could I ask others to run; any technical issue may occur—Man, Brahmin.

This cultivated a certain dependency, however, for non-SIP owners. For example, a Madhesi (other castes) woman with a migrant husband shared – *It is difficult. I get to irrigate only when my neighbor (s) is at home. I do not have boring..., plants dry, or delays in growth if irrigation is not on time. Vegetables need steady irrigation. So, I cultivate rice and wheat.* We did not find sharecroppers from our sample respondents participating in training, receiving any kind of subsidies or being members of irrigation user groups.

#### 4.2.2. Women-friendly SIP technology application

The study finds SIP technology applications are women-friendly. All respondents shared that SIP is easy to use since it is not physically demanding and eliminates the burden of carrying the pumps back and forth from the fields. [...] *women cannot handle diesel pumps and thereby are operated by men, whereas women can easily operate the SIP since it just needs switching on and off,* shared mother-in-law and daughter-in-law using AEPC subsidized SIP. Similar sentiments were shared by users of the other two SIP schemes. With no physical strength required to operate the SIPs, women's dependency on men for irrigation has reduced.

#### 4.2.3. Access to land and livelihood opportunities

The implementation of SIP technology has had both direct and indirect effects. One significant outcome is the increased availability of water for irrigation, which has allowed landless, near-landless, and Dalit farmers to gain access to land and opportunities for making a living. With the help of SIP technology, absentee landowners can now offer their lands for sharecropping to multiple households. For instance, a woman absentee landowner mentioned, *“We have been practicing sharecropping for many decades, but people gradually left due to the lack of irrigation water. However, with access to irrigation technologies, we have been able to provide our lands to 8–9 households for sharecropping once again”* – IDI, ICIMOD. This arrangement has created income opportunities for the poor. A landless Dalit man reported, *“Until now, we had to go to the forest, but at least one member of our family now has employment on this land. It helps cover our expenses and we do not have to buy vegetables anymore”* IWMI-iDE.

Additionally, the study found that the training programs embedded within the ICIMOD and IWMI-iDE schemes, which was part of the SIP initiatives, have played a crucial role in improving the skills and knowledge of participants in vegetable and aquaculture farming.

It is important to note that while SIP technology has yielded positive practical outcomes, some challenges persist for resource-poor Dalit and women farmers. Factors such as the lack of trust and the associated risks of non-payment, due to their disadvantaged economic and social status, have been identified as barriers in accessing land for

lease arrangements. However, the overall impact of SIP technology on increasing access to land, livelihood opportunities, and skill development has been evident in the study findings.

### 4.3. Strategic impacts of SIP

While individual-level practical achievements are important, they alone do not address equity and inclusion concerns related to the benefits of technological advancement. Rules, norms, and relationships affect control and benefits from technology. Measuring strategic changes in power relations is crucial for actual transformation.

#### 4.3.1. Gender stereotypes and roles

The application of SIP technology is accepted as women-friendly because there is no physical risk associated with it. A task that carries risk and physical strength is considered masculine. The ideas of masculinity shape men's role as protectors. Norms as such have shaped who will be responsible for the operation and maintenance of assets like irrigation pumps and, in the long run, ownership and benefits. SIP technology has no visible impact on changes in gender stereotypes within and outside households as could be evidenced by following interview excerpts.

A: *Would your wife operate SIP when it was functional?*

B: *Yes, she knows how to turn on and off SIP. There is no physical danger associated with SIP.*

A: *Does she operate electric pumps as well?*

B: *No.*

A: *Why?*

B: *[...] because there is a danger of electric shocks.*

A: *And do you not fear electric shocks?*

B: *I am aware of situations that can result in shocks. I can deal with it.*

A: *So, are you scared for your wife?*

B: *I am afraid of electric shocks as well, but I tell her not to do it herself. I will do it myself.*

Man, Madhesi, AEPC.

In AEPC and ICIMOD cases, where SIP recipients are well-off farmers, we found women irrigate fields in the absence of husbands or men in the household. The notion that irrigation is a man's job is still intact somehow.

A: *Does your wife irrigate the fields?*

B: *Women do not irrigate fields. They do not know how to irrigate.*

A: *You could teach her like you taught other people.*

B: *She has work at home.*

Man, Dalit Sharecropper, ICIMOD.

Under the IWMI-iDE scheme, while women members of the collectives were found at ease to operate the small-size SIP, operation and maintenance were overseen by men.

#### 4.3.2. Gender relations

Our data confirm the uncontested benefits of SIP. It has enabled women and farmers to cultivate cash crops like vegetables, meet the

family's everyday nutritional and health needs and earn extra income, helping them meet household necessities. However, women have access to SIP technologies through their husbands or men relatives, who are educated and well-networked. Busy with household and farming roles, women do not have time to watch or listen to radio programs, nor are they literate and mobile to visit a government office to gain information on existing subsidies and services. Gender roles for women have changed. However, women have started irrigating the fields without strategic ownership of technology, income, and other benefits.

*He is the "malik [boss]" of everyone. He keeps the income from agriculture and manages remittances from his migrant sons. He looks after his wife, daughter-in-law, and other family members. In our Madhesi community, our women are never ahead of men,* adds a 60-year-old man farmer when we were interviewing a family who had received the ICIMOD SIP, to which everyone present, including daughters-in-law, agreed.

This is particularly found in the case of joint structure households under all three SIP schemes. In the field, we received fewer opportunities of interviewing women privately. Despite our request, we could not control the interview setting. This was also influenced by the assumption that SIP is a technical issue and men could respond better than women. Therefore, even when women were being interviewed, they were constantly looking at their husbands for responses. In some cases, when we were able to remove men from the interview setting, women were still surrounded by mothers-in-law or other women's relatives/neighbors. The inability of women to express views independently reflected tensions around unequal gender relations and subordinated position of women in the family. For instance, we interviewed a single Tharu woman from the IWMI-iDE scheme. Her husband had remarried and never returned. She was living with her in-laws along with her son. She was, making an income through collective farming (supplemented by irrigation technology) and was able to support her son's education and has recently leased land in sharecropping. However, we sensed that she was uncomfortable responding to income-related questions in front of her mother-in-law. So, we made a gesture and asked, 'Do you (have to) ask her before making expenses?' She nodded with a 'yes' gesture in response. Cases such as these demonstrate positional power hierarchies between and among women and men within households.

In this research, we found women's dependency on men for acquiring irrigation technologies and decisions over their use and income, except in migrant households where women have become *de-facto* household heads. The majority of such respondents were non-SIP recipients, from nuclear migrant households and were near landless farmers [less than 0.5 hectares of land] in the collectives. However, in all three schemes, women living with in-laws were found to act under their in-law's guidance and consent. Young mothers *cum* daughters-in-law with migrant husbands were mainly left with very little agency to join saving groups, attend training, or enjoy remittance at their will. They simply work as farm laborer without decision-making power (IDI, Observations). This shows that technology has not necessarily helped to change women's status as helpers on family farms.

Our finding indicates that women possess higher decision-making authority in everyday and operational matters compared to strategic affairs. Women decide mostly about household expenses and children's education. Decisions on crop selection are, in general, joint decisions.

In cases of women de-factor household heads, women mostly make crop selections independently. Decisions such as whether to attend SIP training, to install SIP or not, where to install SIP, and how to use SIP (crop, aquaculture) are taken by men. For example, in the AEPC case, among the four women pump owners we interviewed, only one stated that she had decided to apply for the pump. The other three stated that their family member (husband/brother) had decided to apply in their name.

*[...] In your family, who decides what pump to use for irrigation?*

*My husband...*

*Who decided on installing SIP?*

*My husband...*

*Can you decide on aquaculture, poultry, and goat farming on your own?*

*No.... I cannot.*

*If your husband is not around to help you, can't you do it yourself?*

*There are household chores that I have to do myself.... No vehicle goes towards our field, there are other jobs as well, such as collecting grass for livestock; therefore, it is difficult to manage everything...*

Woman, Madhesi, AEPC.

On one hand, these statements demonstrate a strict demarcation of roles and responsibilities for men and women dictated by local gender norms in the study area, on the other, it is also indicative of additional work burden on women particularly in the absence of men. Similarly, on questions of loans, selection of pumps, and attending training, women opined that permission must be sought from husbands. *[...] When my husband is at home, I consult with him. I should go to the place he tells me to, if he says not to go, then I do not go... I cannot disobey my husband....* Woman, Madhesi, AEPC. Similar sentiments were repeated in the field when women noted that women had rarely been to government offices, seldom stepped outside of their homes, and did not typically access far-off markets.

Additionally, men and women respondents from households with a minimum of 2 Bighas of land (ICIMOD and AEPC) did not seem to feel it was important for women to participate as they were already overburdened with housework and farm work. For most grain producers, the farmers did not need to access far-away markets as intermediaries would visit their homes to collect produced grain. Women typically noted that men in the household led these interactions. However, they said they would also talk to these intermediaries when the men were not home. Men did and were expected to manage market dealings. Women typically from poor households, however, visit local *hattiyas* (weekly markets) in proximity to sell vegetables.

We found that Tharu women enjoy greater mobility than Madhesi and Muslim women. A local politician, economically well-off Muslim businessman, and AEPC SIP recipient, for example, expressed: *Our women do not go to markets... because they do not need to... my wife, who is about 45, has only been to the main city when she has been ill.... There are (other) women here, who are in (farmer) groups, who go to markets [...].* It was interesting to note how women and men from well-off households consider women not participating in 'perma' (labor exchange) practices or wage labor activities as a matter of family pride and status.

We also noted that young and educated daughters-in-law contributing to family income through vegetable and livestock transactions entail better bargaining power within households. However, in general, we found that even though women contribute

equally to farming activities, women have a limited say in agriculture-related decisions. Even if women keep the earnings, record keeping and important decisions on financial issues are made by men.

We found one Madhesi (other castes) woman farmer from a migrant-sending household dealing with land transactions herself. However, when asked how she performed the documentation process related to land dealings, she shared that she takes the help of her maternal brother. On the question of trust by the migrant husband on financial issues, she added, *'trust happens if women perform her duty within norms of the household and take good care of household affairs [children, house, land, properties]. If women are not able to perform the duty of a wife, that may create distrust, objection, and even domestic violence'*, – SIP water user, ICIMOD. Indirect responses to domestic violence over minor issues such as food not being ready on time or burnt food were reported by women using SIP technology in all three schemes. However, the response to domestic violence issues was not direct, mainly because it was found that domestic violence is considered a private affair that should not be discussed with outsiders.

*Domestic violence usually is never reported outside the family. It is resolved within families. It never comes out; neither is there any environment to report it for possible solutions. Woman, Brahmin, ICIMOD.*

Furthermore, technology interacts with local gender norms and relations and influences men and women from various groups differently. Notably, irrigation was traditionally men's responsibility. While irrigation serve as an additional role for women from well-off households as a result of technological simplification, women from migrant households are forced to irrigate the land in the absence of men. Compared to diesel and electric pumps, the advent of SIP, as informed by many women, has helped to save time and labor. Women do not spend time in the field monitoring the water flow and the pump; they neither fear the risk of electrocution. Therefore, they could perform alternative tasks while irrigating the field. However, we observed that women use saved time to perform additional household responsibilities. On the contrary, a shift of irrigation roles from men to women has provided men extra time to get involved in decision-making spaces and networking, such as local politics and leadership roles.

*I wake up at 5 am, start cleaning animal sheds, milking, and preparing tea etc., My old mother-in-law helps with preparing lunch. Then I go 'hattiya' for selling vegetables. I return, and after lunch, I am busy farming, collecting grass etc., until evening. At 7 pm, I prepare dinner for the family and sleep after an hour or two after finishing all work [...] there is too much work ... always something to do... rice, roti, tea [...] cleaning, children [...],* shared a 35-year-old (Madhesi) wife of ICIMOD SIP recipient. Her case is documented as a highly successful example of increased productivity and income for women. What is left undocumented is her hectic schedule and loan obligations. She has withdrawn her membership from various community groups, citing concerns that such involvement would impede her ability to adequately tend to her vegetables, which constitute the primary means of repayment for her loan. Community-based savings groups are a popular and accessible means of securing loans, particularly for women, as they are often located in close proximity, rely on group guarantees in lieu of collateral, and involve individuals with whom the borrower is already familiar. However, the

impact of such financial means on the economic well-being of women is a highly debated issue that warrants further investigation. Therefore, the impact of SIP technology has proven different for men's and women's agency.

### 4.3.3. Property rights and the provision of additional subsidies on SIP

The objective of ICIMOD's SIP scheme was to assess the adoption of the technology by women, who were eligible for a 10% extra subsidy if they owned land. Land rights are widely recognized as a means of empowering women by improving their bargaining power and increasing their economic autonomy (Pradhan et al., 2018; Doss and Meinzen-Dick, 2020). IWMI (forthcoming) shows 24.4 per cent of ICIMOD SIP recipients were women. Within our sample, a few women recipient already had land entitlements, and some had transferred land to their names to receive the additional subsidy. According to the project staff, exceptional efforts were made to convince the families to transfer land in women's names.

*We made huge efforts to convince them. We would say there is no need to transfer all land, but 1–2 kitta (plots) would do. Why would you pay more? Better to transfer 1–2 kitta of land in women's names and get the subsidy. In the case of households with migrants, in-laws had shown concerns that transferring land in the daughters-in-law's name would be a risk since she could elope. In such cases, we would convince them by saying that no one would elope with a small piece of land [...] Man, KII.*

As is evident from the statement, no fixed size was required for the transfer, and a small piece of land was considered sufficient to install the SIP. Usually, not the best piece of land was transferred in women's names. For example, a man Madhesi farmer shared, *'I had told the staff not to install there (wife's land) ... there is too much shade. Later, I moved the panel to this area (with plenty of sun, and land under his ownership)*. As explained in previous sections, decision-making regarding the adoption of SIPs was men's decision. Most of the women who received SIPs were not poor, but were typically elderly and did not farm themselves. Moreover, the transfer of land in women's names in our study areas has provided women with access and management (use) of SIP; however, the control and benefit primarily rest with men.

*He (husband) goes abroad.... I must farm here, and there is also a rebate on registration fees if registered in a woman's name.... That is why it is registered in my name... Woman, Madhesi.*

Interestingly, registering land in women's names has increased to safeguard it from becoming part of family property and prevent potential sharing with brothers, as is evident from this IDI excerpt. *I bought one khatta of land from remittance by my son. The land is registered in my sister-in-law's name [...] If I had registered the land in my name or the name of any of my family members, it would carry the risk of dividing the land among six brothers - Dalit Man, ICIMOD.*

## 5. Discussion

This study adds to a growing body of literature on the adoption of agricultural technologies in Asia, Africa and Latin America by

highlighting the limited adoption of SIP among women and smallholders (Obisesan, 2014; Rola-Rubzen et al., 2020; Bryan and Garner, 2022; Neway and Zegeye, 2022). Factors such as high upfront costs, complex eligibility criteria, a lack of consideration for gendered social networks, and limited outreach and communication regarding SIP to women are prominent in limiting adoption among these groups (Satyavathi et al., 2010; Namara et al., 2014). Even when subsidies, such as those provided by the AEPC, were intended to ensure equitable distribution, they ended up benefitting primarily well-off farmers. Similarly, ICIMOD scheme also resulted in benefits primarily accruing to privileged individuals and households (Namara et al., 2014). Despite being perceived as beneficial and women-friendly, these schemes were found to be ill-suited to the socioeconomic context and experiences of marginal farmers (Mukherji et al., 2017). Additionally, even when SIPs were awarded to women farmers, in most cases, they did not engage in farming themselves or lacked agency to influence strategic decisions such as the adoption and installation of SIP technologies or its multiple uses. In contrast to Nigussie et al.'s (2017) findings, our data does not show women's decision-making power in SIP location choice or water allocation for livestock and domestic use. Instead, their involvement seems primarily focused on irrigation.

The ICIMOD and AEPC SIP schemes have successfully achieved practical livelihood benefits such as enhanced water access, increased crop productivity and income for households with caste, class, and social network privileges (Namara et al., 2014; Wong, 2019). However, the spillover effects on SIP water buyers in terms of improved access to irrigation water were relatively limited. Importantly, the schemes have overlooked underlying gender and social relations within and beyond households. This is evident from the cases of unreported domestic violence, the inability of younger women to exercise free expression in front of older men and women, economic dependency of migrant's wives on in-laws for minor expenses, women's restricted mobility and men's greater participation in public spaces. Women's positions (as mother-in-law, daughter-in-law) within a specific household structure (nuclear/joint) have implications for the adoption of SIPs. As demonstrated by our data, women in nuclear-migrant households or elder women (mothers-in-law or elder daughters-in-law) are more aware about the benefits of SIP, have attended training and keep the earnings themselves; however, in most cases, record-keeping and important decisions on financial issues, including those related to technology and irrigation are done by men. Women decide more about every day and operational matters than performing as farm decision-makers (Maharjan et al., 2012; Belete and Surafel, 2020).

Moreover, with no measures to address deeply entrenched gender and social inequalities, women face additional unpaid household responsibilities, while marginal farmers continue to irrigate under exploitative land-tenant relations (Paris, 1996; Mahat, 2006). In this study, we did not use methods to capture the time usage of men and women. However, interviews indicate women working more than 14 h of unpaid work [5 am–8 pm]. Spending 10.5 h per day in paid and unpaid activities is considered a sign of disempowerment by the Women Empowerment Agriculture Index [WEAI] (Malapit et al., 2013). A study in Ethiopia about the impact of the adoption of small-scale irrigation technologies on women's empowerment exemplifies findings on similar lines. It shows women in technology-adopter households primarily function as family laborer rather than farm decision-makers, thereby, not contributing to women's empowerment (Belete and Surafel, 2020).

Furthermore, SIP technology is considered women-friendly because it involve nil physical risks. Gender stereotypes about irrigation and technology remains unchanged; irrigation is considered men's role, and women's involvement in irrigation is often contingent on men's absence. This demonstrates negotiations of irrigation roles when no other alternatives are available (Siwach, 2020). In usual times, mechanization tasks are dominated by men (Fischer et al., 2018). Similarly, women's mobility to public spaces such as markets is conditioned on their labor needs. These conditions are further complicated by factors such as caste, ethnicity, class, and household structure (Acharya et al., 2010; Datta, 2011). Mobility to such spaces necessitates a significant purpose and adherence to behavioral code, as evident in the case of a woman SIP water user from a migrant household under the ICIMOD scheme and those commuting to government offices, weekly markets, or engaging in daily wage labor or labor exchange practices. Venturing into these spaces without a strong purpose can bring gossip, dishonor, and shame. Women from wealthier sections and those following seclusion-exclusion practices (e.g., the veil system) experience greater mobility constraints, as their honor and family dignity rest on women's shoulders (Siwach, 2020). The majority of women under the ICIMOD and AEPC schemes belonged to affluent households, and relied on men for processing documents and rarely participated in sharecropping (Shah and Memon, 2014). Even when involved in farming, their influence on SIP management decisions was minimal (Ahmed, 2014).

Equal rights to property and access to cultivable land for women and landless farmers are embedded in the Constitution of Nepal (2015), Agriculture Development Strategy (2015), Land Use Policy (2015), and National Land Policy (2019) (Updety, 2021). In addition, the Civil Code (2017) provisions equal inheritance laws ensuring equal rights to sons and daughters over ancestral property regardless of their marital status. Despite legal provisions, implementation continues to be problematic. The tax rebate on women's land registration has motivated a majority to escape higher taxation and led to an increase in land ownership among women from 19.71% in 2011 to 26% in 2015 (Chhatkuli et al., 2020).<sup>5</sup> Our findings, nevertheless, demonstrates the limited impact of tax rebate policy and ICIMOD extra subsidy model on women's empowerment. It has increased women's access to statutory land ownership. However, it has not provided full control over the property (Pradhan et al., 2018).

These findings emphasize the relevance of interventions that target deeply entrenched gendered constraints as outlined in the theory of change framework, as these are critical for women's capabilities, choice and decision-making.

The IWMI-iDE scheme illustrates that low-cost and intersectional projects could benefit the most marginal category of farmers – landless, near landless, women, single women and even Musahars (Dalits) – who were traditionally not involved in agriculture. These collectives were, however, tested on a very small scale. The scheme has enabled women and landless farmers access to land and irrigation water; however, it is inadequate for ensuring year-round food sufficiency – first, the land size is extremely small. Second, small-size sunflower SIP is insufficient for irrigation

<sup>5</sup> The government provides a tax rebate of up to 25 to 50% depending upon different criteria.

beyond small vegetable farms. Forest products and wage labor are still two of the main sources of income for landless Dalits. To determine whether the intervention has facilitated changes in gender and social relations, it is necessary to scale the plan at a wider scale, followed by a longitudinal study to identify the gender egalitarian and sustainable impacts of SIP collectives.

## 6. Conclusion

This research has shown that irrigation schemes designed to improve access to irrigation technologies and services for women and disadvantaged groups has reinforced gender and social inequality. These interventions, which are implemented by both the state and non-state actors overlook the different needs and experiences of men and women farmers, leading to the concentration of irrigation subsidies, services, and technologies among the elite. Additionally, the practice of lumping all women together under the same umbrella has led to shallow targeting of women farmers and the use of one-size-fits-all solutions. This has increase household income and agricultural productivity, but ultimately reinforced and perpetuated unequal gender roles and relations. Our analysis also demonstrates that interventions targeted at marginalized women farmers are limited in scale, inadequate to meet the year-round food requirements of their households and plagued with questions of sustainability. Moreover, like other SIP interventions, they do not prioritize strategic changes in gender and social relations as primary objectives.

In Nepal, GESI is increasingly mainstreamed in institutional policies (e.g., AEPC's 2018 GESI policy), however, it is not reflected in national energy policy or programs. This study validates this gap and shows disregard for issues of inequity, diversity and intersectionality at the program implementation level. These findings highlight the importance of integrating GESI considerations at all levels of energy policy and program implementation to address women's needs and concerns. Establishing clear GESI criteria, distinguishing whether a project is GESI aware, GESI responsive or GESI transformative would ensure more accurate metrics towards women's empowerment (Mahat, 2006; Tavenner and Todd, 2022).

SIP technology may mean different for different women. For example, for women from high caste and class with men in the households, SIP may cause additional irrigation or household roles. In contrast, for marginal land-owning or sharecropper women in a nuclear or migrant household, it may denote comparatively easier access to water as participants (not owners). In some cases, access and management of SIP may or may not be empowering, but the crucial factor would be convenient and timely access to water to reduce expensive irrigation costs and eliminate the need for tiring negotiations to obtain irrigation services from land owners. Likewise, irrigation technologies could have differential impacts on young girls and boys and other relations in the household. This study provides empirical support for the theory of change by Kabeer (2018), which calls for measures to address gendered "structures of constraints" in order to achieve gender transformative interventions. In alignment with the framework, the study underscores the need to investigate larger and diverse strategic impacts of technology interventions and moving away from the simplistic aim of hitting gender targets or limiting achievements to practical outcomes. To facilitate meaningful women's empowerment, it is essential to

recognize the complex intersectional aspect of women's experiences with technology. Essentially, whether or not the SIP outcomes such as access, ownership, or decision-making empower women should entail measurements on whether the achieved outcomes challenge, reinforce or reproduce unequal gender and social relations.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## Author contributions

GS: conceptualization, data curation, analysis, investigation, methodology, writing – original draft, and writing – review and editing. LU: data collection, writing – presentation of a case in the paper, and writing – review and editing. MK: review and feedback and project leader - Solar-Nepal. AM: review, editing, funding, and project leader SoLAR-SA. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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