Promoting Sustainable Agriculture Using Solar Irrigation: Case Study of Small-Scale Farmers in the Philippines

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Abstract

Solar irrigation presents a promising solution to promote sustainable agriculture, particularly in regions facing water and energy scarcity. This case study investigates the benefits and challenges of adopting solar-powered irrigation systems (SPIS) among small-scale farmers in the Philippines. Despite the economic benefits and environmental impacts, its acceptance is challenged by the high investment cost, skepticism about its reliability, and lack of knowledge of the technology. This brief provides policy recommendations to make SPIS accessible to small-scale farmers and broader implications to achieve SDGs 2 and 13 by promoting sustainable agriculture while enhancing food security, reducing poverty, and mitigating climate change in the agriculture sector.

Introduction

Small-scale farmers play a crucial role in global food production, particularly in regions where large-scale commercial agriculture is less prevalent. For instance, the Asia-Pacific region, which holds 60% of the world's population, comprises 70% of small-scale food producers and contributes 80% of the region's food (UN-FAO, 2021). In the Philippines, the agriculture sector is dominated by small farmers cultivating 1 ha or less (57%) and 1-3 ha (32% of the total 7.2 million ha) (World Bank, 2021). However, these farmers generally have limited opportunities for livelihood improvement because of limited farm size, poor knowledge of production and marketing, and difficulties accessing finance (Oakeshott, 2018). They also face challenges in farm production, including limited access to water for irrigation, the increasing cost of diesel for irrigation, and changing climate patterns, which hinder their productivity and livelihoods. In recent years, integrating renewable energy technologies into agriculture production has emerged as a promising solution to address these challenges while promoting sustainability.

Among these technologies, solar-powered irrigation systems (SPIS) have garnered significant attention for their potential to provide small-scale farmers with reliable and affordable water access for irrigation (Guno & Agaton, 2022). By harnessing the power of the sun to pump water from underground sources, rivers, or other surface water bodies, SPIS offers a sustainable alternative to traditional diesel pumps significantly reducing the operational costs and the associated health risks of air pollutants from burning diesel fuel (Guno, 2024). However, the initial investment for SPIS, ranging from USD 1800-2400 (Guno & Agaton, 2022), is too costly for a typical small-scale farmer earning an average of USD 2,000 each year (World Bank, 2021). This brief examines the socio-economic and environmental factors that influence the adoption and scalability of SPIS. By taking the perspective of small-scale farmers in the Philippines, this case study seeks to identify the benefits and challenges that can inform future initiatives to achieve SDGs 2 and 13 by promoting sustainable agriculture while enhancing food security, reducing poverty, and mitigating climate change in the agriculture sector.

Benefits

Cost Savings

Table 1 summarizes the parameter estimations based on the survey conducted with 39 small-scale farmers who either own, transient, or share rice farmland not more than 2 hectares in areas that are either fully irrigated by governmental facilities, rain-fed, or privately irrigated through diesel-powered pumps. The average investment cost for a diesel irrigation system is USD 577 per hectare, including the price of the diesel generator, water pump, drilling of water source, installation costs, and the organized structure to protect the machinery from extreme weather conditions. The fuel consumption depends on the amount of water needed by the crops, which are affected by soil type, temperature, cloudiness, and humidity, as well as the proximity of the farm to the national irrigation system, weather conditions, distance from the water source, topography, and the efficiency of the pump (Guno & Agaton, 2022). On average, each farmer uses 74.55 liters of diesel per hectare in all cropping seasons of the year. Given this value, farmers allocate an average of USD 394 for fuel costs per hectare every year in addition to other operational and maintenance costs of USD 375 per hectare annually. With an average of 36 hours of continuous irrigation at least once a week at the beginning of the cropping season, and while considering the area of the rice paddy, depth of water, and extreme weather conditions, the farmers truly spend huge fuel costs for the irrigation of rice fields.

Table 1. Comparative Summary of Costs for Diesel and Solar Irrigation Systems

	Unit	Diesel	Solar
Average Investment Cost	USD/ha	577	2100
Fuel Consumption	L/ha/yr	74.55	
Fuel Cost	USD/ha/yr	394	
Other Operational and Maintenance Costs	USD/ha/yr	375	140

Data source: (Guno & Agaton, 2022)

On the other hand, the SPIS costs an average of USD 2100 per hectare of initial investment, which includes the pump and controller, solar panel and accessories, grounding, PV Cable, and the cost of mounting, including the labor. The 3hp SPIS is intended to irrigate 2-3 hectares of farmland with a water output of 19m3/h. The SPIS has no operational costs as it runs on energy from sunlight. The operational cost is USD 140/ ha, including the constant cleaning of the panels to ensure the maximum capture of sunlight and the replacement costs for a submersible water pump that needs to be replaced in 8 to 15 years, depending on the siltation and quality of the water source.

Compared to diesel-based irrigation, SPIS is 264% more expensive than diesel. However, its maintenance and operational cost is 239% lower, implying an average annual savings of USD 629/ha from fuel and other maintenance and operational costs. This value is a significant savings from the perspective of small-scale farmers earning an average of USD 2,000 income annually (World Bank, 2021).

Economic Benefits

In terms of economic benefits, Table 2 summarizes the results of the economic analysis for shifting irrigation systems from diesel to solar. The findings show that for every hectare of agricultural land, a farmer can save an average of USD 394 for fuel costs annually and USD 235 for other maintenance and operational costs. This implies that replacing the diesel-powered system with SPIS to perform the same average amount of water output and utilization rate per hectare of land per year saves a farmer up to an average of USD 629/ha annually, which can already recover the cost of the technology in 2.88 years. Moreover, the returns on investment at 315% imply that, while the SPIS may be costly from the perspective of a small-scale farmer, the value of an investment can be recovered and quadrupled at the end of the effective lifetime of the technology.

Table 2. Economic Impacts of the Adoption of SPIS

Economic Indicators	Unit	Value
Fuel Cost Savings	USD/ha/yr	394
Returns on Investment	%	315
Payback Period	years	2.88
Net Present Value	USD/ha	4517

Considering the time value of money at a 10% discount rate and a valuation period of 25 years, the net present value of the technology is USD 4517/ha. This implies that shifting to SPIS generates an additional value of USD 4517/ha to the farmers from the cost savings. This finding supports previous claims that the solar irrigation system is a viable project with a positive net present value (Guno, 2024; Islam & Hossain, 2022; Mishra et al., 2022). Considering the increasing diesel prices (Agaton, 2022; Batac et al., 2022), cost savings are expected to increase, making SPIS more economically viable in the long run. Additionally, SPIS's viability is expected to improve in the following years with the continuously falling prices of solar panels (Gaboitaolelwe et al., 2023; Libra et al., 2023).

Environmental Impacts

Table 3 summarizes the environmental implications of adopting SPIS in terms of saved fossil fuel demand, reduced carbon footprint, and avoided air pollutants. Based on the results of the survey, a farmer can save an average of 75 liters of diesel per hectare annually after shifting to SPIS. These energy savings may seem insignificant, but if the local farmers adopt an own-use SPIS for small-scale farming, this implies a huge potential in reducing diesel demand if implemented on a large scale and collectively throughout the country. Considering the 360 thousand hectares of land not covered by the national irrigation system (Cogay et al., 2020), adopting SPIS implies saving up to 136 million liters of diesel demand annually in the country. This value is significant to the Philippines as the country is too dependent on imported oil from other countries (Collera & Agaton, 2021; Navarro et al., 2023). Hence, the widespread adoption of SPIS contributes to national energy security and sustainability.

In terms of greenhouse gas (GHG) emissions, shifting to SPIS reduces the environmental footprint of agriculture production by 5 tons CO_2eq/ha annually based on the energy fuel saved. Note that this value does not account for the life cycle of the two technologies, including the life cycle cost and environmental impact of the solar PV batteries (Costa et al., 2023; Huang et al., 2023).

Table 3. Environmental Impact of the Adoption of SPIS

Environmental Impact Indicators	Unit	Diesel
Energy Savings	L/ha/yr	75
GHG Emission Reduction	tonCO_2eq/ha/yr	5
Air Pollutant Avoidance		
Carbon monoxide	g/ha/yr	150
Nitrous oxides	g/ha/yr	3
Sulfur oxides	g/ha/yr	194
Particulate matter	g/ha/yr	15

For the air pollutants, shifting diesel to solar results in the avoidance of 150g/ha/yr carbon monoxide, 3 g/ha/yr nitrous oxides, 194 g/ha/yr sulfur oxides, and 15 g/ha/yr particulate matter. These air pollutants have different toxicological impacts on humans, including respiratory and cardiovascular diseases, neuropsychiatric complications, eye irritation, skin diseases, long-term chronic diseases, and major environmental risk factors. Therefore, replacing diesel-based irrigation with SPIS avoids air pollution from the combustion of fuels while reducing the associated health risks to farmers and the communities nearby (Balali-Mood et al., 2016; Reşitoğlu et al., 2014).

Challenges

Despite SPIS's potential economic and environmental benefits, its widespread adoption is challenged by several factors, particularly by small-scale farmers with limited financial and physical resources. The majority (69%) of the surveyed small-scale farmers are willing to purchase or shift to SPIS, 26% are unwilling, and the rest prefer to wait. Farmers who are not willing to purchase SPIS are aware of its benefits but refuse, mainly because of its high initial cost given the small farm area. Other farmers prefer to continue using diesel-powered technology due to familiarity. In some cases, farmers still rely on the irrigation provided by the National Irrigation System and the abundant rainfall during the rainy season while using pumps during summer.

Regarding awareness of SPIS, some farmers are willing but are quite hesitant as they are not fully informed of the SPIS technology, such as the number of years they will last and their efficiency compared with diesel-powered pumps. Other farmers are also postponing investment as they just bought their diesel pumps and will be waiting until the pumps need replacement or the SPIS is assured to be as efficient as the diesel-based irrigation system.

Policy recommendations

Based on the potential benefits and challenges presented, the following are policy recommendations to further promote sustainable agriculture using SPIS.

- *Financing*. Develop subsidies and other financing schemes to assist farmers or cooperatives and tenants who do not benefit from the national irrigation projects, to purchase SPIS.
- *Clustering*. To reduce the cost and maximize the utilization of SPIS, several areas can be clustered for the selected irrigation schemes where water user associations are already established.
- *Technical Assistance and Training*. National government agencies should offer technical assistance and training programs including workshops, project demonstrations, or extension services of experts to help small-scale farmers understand how to use and maintain SPIS effectively.
- *Multiple Use*. To maximize the use of SPIS, utilization other than irrigation must be identified, particularly during rainy seasons and periods when water is no longer needed in production.
- *Monitoring and Evaluation*. Mechanisms for monitoring and evaluation should be established to assess the impact of policies and programs aimed at promoting SPIS adoption. This can inform future decision-making and ensure that interventions achieve their intended outcomes.
- *Research and Development*. The government must provide incentives and funding for the R&D of sustainable technologies for agriculture production to make SPIS more affordable, efficient, and suitable for the needs of small-scale farmers.
- *Information, Education, and Communication*. In cooperation with the academe and non-governmental organizations, the government should increase information dissemination on the advantages of using renewables, highlighting its economic and environmental benefits for a more sustainable agriculture production.

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