Online ISSN: 3082-5121
Aloysian Interdisciplinary Journal
of Social Sciences, Education, and Allied Fields
https://journals.aloysianpublications.com
Volume 1 Issue 5 (2025)

Status of Solar Power Irrigation System (SPIS) Project and Productivity of Rice Farmers in Region XII

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Publication Date: May 23, 2025 DOI: 10.5281/zenodo.16744453

Abstract

A critical component of agricultural productivity is irrigation, which ensures a reliable water supply, especially in arid and semi-arid regions. Solar Power Irrigation System (SPIS) is powered by solar energy, using photovoltaic (PV) technology to convert solar energy into electrical energy to operate a DC or AC motor-based water pump. The study was conducted in Sultan Kudarat, South Cotabato, and Cotabato Province, from March to April 2025, to assess the established solar-powered irrigation systems and the productivity of rice farmers in Region XII. This study explores the socio-demographic profile, farming practices, and the impact of the Solar Power Irrigation System (SPIS) on rice production in Region XII, Philippines. Rice yield increased after SPIS implementation, particularly during the dry season. On average, yields reached 65.86 bags/ha in the wet season and 51.82 bags/ha in the dry season, representing gains of 12.14 and 12.36 bags/ha, respectively. Correspondingly, net income increased to ₱42,872.14 in the wet season and ₱40,590.71 in the dry season, indicating substantial financial improvements for farmers, especially during drought conditions. It is recommended that the Solar-Powered Irrigation System (SPIS) project, which has benefited rice farmers, be replicated and adopted in other water-scarce areas of Region XII to help improve irrigation and boost rice production.

Keywords: *Solar Power Irrigation System (SPIS), rice farmers, agricultural productivity, sustainable irrigation, renewable energy in agriculture, Region XII Philippines, farm income improvement*

INTRODUCTION

Agriculture remains the backbone of many economies, particularly in developing countries, where it employs a large portion of the population and contributes significantly to Gross Domestic Product (GDP). A critical component of agricultural productivity is irrigation, which ensures a reliable water supply, especially in arid and semi-arid regions. However, traditional irrigation systems often depend on grid electricity or diesel-powered pumps, both of which pose sustainability, availability, and cost challenges.

In response to these limitations, solar-powered irrigation systems (SPIS) have emerged as a sustainable, renewable, and cost-effective alternative. These systems utilize solar photovoltaic (PV) technology to convert sunlight into electricity, which powers water pumps used for irrigation. A key advantage of SPIS is its ability to operate independently of grid electricity, making it particularly well-suited for rural and remote areas where infrastructure is lacking (IRENA, 2016).

David (2003) identified poor irrigation performance in the Philippines as a result of multiple interrelated factors: inadequate data for planning, weak institutional capacity, flawed system design, poor construction standards, and fragmented support services. These challenges are exacerbated by complex socioeconomic and institutional frameworks. Mismanagement during the early stages of project implementation, such as errors in estimating irrigable land, has led to underperforming irrigation projects that do not meet their intended goals (Tabios & David, 2014).

Solar-powered irrigation systems offer a viable solution to these entrenched issues. Their advantages include the provision of clean, reliable water; applicability in remote and underserved areas; and cost-effectiveness over the long term (IRENA, 2016).

The performance and effectiveness of any irrigation system, including SPIS, can be evaluated using key metrics such as total irrigated area, crop yield per hectare, cropping intensity, irrigation service fee collection rates, and the overall viability of the agricultural sector (FAO, 2018). Moreover, it is essential to consider external factors such as socioeconomic dynamics, political conditions, and the availability of financial and natural resources when assessing system effectiveness (United Nations, 2015).

In light of these considerations, this study proposes to conduct a survey assessing the current status, effectiveness, and impact of solar-powered irrigation systems on rice farmers in Region XII of the Philippines. The study aims to evaluate the technical feasibility, economic viability, and environmental sustainability of SPIS. Furthermore, it will examine how these systems contribute to improving agricultural productivity and enhancing the livelihoods of smallholder farmers in the region.

REVIEW OF LITERATURE AND RELATED STUDIES

This chapter presents a comprehensive review of relevant literature and previous studies that underscore the importance and relevance of the present research. It draws upon both local and international sources to provide a well-rounded perspective on the development, implementation, and impacts of sustainable irrigation technologies, particularly the Solar-Powered Irrigation System (SPIS). By examining various scholarly articles, policy reports, and empirical studies, this chapter aims to establish a strong theoretical and conceptual foundation for the current study.

Furthermore, it offers a critical synthesis of existing knowledge, highlighting key trends, research gaps, and unresolved issues within the field. This synthesis not only contextualizes the current investigation within the broader academic and practical discourse but also enhances the coherence and focus of the study by identifying how the present research contributes new insights or addresses limitations in previous work. Ultimately, this chapter enables a deeper understanding of the research topic, guiding the formulation of research questions, methodologies, and analytical frameworks used in the succeeding chapters.

As climate change becomes a global concern, countries worldwide are shifting to renewable energy to reduce their carbon footprint and secure a more sustainable future. In the Philippines, heavy reliance on fossil fuels has resulted in high greenhouse gas emissions, prompting the government to explore cleaner, more self-sufficient energy solutions. To address this, the Philippine government is actively promoting the development of alternative renewable energy sources, including solar, wind, and biomass (Gaboitaolelwe, 2023). One of the primary challenges faced by farmers, particularly in regions like the Philippines, is limited access to water for irrigation. Studies indicate that increasing water scarcity—driven by factors such as prolonged drought and unsustainable water usage—directly impacts crop yields and overall farm productivity (Agaton & Guno, 2024). Recognizing this critical issue, the integration of renewable energy technologies into agricultural production has emerged as a viable and sustainable solution. Renewable energy has the potential to mitigate the effects of water scarcity, reduce reliance on fossil fuels, and enhance climate resilience (Karanjikar et al., 2024).

The pursuit of sustainable agriculture is not merely an environmental concern; it is essential for achieving interconnected Sustainable Development Goals (SDGs), including poverty reduction, food security, and sustainable economic growth. A growing global population, increased food demand, and shrinking agricultural land necessitate a transition to sustainable production practices. Globally, methods such as precision agriculture, conservation agriculture, organic farming, agroforestry, and integrated agro-farming systems are being employed to address these challenges (Guno & Agaton, 2022). In the context of sustainable agriculture and global food security, the adoption of efficient irrigation practices is paramount (Touil, 2022). However, traditional irrigation methods are often characterized by inefficiencies and excessive water wastage, leading to significant economic and environmental challenges. Inefficient irrigation practices not only strain freshwater resources but also increase energy consumption and operational costs for farmers (Wanyama, 2023). As a result, the need for innovative and sustainable irrigation solutions has become increasingly evident.

Economic Viability and Farmer Adoption

According to N. Khan et al. (2024), the findings of the study reveal that farmers using solar energy experience a significant improvement in technical efficiency, with 15.8 percent of them achieving a 7.643 percent increase, after accounting for self-selection bias. Furthermore, the positive effects are more pronounced among larger farms and those with greater farming experience. This study underscores the importance of evidence-based approaches in implementing solar energy solutions, highlighting their potential to foster sustainability and equitable development at the grassroots level. The research culminates with policy recommendations that underscore the importance of promoting photovoltaic solar energy use among farmers to improve food security and increase agricultural productivity. Besides, SIF adoption impact analysis in the Philippines revealed that the adoption not only aided in GHG emissions reduction by up to 26.5 tons CO_2eq/ha/year but also contributed to the energy sector by savings between 11.4 and 378.5 L/ha of diesel per year with an average of 315% returns on investment (Guno and Agaton, 2022). Furthermore, SIF adoption in Pakistan has significantly contributed to reducing operational costs, increasing farmers' income, reducing 17,622 tons of CO_2 emissions per year, and saving 41% of water usage (Raza et al., 2022).

Technological Development and System Design

The embedded solar-powered water pump system was considered an efficient irrigation technique for rice fields, and farmers responded favorably. On the other hand, a complicated assembly process is needed for proper installation. It would require more experienced technicians. The said tests prove that performance is not affected by temperature. For fields of equal size, the system fills a holding tank in 2 minutes and 24 seconds. The study reflected direct proportionality between the field area and the water demand (Falcon et al., 2024c). Smart water irrigation has the potential to revolutionize agriculture, enhance environmental sustainability, and address pressing global challenges related to water resources and food security. Recent advancements in solar-powered irrigation systems have led to more efficient and automated agricultural practices. These systems typically consist of solar panels, water pumps, and control mechanisms (Abdelkerim et al., 2013; Waleed et al., 2019). Multithreading designs and embedded systems have improved real-time management and reduced power consumption (Selmani et al., 2018). Integration of sensors, such as soil moisture and water level detectors, enables precise water management (Abdelkerim et al., 2013; Daniyan et al., 2019). Wireless control features, including GSM modules and SMS commands, allow for remote operation and monitoring (Waleed et al., 2019; Daniyan et al., 2019). These systems often incorporate microcontrollers for automation and intelligent decision-making (Abdelkerim et al., 2013; Daniyan et al., 2019). The use of solar power not only reduces energy costs and environmental impact but also enables standalone operation in areas with limited access to conventional power sources (Abdelkerim et al., 2013; Daniyan et al., 2019).

Solar-Powered Irrigation Systems (SPIS) as a Sustainable Solution

In response to irrigation challenges**,** Solar-Powered Irrigation Systems (SPIS) have emerged as a promising technology, particularly for small-scale farmers. These systems leverage solar energy to pump water, providing a reliable and cost-effective irrigation solution. By utilizing solar energy, SPIS offers a sustainable alternative to traditional diesel-powered pumps, reducing operational costs and minimizing health risks associated with air pollution from diesel combustion (Guno, 2024). A study by Escoto & Abundo (2024) titled *"A Framework to Assess Solar PV Irrigation Systems (SPIS) for Sustainable Rice Farming in Sorsogon, Philippines"* investigated the viability and sustainability of SPIS for rice cultivation. The study revealed that 17% of Sorsogon's land area is suitable for SPIS deployment. Specifically, a one-hectare farm was found to require approximately 3.3 kWh of energy daily, powered by a 1.1 kW peak power water pump. The most cost-effective energy configuration, a hybrid solar PV system with a supplementary diesel generator, achieved an annual energy output of 8,547 kWh, with the lowest net present cost (₱1,079,642) and levelized cost of electricity (₱17.79/kWh). Beyond evaluating the economic viability of the Solar-Powered Irrigation System (SPIS), the study also underscored its broader developmental potential, particularly its alignment with global sustainability efforts. The findings revealed that SPIS initiatives can contribute to 27 positive synergies across various Sustainable Development Goals (SDGs), including goals related to clean energy (SDG 7), zero hunger (SDG 2), climate action (SDG 13), and responsible consumption and production (SDG 12). However, the research also identified three potential trade-offs, such as land use conflicts, resource allocation challenges, and potential maintenance burden on end-users, which must be carefully managed to maximize net benefits. (Türkmen, 2020)

Similarly, Jitesh Kumar's (2019) study**,** *"A Research Paper on Solar-Powered Irrigation Systems,"* explores the practical implementation of solar photovoltaic (PV) technology for agricultural irrigation. The study details how solar panels can directly power water pumps and control systems, with grid-connected capabilities enabling surplus energy generation. The research highlights several advantages of solar-powered irrigation, including reduced energy vulnerability and minimal maintenance requirements. Additionally, integrating tracking arrays enhances pumping efficiency. While initial investment costs remain high, the study underscores the long-term economic and environmental benefits of SPIS in addressing persistent irrigation challenges. **A** 2022 study on the *"Performance Assessment of a Solar-Powered Irrigation Project in Nueva Ecija"* confirms that solar-powered irrigation provides a reliable and cost-effective energy solution**,** particularly in rural areas with high diesel prices or limited grid access. The study highlights the suitability of SPIS for both large-scale and decentralized small-scale irrigation applications (Pandya, 2019). Kusakana and Jovanovic (2017) discussed the feasibility of solar-powered water pumping systems in agricultural applications, particularly in remote regions where access to conventional energy sources is limited. Their research found that SPIS systems offer environmental and economic benefits, including lower operational costs and the reduction of carbon emissions.

Economic and Environmental Benefits of Solar Power Irrigation System

Flora (2018) emphasizes the practical benefits of solar energy for farmers**,** including reduced diesel costs, lower pollution, and improved agricultural productivity. In response, the Department of Agriculture (DA) has implemented solar-powered irrigation projects nationwide, utilizing surface water and solar energy to reduce dependence on fossil fuels and groundwater extraction. Within off-grid renewable distributed energy systems, solar irrigation systems allow for boosting local food production, answering basic needs and improving the standard income in a direct way the standard income, thus representing a first solid step in creating a self-sustaining circle. Starting from a close and comprehensive knowledge of the territory, of the targeted users' needs and social conditions, given by the "Employ project," an irrigation system for a specific area is described. Technical-economic feasibility of different solar pumping solutions (water storage, direct photovoltaic coupling, battery storage) has been analyzed for the irrigation system.

Direct solar irrigation system is found to be the simplest, most efficient, and lowest-cost solution (Bricca et al., 2019). Climate change has become a major constraint on the development of rain-fed agriculture due to the decline in rainfall. Therefore, irrigated agriculture is an alternative allowing farmers to have more access to water to meet crop water requirements. However, irrigated agriculture faces a major constraint related to the accessibility of energy sources used in pumping water. In general, the most common energy sources used in pumping water for irrigation are fuel and electricity. Nevertheless, they are very expensive, are not always accessible, particularly in rural areas in Africa, and harm the environment; hence, the need to find alternatives to solve this problem (Diop, 2020).

Global Perspective on Solar-Powered Irrigation

In **India**, the Green Revolution addressed food shortages through high-yield crop production. However, extensive groundwater irrigation using diesel/electric pumps led to environmental issues like air pollution and carbon emissions. As a sustainable solution, India is shifting to solar-powered irrigation systems (SPIS) to reduce fossil fuel dependency and greenhouse gas emissions. With 60% of irrigation relying on groundwater and 26 million pumps powered by coal-fired electricity or diesel, SPIS presents a viable alternative. Studies indicate that solar drip irrigation conserves 50%-60% more water than conventional systems (Thokal, Mohod & Dhande, 2024). Sharanangat (2024) explores automated solar-powered irrigation systems, integrating moisture sensors and smart controls for optimized irrigation efficiency. These systems detect soil moisture levels and adjust water flow accordingly, preventing over- or under-watering. Solar-powered smart irrigation reduces reliance on grid power, minimizes water wastage, and lowers carbon footprints. Further advancements include battery storage, remote monitoring, and GSM-based control systems, allowing farmers to manage irrigation remotely. According to Durga et al. (2024), with the depletion of fossil fuels and the threat of climate change, solar-powered irrigation systems are gaining traction as a sustainable alternative to traditional irrigation methods. The research reviewed confirms the technical, economic, and environmental feasibility of SPIS, reinforcing its role in climate resilience, cost reduction, and enhanced agricultural productivity. By integrating solar irrigation with smart technologies, farmers can conserve water, reduce energy costs, and improve farm efficiency, making SPIS a vital tool for sustainable agriculture worldwide.

Objectives of the Study

The general objective of the study was to assess the established solar-powered irrigation systems and the productivity of rice farmers in Region XII.

Specifically, this study aims to:

1. Determine the socio-demographic profile of the respondents in terms of their age, gender, civil status, educational attainment, sources of income, and years in farming;
2. Determine the profile of the SPIS project in terms of its beneficiaries, location, irrigation fees, year established, number of members, and service area;
3. Determine the farming profile of SPIS in Region XII according to planting schedule, harvesting practices, number of days to harvest, and reason for choosing farming practices;
4. Identify the production of rice farmers before and after SPIS;
5. Determine if there are significant differences in the productivity of farmers before and after the SPIS project; and
6. Identify the issues and concerns related to the SPIS Project.

Materials

The materials required both data collection tools and technological resources to support the research process. Foremost among these were structured questionnaires, which were designed to gather essential information from respondents regarding their experiences, perceptions, and satisfaction with the SPIS. These questionnaires were distributed in printed form, and respondents were provided with ballpoint pens to complete them, ensuring convenience and efficiency during the data-gathering process. In addition, cell phones were used by the research team for various purposes, including coordinating fieldwork, taking notes, capturing on-site images, and recording responses, when necessary, especially in remote areas where traditional means were not feasible.

The primary equipment evaluated in this study was the operational Solar-Powered Irrigation Facilities located across different provinces within Region XII. These facilities served as the central focus of the research, and their performance, functionality, and impact on agricultural productivity were closely examined.

Locale of the Study

The study was conducted in selected provinces within Region XII, specifically targeting South Cotabato, Sultan Kudarat, and North Cotabato. These provinces were chosen as the primary research sites due to the presence of operational Solar-Powered Irrigation System (SPIS) facilities actively serving local farming communities. These facilities represented a range of implementation contexts, allowing for a more comprehensive assessment of the system's effectiveness and impact across different geographical and socio-economic settings.

To facilitate the research process, a verified list of operating farmer groups or associations managing or benefiting from SPIS units was provided. This list served as a reference for identifying respondents and ensuring that the data collected was grounded in direct experience with the technology. Field visits were conducted in coordination with local agricultural offices and community leaders to ensure accessibility and participation.

The data collection phase was scheduled for March 2025. During this period, the research team traveled to the identified locations to administer questionnaires, conduct interviews, and perform on-site observations. The timing of the data collection was planned to coincide with the agricultural season when SPIS usage was expected to be at its peak, thereby allowing for more accurate and relevant insights.

Project Coordination

To ensure the smooth and effective implementation of the study, proper coordination was established with the target municipalities through their respective Municipal Agriculture Offices (MAOs). These offices served as the primary point of contact for initiating local engagement, obtaining necessary permissions, and aligning the research activities with ongoing agricultural programs. During the initial coordination meetings, the research team presented and discussed the full details of the project, including its objectives, scope, methodology, and expected outcomes. This dialogue helped ensure transparency, foster local support, and clarify the roles of all stakeholders involved.

In preparation for data collection, the Municipal Agriculture Offices assisted in the pre-identification of potential sites where operational Solar-Powered Irrigation System (SPIS) units were located. These sites were shortlisted based on accessibility, the functionality of the SPIS units, and the willingness of local farmer-beneficiaries to participate in the study.

Furthermore, coordination was extended to the Barangay Local Government Units (BLGUs) where the identified sites were situated. Engaging with barangay officials was crucial for facilitating fieldwork activities, ensuring the safety of the research team, and securing community cooperation. Barangay leaders were informed about the study's purpose and procedures, and their assistance was sought in mobilizing

Online ISSN: 3082-5121
Aloysian Interdisciplinary Journal of Social Sciences, Education, and Allied Fields
https://journals.aloysianpublications.com
Volume 1 Issue 5 (2025)

respondents, organizing venues (if needed), and addressing any logistical challenges that arose during data collection. Through this multi-level coordination approach, the study aimed to build strong local partnerships and promote an inclusive, community-based research process.

Identification of Respondents

The primary respondents of this study were the members of the operating groups responsible for the day-to-day management and oversight of the Solar-Powered Irrigation System (SPIS) facilities. These individuals were considered key informants, as they possessed direct knowledge and experience related to the planning, operation, maintenance, and overall impact of the SPIS units on their agricultural activities. Their insights were crucial in evaluating the effectiveness, efficiency, and sustainability of the irrigation systems within their respective communities.

To ensure representativeness and manageability of the data collection process, a sample size equivalent to 10 heads of each SPIS beneficiary group was selected to participate in the study. The selection process followed a simple random sampling technique, ensuring that every member, regardless of age, had an equal chance of being included in the sample. This approach allowed for diversity in perspectives while maintaining the objectivity and statistical reliability of the findings.

The inclusion of members from different age groups, farming backgrounds, and levels of involvement in SPIS operations helped provide a well-rounded understanding of how the system functioned in real-world settings and how it affected various stakeholders within the community. Before data collection, the selected respondents were informed of the study's purpose and their voluntary participation, with assurances of confidentiality and ethical handling of their responses.

Preparation of Questionnaires for the Survey

The primary data-gathering instrument for this study was a structured questionnaire, which was developed by the student researcher in close consultation with agricultural engineers who possessed technical expertise in the design, implementation, and operation of Solar-Powered Irrigation Systems (SPIS). Their input was instrumental in ensuring that the questionnaire covered all relevant technical, operational, and user-experience aspects of the SPIS, thereby enhancing the accuracy and depth of the data collected.

To further ensure the academic rigor and appropriateness of the instrument, the questionnaire underwent a thorough review and approval process by the research adviser. The adviser provided guidance on the structure, clarity, and alignment of the questions with the study's objectives and research framework.

The content of the questionnaire was carefully crafted to reflect the key variables and expected outcomes of the study. Additionally, it contained both closed-ended and open-ended questions to capture quantitative data as well as qualitative insights. By aligning the questionnaire with the specific goals of the research, the instrument served as a reliable tool for gathering meaningful and actionable data.

Survey Implementation and Data Collection Process

The survey was carried out by students in close collaboration with designated Agricultural Extension Workers (AEWs) from their respective municipalities. This partnership ensured that both academic rigor and practical field expertise were applied throughout the data collection process. Respondents, who included farmers, community leaders, and other relevant stakeholders, were interviewed according to a structured methodology designed to capture accurate and comprehensive information. All essential data were systematically gathered, recorded, and securely stored for further analysis.

The use of questionnaire surveys provided a flexible and effective approach to gathering a diverse range of information across various contexts. Such surveys were employed in numerous settings, including program evaluations where multiple projects had been implemented. In such cases, input was sought from a wide array of project managers to gain insights into the program's reach, effectiveness, and areas for improvement. Alternatively, the surveys aimed to assess the impact of specific initiatives on business communities within defined geographic locations, capturing localized perceptions and economic effects.

Additionally, a small-scale qualitative survey was conducted as a follow-up to further explore themes or trends identified in the initial quantitative research. This qualitative phase provided deeper insight into stakeholder perspectives, behavioral patterns, and contextual challenges that might not have been fully captured through standard survey instruments. As noted by Stuart MacDonald and Nicola Headlam, such qualitative investigations enhanced the understanding of initial findings and provided valuable context for interpretation.

Data Consolidation and Report Generation

Once the data collection phase had concluded, the responsibility for data consolidation rested with the student. This involved organizing, cleaning, and summarizing the gathered data into a structured format suitable for analysis. Using appropriate analytical tools and techniques, the students interpreted the results in alignment with the study's original objectives. Based on this analysis, the students generated a comprehensive report that outlined the findings, provided evidence-based interpretations, and formulated recommendations for future actions or policy development. This final report served as a critical output of the research process, reflecting both the empirical data and the analytical rigor applied throughout the study.

Research Design and Analysis

The study used a descriptive research tool, using frequency and distribution analysis. The gathered data underwent a thorough and systematic analysis. This analysis involved organizing the data, cleaning it for accuracy, and applying relevant statistical or qualitative methods to derive meaningful insights. The results of this analysis were carefully interpreted in the context of the study's objectives, ensuring that the findings were both relevant and actionable. A t-test was also used in this study to quantify and verify whether the independent variables (e.g., SPIS effectiveness or demographic traits) have a real, statistically significant impact on outcomes like crop yields and return on investment. Once the analysis was complete and the results had been clearly outlined, a comprehensive final report was prepared. This report provided an in-depth overview of the study's findings, included a detailed interpretation of the data, and offered evidence-based recommendations for future action. The final report was submitted after the study, serving as a formal document that summarized the research process, findings, and recommendations for the relevant stakeholders or decision-makers.

RESULTS AND DISCUSSION

This chapter presents the results of the gathered data to evaluate the established solar-powered irrigation systems and the productivity of rice farmers in Region XII.

Socio-Demographic Profile of the Beneficiaries of the Solar-Powered Irrigation System (SPIS) in Region XII

The following tables present the socio-demographic profile of farmers in Region XII, encompassing key variables such as age, gender, civil status, educational attainment, sources of income, and years of farming experience. These individuals are recognized beneficiaries of the Solar-Powered Irrigation System (SPIS) initiative implemented in the region.

Table 2. Socio-Demographic Profile of SPIS Recipients in Region XII in terms of Age.

Recipient	Age (%)
NMSFA	48
CBSIA	54
PSPIS	48
DSPIS	50
SWISAM	51
PPIIA	47
NSWISA	44
CFFA	55
DIA	47
MIA	52
MSWISA	50
SIRSOPIA	51
ISPIS	53
SINSIA	49

Regarding age, the data in Table 2 reveal that the youngest average age of farmers was recorded in Surallah at 44 years, while the oldest was observed in Palimbang at 55 years. The overall mean age across the surveyed associations was 50 years, categorizing most farmers as middle-aged. Younger farmers are usually more physically fit and capable of performing labor-intensive tasks, such as land preparation, harvesting, or herding. Middle-aged adults often have the most technical knowledge and practical farming experience.

This age range suggests that, regardless of being relatively young or older, the farmers remained physically capable and actively involved in cultivating their farmlands productively.

Table 3. Socio-Demographic Profile of SPIS Recipients in Region XII in terms of Gender.

Recipient	Gender (%)	
	Male	Female
NMSFA	90	10
CBSIA	93	7
PSPIS	89	11
DSPIS	95	5
SWISAM	95	5
PPIIA	96	4
NSWISA	88	12
CFFA	93	7
DIA	93	7
MIA	89	11
MSWISA	94	6
SIRSOPIA	95	5
ISPIS	92	8
SINSIA	93	7

The gender distribution among respondents showed significant male dominance, with 92% identified as male and only 8% as female. This highlights the traditionally male-oriented nature of farming in the area, while also emphasizing that gender does not limit one's ability to engage in agricultural activities. It lies in recognizing and addressing the different roles, responsibilities, access to resources, and decision-making power of men and women in farming. Women are less likely to own or have access to modern tools and equipment like tractors, irrigation systems, or mobile phones for market information. Cultural norms may prevent women from using certain types of equipment, especially if it is seen as “men’s work.” Women often face mobility restrictions, limited access to transport, or a lack of information about prices and buyers. Social norms or household responsibilities may keep them from traveling to distant markets.

Male farmers often undertake labor-intensive tasks in agriculture, such as land preparation, plowing, digging, and harvesting heavy crops, due to factors like physical capability, cultural norms, and access to tools and machinery. This division of labor positions men in crucial roles for executing heavy-duty operations essential for farm productivity and efficiency. Studies have shown that in many agricultural settings, men are primarily responsible for tasks requiring significant physical strength, including land preparation and the operation of machinery, while women's contributions are often centered around planting, weeding, and post-harvest processing. These roles are influenced by cultural norms and the availability of resources, which can limit women's access to mechanized tools and training, thereby reinforcing traditional labor divisions (*Gender Issues in Agricultural and Rural Development Policy in Asia and the Pacific*, n.d).

Table 4. Socio-Demographic Profile of SPIS Recipients in the Region in terms of Civil Status.

Recipient	Civil Status (%)		
	Single	Married	Widow
NMSFA		99	1
CBSIA		100	
PSPIS	2	95	3
DSPIS		97	3
SWISAM		100	
PPIIA		100	
NSWISA	2	98	
CFFA		100	
DIA	1	99	
MIA		100	
MSWISA		100	
SIRSOPIA		100	
ISPIS		100	
SINSIA	1	98	1

In terms of civil status, the majority of farmers were married, with an average of 99 married members per association. Only a small fraction were single (0.43%) or widowed (0.57%), indicating a strong representation of family-based farming households. Marital status plays a critical role in shaping the responsibilities and contributions of farmers within agricultural communities. Research consistently shows that the majority of farmers are married, underscoring the dominance of family-based farming systems. For example, a study conducted in selected barangays of Cawayan, Masbate, Philippines, found that 90% of farmers were married, while only 3% were single and 5% were widowed. Similarly, 2016 data from the Philippine Rice Research Institute (PhilRice) confirmed that most Filipino rice farmers were married.

Married farmers often benefit from the availability of family labor, which is essential for efficiently managing agricultural operations and boosting productivity. On the other hand, single farmers may face labor shortages, limiting their ability to handle larger-scale farms. However, with fewer family obligations, they may be more inclined to migrate, pursue training opportunities, or adopt innovative agricultural practices.

Widowed farmers, particularly women, encounter distinct challenges. In some regions, they may face loss of land or property rights, especially where inheritance laws favor male heirs. For example, in certain African countries, widows may lose access to land upon their husband's death due to customary practices. Additionally, widows often assume both farming and household responsibilities, frequently with fewer resources. They may rely on extended family or community networks for labor and support in farming activities.

In agricultural communities, marital status significantly influences farmers' roles and responsibilities. Studies indicate that a substantial majority of farmers are married, highlighting the prevalence of family-based farming households. For instance, research conducted in selected barangays of Cawayan, Masbate, Philippines, revealed that 90% of farmers were married, with only 3% single and 5% widowed (Narciso et al., 2023). Similarly, data from the Philippine Rice Research Institute (PhilRice) in 2016 showed that the majority of Filipino rice farmers were married (PhilRice, 2016).

Table 5. Socio-Demographic Profile of SPIS Recipients in Region XII in terms of Educational Attainment.

	Educational Attainment (%)			
Recipient	High School LEVEL	High School Grad	College Level	College Grad
NMSFA	10	85	2	3
CBSIA	33	65	2	
PSPIS	21	73	6	
DSPIS	6	80	8	6
SWISAM	12	84	4	
PPIIA	21	75	4	
NSWISA	2	89	9	
CFFA	17	80	3	
DIA	14	79	6	1
MIA	8	89		3
MSWISA	7	91	2	
SIRSOPIA	6	86	6	2
ISPIS	8	82	8	2
SINSIA	14	77	8	1

Educational attainment among the respondents reflected a relatively well-educated farming population, with an average of 81.07 members per association having completed high school.

For example, in Albay, the average formal education is eight years, suggesting many have completed some high school education. In Kalinga, the average formal education is nine years, indicating a similar trend (PhilRice, 2016; Salazar et al., 2017; Reyes & Esguerra, 2019). This level of education may support the effective adoption and management of modern agricultural technologies, such as the Solar-Powered Irrigation System (SPIS). The combination of maturity, educational background, and reliance on farming as a primary livelihood suggests a strong potential for sustaining solar-powered irrigation systems within these communities.

Supporting literature reinforces these findings. According to Rana et al. (2021), education and extension services had a statistically significant positive impact on the adoption of SPIS, while factors such as access to credit, farm size, and off-farm income were associated with lower adoption rates. Furthermore, farmers who utilized solar-powered irrigation systems demonstrated a higher livelihood index across various capital indicators—namely human, social, natural, and technical—compared to users of diesel-powered systems.

Table 6. Socio-Demographic Profile of SPIS Recipients in Region XII in terms of Sources of Income.

Recipient	Sources of Income (%)	
	Farming	Business
NMSFA	100	7
CBSIA	100	2
PSPIS	100	10
DSPIS	100	6
SWISAM	100	9
PPIIA	100	5
NSWISA	100	11
CFFA	100	8
DIA	100	10
MIA	100	14
MSWISA	100	2
SIRSOPIA	100	2
ISPIS	100	7
SINSIA	100	4

Farming remained the primary source of income for 100% of the respondents, underscoring the agricultural dependency of the community. Additionally, 6.93% of the farmers reported engaging in business ventures as a secondary income source, demonstrating efforts toward income diversification. It supports both subsistence needs (growing food to eat) and cash income (selling produce). It provides daily survival and economic stability by producing food and goods that can be sold in markets. It allows families

Online ISSN: 3082-5121
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Volume 1 Issue 5 (2025)

to buy the food they do not grow, pay for education, healthcare, and clothing, save for emergency cases, and invest in farm improvements.

Table 7. Socio-Demographic Profile of SPIS Recipients in the Region in terms of Years in Farming.

Recipient	Years in Farming
NMSFA	26
CBSIA	35
PSPIS	23
DSPIS	29
SWISAM	31
PPIIA	26
NSWISA	23
CFFA	30
DIA	21
MIA	29
MSWISA	25
SIRSOPIA	33
ISPIS	35
SINSIA	23

The respondents had been involved in farming for a substantial period, with experience ranging from 21 to 35 years and an average of 27.79 years. This extensive experience contributes to their resilience and adaptability in embracing new technologies. The more years a farmer has been involved in agriculture, the more practical knowledge they acquire, such as crop management, seasonal planting and harvesting, pest and disease control, and soil and water conservation and techniques. They are better at identifying and responding to farming challenges such as drought, pests and diseases, and market prices. Their ability to adjust quickly helps reduce losses and improve farm sustainability. Farmer's experience also leads to smarter decisions in crop selection, input use, and market timing. Experienced farmers tend to know what works best on their land, which boosts productivity and profitability. Long-time farmers often serve as mentors or trainers to younger or less experienced farmers. Their experience becomes a valuable community resource, helping to spread best practices and local wisdom.

According to studies, years of farming experience significantly enhance a farmer's practical skills and decision-making abilities, leading to improved productivity and resilience in the face of agricultural challenges (FAO, 2014; Asfaw & Maggio, 2017).

Solar Power Irrigation System Project Profile in Region XII

The table below outlines a total of 14 solar-powered irrigation systems (SPIS) that have been established in multiple municipalities within the Provinces of Cotabato, South Cotabato, and Sultan

Kudarat. These systems are managed and operated by various farmer associations and cooperatives, with their primary function being to support rice production, a key agricultural activity in the region.

Table 8. Solar Power Irrigation System Project Profile in Region XII in terms of Location.

Recipient	Location
NMSFA	Pigcawayan, Cotabato
CBSIA	Pigcawayan, Cotabato
PSPIS	Kabacan, Cotabato
DSPIS	Kabacan, Cotabato
SWISAM	Kidapawan City, Cotabato
PPIIA	M'lang, Cotabato
NSWISA	Surallah, South Cotabato
CFFA	Palimbang, Sultan Kudarat
DIA	Antipas, Cotabato
MIA	Antipas, Cotabato
MSWISA	Matalam, Cotabato
SIRSOPIA	Senator Ninoy Aquino, Sultan Kudarat
ISPIS	Midsayap, Cotabato
SINSIA	Tulunan, Cotabato

Geographically, Cotabato Province hosted the majority of these systems, with 10 out of the 14 installations located within its boundaries. In contrast, Sultan Kudarat and South Cotabato had 2 and 1 systems, respectively. Agroecological conditions, including farm topography and elevation, affect the choice of management strategies (Tey et al., 2017).

Table 9. Solar Power Irrigation System Project Profile in Region XII in terms of Irrigation Fee.

Recipient	Irrigation Fee per cropping
NMSFA	1000
CBSIA	900
PSPIS	900
DSPIS	1000
SWISAM	990

PPIIA	1500
NSWISA	1000
CFFA	500
DIA	1000
MIA	1000
MSWISA	1000
SIRSOPIA	1000
ISPIS	1000
SINSIA	1000

In terms of irrigation fees, the charges varied significantly, ranging from Php 500 to Php 1,500 per hectare. The most affordable rate was imposed by the Coastal Farmers and Fisherfolks Association at Php 500 per hectare, while the highest fee was levied by the Palma Perez Integrated Irrigators Association at Php 1,500 per hectare. These irrigation fees are used in addition to the maintenance of the SPIS.

Table 10. Solar Power Irrigation System Project Profile in Region XII in terms of Year Established.

Recipient	Year Established
NMSFA	2019
CBSIA	2018
PSPIS	2018
DSPIS	2019
SWISAM	2018
PPIIA	2017
NSWISA	2020
CFFA	2020
DIA	2019
MIA	2019
MSWISA	2017
SIRSOPIA	2017
ISPIS	2020
SINSIA	2018

Regarding the construction timeline, most of the SPIS installations were implemented between 2017 and 2020, with the peak period occurring between 2018 and 2019, during which several systems were installed. Membership sizes within the operating associations also varied considerably, ranging from as few

Online ISSN: 3082-5121
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as 10 members to as many as 46. Notably, the Capayuran-Balogo Solar Irrigators Association had the largest membership base, with 46 members.

Table 11. Solar Power Irrigation System Project Profile in Region XII in terms of Number of Members.

Recipient	Number of Members
NMSFA	25
CBSIA	46
PSPIS	25
DSPIS	37
SWISAM	37
PPIIA	10
NSWISA	15
CFFA	27
DIA	30
MIA	25
MSWISA	30
SIRSOPIA	30
ISPIS	33
SINSIA	21

As gleaned in Table 11, there are 391 total members. 81.59 %, 3.84 %, and 14.58 % are from Cotabato, South Cotabato, and Sultan Kudarat, respectively. More members mean there are more hands available to operate, maintain, and manage the SPIS. Tasks like cleaning solar panels, checking pumps, rotating water access, and conducting repairs are easier when labor is shared, which enhances the system's long-term viability. It also encourages the establishment of irrigation schedules, conflict-resolution policies, and rules for equitable water access, which promote efficiency and fairness in water distribution. In a larger group, members bring diverse experiences and knowledge, which boosts the adoption of best practices for irrigation, crop rotation, and water-saving methods.

The concept of "communality," encompassing commons, community, and polity, is crucial for sustaining these systems amidst changing socio-environmental contexts (Hoogesteger et al., 2023).

Table 12. Solar Power Irrigation System Project Profile in Region XII in terms of Service Area (ha).

Recipient	Service Area (ha)
NMSFA	40
CBSIA	15
PSPIS	4

DSPIS	15
SWISAM	20
PPIIA	7
NSWISA	10
CFFA	32
DIA	3
MIA	15
MSWISA	25
SIRSOPIA	40
ISPIS	24
SINSIA	15

The service area, the extent of land that an irrigation system can effectively cover, is a critical factor influencing both the adoption of Solar-Powered Irrigation Systems (SPIS) and their impact on agricultural activities. In terms of service area, the irrigation systems catered to land areas spanning between 3 and 40 hectares. The largest service coverage, at 40 hectares, was jointly held by the Northern Manuangan Solar Farmers Association and the Sitio Riverside Solar Powered Irrigation Association. Collectively, all 14 SPIS installations were dedicated exclusively to rice cultivation, underscoring the crop's importance and centrality to the agricultural economies of these provinces. Larger areas necessitate more solar panels, higher-capacity pumps, and extensive water conveyance infrastructure to ensure adequate water distribution. Expanding the irrigated area increases energy demands, requiring a proportional increase in solar panel capacity to maintain system efficiency.

Farming Profile of SPIS Recipients in Region XII

Table 13. Farming Profile of SPIS Recipients in Region XII in terms of Planting Schedule.

Recipient	Planting Schedule		
	First Cropping	Second Cropping	Third Cropping
NMSFA	May	October	March
CBSIA	May	October	Weather Dependent
PSPIS	May	November	Weather Dependent
DSPIS	May	November	Weather Dependent
SWISAM	May	October	Weather Dependent
PPIIA	March	August	Weather Dependent
NSWISA	May	October	February
CFFA	May	November	No crop planted
DIA	January	June	Weather Dependent
MIA	May	October	February
MSWISA	May	October	Weather Dependent

SIRSOPIA	May	October	Weather Dependent
ISPIS	January	May	Weather Dependent
SINSIA	May	November	Weather Dependent

Cropping activities are categorized into three distinct periods: First Cropping, Second Cropping, and Third Cropping, each with clearly defined planting and harvesting timelines tailored to local climatic conditions.

Each association follows a schedule based on regional weather patterns, resource availability, and specific agricultural objectives. Notably, all associations included in the study utilize combined harvesters and mechanized tools that significantly enhance labor efficiency. This widespread adoption of mechanization reflects a collective shift toward modernized farming techniques aimed at reducing manual labor, minimizing harvesting time, and addressing rural labor shortages. The use of such equipment signifies a broader move toward increased efficiency and sustainability in rice production.

Planting schedules across associations are largely dependent on weather patterns, particularly rainfall, underscoring the importance of climatic conditions in determining optimal planting times. For instance, the First Cropping season is consistently observed to begin in May, regardless of location, indicating a shared understanding of seasonal reliability during this period. The Second Cropping season typically follows between October and November, suggesting a prevalent biannual cropping pattern designed to optimize yields during favorable weather conditions. In contrast, the Third Cropping period exhibits considerable variability: while some associations proceed with planting between February and March, others forgo this cycle altogether due to constraints such as inadequate rainfall or limited resources.

A closer examination of specific regions, such as Northern Manuangan and Capayuran-Balogo, reveals a strong reliance on natural rainfall as the primary source of irrigation, particularly critical in rice cultivation. This dependence highlights the importance of synchronizing planting schedules across associations to maximize the efficient use of limited water resources. Synchronization also facilitates streamlined harvesting operations and mitigates pest infestations, as uniform crop stages across fields hinder the proliferation of pests that thrive under staggered planting conditions.

The study further emphasizes the importance of adaptability in the face of changing weather patterns. Many associations reported adjusting their planting and harvesting schedules in response to climate variability, including prolonged dry spells and erratic rainfall. These adaptive strategies demonstrate the farmers' resilience and responsiveness to environmental challenges, enabling them to sustain productivity and reduce the risk of crop failure.

Table 15. Farming Profile of SPIS Recipients in Region XII in terms of Number of Days to Harvest Rice.

Recipient	Number of Days to Harvest
NMSFA	110
CBSIA	105
PSPIS	115
DSPIS	115
SWISAM	105

PPIIA	110
NSWISA	105
CFFA	110
DIA	105
MIA	105
MSWISA	110
SIRSOPIA	105
ISPIS	105
SINSIA	110

The duration from planting to harvest is relatively consistent, ranging from 105 to 115 days, which aligns with the standard growth cycle for rice crops. This uniformity indicates a shared understanding of crop development timelines and reinforces the presence of standardized agricultural practices among the associations. The uniformity in the number of days to harvest within the area can be largely attributed to the specific rice variety that the farmers have planted. Many farmers in the region cultivate the same or similar high-yielding and climate-resilient rice varieties, which have consistent growth durations. Additionally, government intervention plays a significant role in this uniformity, as the distribution of certified rice seeds through agricultural programs ensures that farmers receive standardized seed varieties. These government-supported seed distribution initiatives not only promote the use of improved rice varieties with predictable maturation periods but also help enhance overall crop productivity and food security. Consequently, the combination of planting similar rice varieties and the government's role in providing these seeds contributes to synchronized harvesting times across the farming communities.

Table 16. Farming Profile of SPIS Recipients in Region XII in Terms of Reason for Choosing Farming Practices.

Recipient	Reason for Choosing Farming Practices		
	Synchronize planting	Easy method of harvesting	Rainfall dependent
Different SPIS respondents in Region XII	125	140	110

One of the most frequently cited motivations for current planting practices is the need for synchronized planting. This strategy not only maximizes harvesting and water-use efficiency but also contributes to a more coordinated and manageable farming cycle. The lists of 14 SPIS (Small-Scale Irrigation Support) recipient organizations in Region XII indicate their harvesting method. All the listed

Online ISSN: 3082-5121
Aloysian Interdisciplinary Journal of Social Sciences, Education, and Allied Fields
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recipients use the Combined Harvester for their harvesting practices. It indicates that 100% of the SPIS recipients use combined harvesters for harvesting their crops. A multi-functional harvester is a modern agricultural machine that performs three functions at once: reaping, threshing, and winnowing, which significantly increases harvesting efficiency. Rainfall patterns play a crucial role in supporting healthy crop growth, particularly in areas that receive limited water distribution from irrigation systems. Consistent and well-timed rainfall can help maintain adequate soil moisture levels, which are essential for seed germination, nutrient uptake, and overall plant development. This is especially important in upland or remote areas where irrigation canals may be lacking and depend on water in their SPIS.

Table 17. Production (bag/ha) of Rice Farmers before and after the Solar Power Irrigation System Project, 2024.

Production (bag/ha) of Rice Farmers before and after Solar Power Irrigation System

Recipient	Before Solar Power Irrigation System		After Solar Power Irrigation System		Mean	
	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season
NMSFA	69	50	79	59	74	54.5
CBSIA	73	56	80	67	76.5	61.5
PSPIS	67	50	77	65	72	57.5
DSPIS	63	52	72	60	67.5	56
SWISAM	58	45	67	54	62.5	49.5
PPIIA	49	36	69	55	59	45.5
NSWISA	48	34	85	76	66.5	55
CFFA	57	45	68	53	62.5	49
DIA	54	43	65	55	59.5	49
MIA	63	48	76	64	69.5	56
MSWISA	48	33	54	37	51	35
SIRSOPIA	50	39	62	45	56	42
ISPIS	65	49	73	54	69	51.5
SINSIA	73	59	80	68	76.5	63.5
Mean	**59.79**	**45.64**	**71.93**	**58.00**	**65.86**	**51.82**
SD	**9.07**	**7.95**	**8.37**	**9.92**	**7.77**	**7.62**

Table 17 presents detailed data on the yield of rice production, expressed in bags per hectare, for 14 farmer associations located in Cotabato, South Cotabato, and Sultan Kudarat. The data compares yields before and after the adoption of Solar-Powered Irrigation Systems (SPIS) during both wet and dry cropping

seasons. The results consistently demonstrate a positive impact of SPIS adoption, with all 14 associations reporting yield increases in both seasons.

The average production yield of rice farmers before the adoption of SPIS during wet season gained 59.79 bags/ha and 45.64 bags/ha in dry season while after the adoption of SPIS, farmers average production yield during wet season was 71.93 bags/ha and 58.00 bags/ha on dry season which means that there was an increase on 12.14 bags/ha on wet season and 12.36 bags/ha on dry season respectively. Regardless of the adoption of SPIS, the average production yield on the wet season was 65.86 bags/ha and 51.82 bags/ha on the dry season.

The data demonstrate that SPIS led to a substantial and consistent improvement in rice production for all recipients, regardless of the season. Dry season productivity improved significantly, closing the gap between seasonal yields. This suggests that SPIS effectively mitigates the impact of water scarcity, which is typically more pronounced in dry months.

The implementation of SPIS led to marked improvements in agricultural productivity, with more pronounced yield gains observed during the dry season. This suggests the critical role of SPIS in mitigating the effects of water scarcity during rain-deficient periods.

Beyond the local context, global research supports the viability and sustainability of solar-powered irrigation. SPIS has emerged as a cost-effective and environmentally sustainable alternative to conventional diesel or electric pumps. Studies conducted in India, for instance, show that SPIS adoption can result in productivity increases of 9–10% in crops such as rice and wheat (Kishore et al., 2017). Furthermore, in drought-affected regions of Bihar, India, SPIS enabled farmers to continue paddy cultivation while 40% of surrounding farmland remained fallow (Kishore et al., 2017b). Additional research has found that low-cost solar pumps offer positive benefit-cost ratios ranging from 1.02 to 1.18, depending on the season (Kundu et al., 2023), reinforcing the economic feasibility of the technology.

Cobb-Douglas production function analysis further indicates that SPIS-based rice farming is significantly influenced by factors such as the cost of solar irrigation, seeds, harvesting, and transportation. These differ from non-SPIS systems, where labor cost tends to play a more dominant role (Shakib et al., 2023). Moreover, diesel- and electricity-based irrigation systems increasingly face challenges due to rising fuel costs and unreliable power supplies, making solar alternatives more attractive (Kundu et al., 2023). Although solar pumps require higher initial investments, they are both economically viable and environmentally sustainable. These benefits underscore the importance of supportive policies to promote the wider adoption of solar irrigation, particularly in regions vulnerable to water scarcity.

In Southeast Asia, including Thailand, irrigation availability has historically shaped rice production trends, especially during dry seasons. From the late 20th to early 21st century, rice yields in Thailand increased steadily due to expanded irrigation infrastructure, high-yielding varieties, and improved agronomic practices. However, recent fluctuations in production, partly due to changing water availability, further emphasize the importance of stable and sustainable irrigation solutions like SPIS in ensuring long-term agricultural productivity (Suwanmontri et al., 2020).

Additional evidence from a study conducted in Agusan del Sur, Philippines, using both quantitative and qualitative approaches, highlighted the economic, environmental, and social benefits of SPIS implementation. Key findings included a doubling of rice yields during the dry season in municipalities such as San Francisco and Sta. Josefa, along with a significant reduction in fuel costs, from 69% down to 34%, following the adoption of SPIS. Beneficiary assessments across four municipalities revealed varying levels of satisfaction with SPIS utilization and extension services, underscoring the critical role of government agencies in enhancing farmer productivity and promoting sustainable agricultural practices.

Environmentally, the shift to SPIS led to measurable benefits, including an annual reduction of 14,803.826 gallons of carbon dioxide emissions and significant decreases in fossil fuel consumption, saving approximately 181.774 gallons of gasoline and 1,268.173 gallons of diesel per year (Dalman et al., 2024). These findings underscore the environmental sustainability and cost-effectiveness of solar-powered irrigation as a viable alternative to conventional systems.

Online ISSN: 3082-5121
Aloysian Interdisciplinary Journal of Social Sciences, Education, and Allied Fields
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Table 18. Net Income of SPIS Recipients in Region XII Before and After the Use of Solar-Powered Irrigation Systems, 2024.

Recipient	Before Solar Power Irrigation System		After Solar Power Irrigation System		Mean	
	Wet Season	Dry season	Wet Season	Dry season	Wet Season	Dry Season
NMSFA	43,760.00	32,360.00	55,760.00	52,000.00	49,760.00	42,180.00
CBSIA	47,920.00	40,680.00	56,200.00	58,240.00	52,060.00	49,460.00
PSPIS	43,680.00	43,600.00	56,080.00	52,000.00	49,880.00	47,800.00
DSPIS	39,520.00	35,500.00	49,880.00	54,080.00	44,700.00	44,790.00
SWISAM	33,320.00	29,160.00	44,680.00	46,800.00	39,000.00	37,980.00
PPIIA	25,960.00	29,900.00	46,760.00	37,440.00	36,360.00	33,670.00
NSWISA	24,920.00	51,740.00	63,400.00	35,360.00	44,160.00	43,550.00
CFFA	32,580.00	27,720.00	46,720.00	46,800.00	39,650.00	37,260.00
DIA	30,160.00	31,200.00	43,600.00	44,720.00	36,880.00	37,960.00
MIA	39,520.00	40,560.00	49,300.00	49,920.00	44,410.00	45,240.00
MSWISA	24,920.00	12,880.00	34,160.00	34,320.00	29,540.00	23,600.00
SIRSOPIA	25,000.00	20,800.00	40,480.00	40,560.00	32,740.00	30,680.00
ISPIS	42,100.00	31,160.00	52,920.00	50,960.00	47,510.00	41,060.00
SINSIA	47,920.00	44,720.00	59,200.00	61,360.00	53,560.00	53,040.00
Mean	**35,805.71**	**33,712.86**	**49,938.57**	**47,468.57**	**42,872.14**	**40,590.71**
SD	**8,705.23**	**10,111.31**	**7,912.10**	**8,265.90**	**7,380.69**	**7,825.05**

Table 18 shows the average net income before and after the implementation of the Solar Power irrigation System (SPIS) of rice production in Region XII in two farming seasons: wet and dry. Before the adoption of SPIS, the average net income of farmers during the wet season was ₱35,805.71 and ₱33,712.86 in the dry season. After the adoption of SPIS, the average net income of farmers during the wet season was ₱49,938.57 and ₱47,468.57 in the dry season. The average net income on both seasons before SPIS was ₱42,872.14, and after the SPIS was ₱40,590.71, respectively. It has an average income increased on wet at ₱14,132.86 and ₱13,755.71 in dry season.

There was a significant average income increase in both seasons, indicating that SPIS contributed to higher productivity and earnings, and it helped even more in dry months. It demonstrates that SPIS not only enhances farm profitability but also offers a reliable and sustainable solution during water-stressed periods.

These outcomes underscore the effectiveness of SPIS as a sustainable, cost-efficient investment that promotes both agricultural productivity and income stability throughout the year.

Further supporting this evidence, Sunny et al. (2022) reported that insufficient rainfall and limited surface water resources during the dry season in northern Bangladesh have led to increased reliance on groundwater. Traditional irrigation systems in the region, which are primarily diesel- or electric-powered, are associated with higher operational costs, energy demands, and environmental degradation. In contrast, solar irrigation systems harness the region's abundant sunlight, offering a clean and renewable alternative that addresses these challenges effectively.

Similarly, Mitra et al. (2021) emphasized that solar irrigation pumps (SIPs) are increasingly promoted across South Asia as a strategy to overcome water-energy constraints and enhance agricultural resilience. The economic benefits are significant. For example, rice farmers who adopted solar irrigation reported a 1.88% to 2.22% reduction in irrigation costs, a 4.48% to 8.16% increase in return on investment (ROI), and a 0.06% to 0.98% reduction in total production costs compared to non-adopters.

A study by Agaton et al. (2024), using a real options approach, confirmed the economic viability of SPIS for small-scale rice farmers in the Philippines. The findings indicated that the technology offers cost savings and favorable investment returns, making it a practical solution for sustainable agricultural production.

Additionally, Shakeb et al. (2023) found that solar irrigation yields higher profitability in *boro* rice production in Bangladesh. Their analysis showed that net returns and benefit-cost ratios (BCRs) for solar-powered rice production per hectare significantly outperformed those of conventional systems in regions such as Rangpur and Bogura.

In Indonesia, a community-led initiative introduced an automated solar-powered irrigation system to improve the low productivity of rainfed lowland rice during the dry season. The initiative included farmer training and promoted the cultivation of chili using the new system. The outcomes were notable—chili yields reached 6.75 t/ha, generating IDR 46,182,061 in income. The investment showed strong viability, with a net present value (NPV) of IDR 154,918,858, an internal rate of return (IRR) of 36% (well above the 6% discount rate), a profitability index (PI) of 1.99, and a payback period of only 2.5 years. Furthermore, 53% of participating farmers expressed interest in adopting the technology for the next dry season, highlighting its perceived benefits and practical appeal (Ardiansyah & Agustina, 2023).

Issues and Concerns on the Solar Power Irrigation System and Production of Rice Farmers in Region XII

A comprehensive survey was conducted among 14 farmer and irrigator associations to identify the key challenges affecting agricultural productivity and sustainability in their respective areas. The findings revealed a broad spectrum of issues, ranging from technical to economic, which collectively hinder the growth and resilience of local farming systems.

Online ISSN: 3082-5121
Aloysian Interdisciplinary Journal of Social Sciences, Education, and Allied Fields
https://journals.aloysianpublications.com
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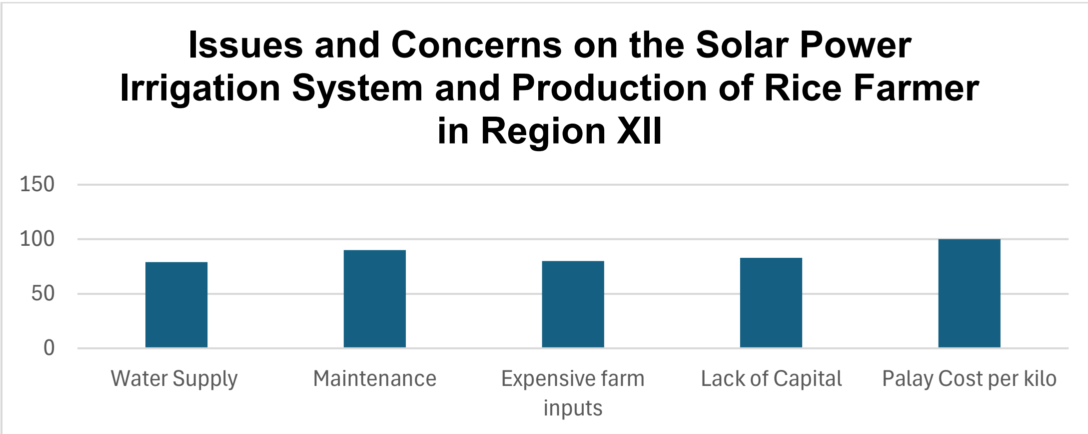

Figure 2. Issues and Concerns on the Solar Power Irrigation System and Production of Rice Farmers in Region XII

As illustrated in Figure 2, the survey identified several critical challenges faced by farmers with their agricultural operations and the use of the Solar-Powered Irrigation System (SPIS). The primary concerns included the fluctuating price of palay (unhusked rice) per kilo, the maintenance and upkeep of irrigation systems, the lack of access to capital, the high cost of farm inputs, and the availability of a reliable water supply.

Among these, the most frequently reported concern was the low and unstable buying price of palay. Farmers expressed dissatisfaction with the inconsistency and overall decline in market prices, which significantly affects their income and profitability. Even when production levels are high, thanks in part to improved irrigation, low selling prices can negate financial gains.

The second major issue identified was the maintenance of the SPIS itself. Farmers face difficulties in sustaining the operational efficiency of the system due to factors such as a lack of technical know-how, the high cost of repairs, and the unavailability of local technicians or support services. Equipment such as solar panels, water pumps, and control units requires regular maintenance, and when breakdowns occur, many farmers are either unprepared or financially incapable of addressing the problem promptly. This can lead to system downtimes, affecting irrigation schedules and overall crop health.

A third concern is the lack of access to capital or financial resources. Many farmers struggle to secure loans or funding that would enable them to adopt new technologies, expand their operations, or even cover recurring expenses such as labor, fuel, and other operational costs. Without sufficient financial support, the potential benefits of SPIS, such as improved yields and efficiency, remain out of reach for many smallholder farmers.

Additionally, farmers cited the high cost of farm inputs, including seeds, fertilizers, and pesticides, as a major challenge. These inputs are necessary to maximize the productivity made possible by improved irrigation, yet their rising costs limit farmers' ability to fully benefit from systems like SPIS.

Finally, water supply availability emerged as a key issue. While SPIS aims to provide a consistent irrigation source, farmers noted irregular or insufficient water flow at times. This may be due to limited solar energy during cloudy or rainy days, inadequate storage systems, or distribution inefficiencies within the irrigation infrastructure.

As noted by F. Hussain et al. (2023), a holistic and regulated approach is essential to ensure that the adoption of solar irrigation supports long-term agricultural sustainability, rather than creating new environmental and economic challenges. In Pakistan, for example, SPIS is emerging as a cost-effective and sustainable irrigation solution, particularly for off-grid and remote areas. However, these systems face notable challenges, including high upfront costs, limited access to spare parts, lack of technical expertise, weak regulatory frameworks, insufficient financing options, and limited social acceptance. The most pressing concern is the risk of groundwater overexploitation resulting from unregulated SPIS use.

Summary of Findings

The survey of Solar-Powered Irrigation System (SPIS) recipients reveals important demographic, socio-economic, and operational insights that impact the sustainability and effectiveness of SPIS interventions.

Based on the socio-demographic profile of the respondents, most of the farmers are married and 92% male and 8% female, categorized as middle-aged. They were on the farm, averaging at 27.79 years of experience, and their main source of income relied on farming, and they also engaged in business ventures as another source of income for daily survival. The highest educational attainment was a high school graduate, representing 81.07% of the respondents.

Solar Power Irrigation System is mostly located in Cotabato Province and managed by various farmers' associations and cooperatives since it was established from 2017-2020, with an average number of members consisting of 28. They were also collecting fees for irrigation ranging from 500.00 up to 1,500.00 per hectare, servicing between 3 to 40 hectares.

The farming profile of the respondents followed a different planting schedule on first cropping from January to May and May to November for their second cropping schedule, but weather weather-dependent at the time for the third cropping season. They have the same rice varieties on different days to harvest, ranging from 105-115 days, as they have received farm input distribution from the government interventions. Some reasons for choosing farming practices are rainfall-dependent, synchronized planting, and an easy method of harvesting. It was documented that among the 14 established SPIS, only 64% were fully functional and 36% were partially functional, and in all established SPIS, it was reported that 80% of the water reservoirs and 50% of the solar panels had an infrastructure issue.

Rice production in Region XII was noticeable after the establishment of the Solar Power Irrigation System (SPIS) and showed documented yield increases during both seasons. In average, wet season has 65.86 bags/ha while dry season has an average of 51.82 bags/ha which clearly states that SPIS while the average net income rose to ₱42,872.14 in the wet season and ₱40,590.71 in the dry season which means that the production and net income of rice farmers has a significant difference in both seasons, more effectively in dry season, after the adoption of SPIS.

The fluctuating palay cost per kilo is the leading issues and concern in all respondents followed by the maintenance of the SPIS which cost very expensive. It was also noted that lack of capital, expensive farm inputs and water supply at-least in all areas was documented that hinders rice production and income of farmers in Region XII.

Conclusion

The implementation of the Solar-Powered Irrigation System (SPIS) in Region XII has demonstrated a clear and positive impact on both rice production and farmer income. Yield data reveal a significant increase in productivity on both wet and dry seasons, with average gains of 12.14 bags per hectare during the wet season and 12.36 bags per hectare during the dry season. The slightly higher improvement during the dry season underscores the effectiveness of SPIS in addressing water scarcity and enhancing resilience during drought periods.

Economically, rice farmers experienced marked improvements in net income following the adoption of SPIS, confirming that the system not only boosts agricultural productivity but also contributes to the financial stability of farming households, particularly in water-limited conditions.

However, despite these benefits, several challenges persist that hinder the full potential of SPIS. Issues such as fluctuating palay prices, high maintenance costs, limited access to capital, expensive farm inputs, and inconsistent water supply in certain areas continue to pose significant barriers to maximizing rice production and income generation. Addressing these concerns is crucial to ensuring the long-term success and sustainability of SPIS in the region.

Recommendations

To address the challenges surrounding the Solar-Powered Irrigation System (SPIS) and to help rice farmers achieve optimal production yields, the government and relevant stakeholders must prioritize the repair and upgrading of existing SPIS infrastructure. Strong government support is essential to promote accountability and foster a sense of ownership among local communities, particularly the 14 beneficiary farmer associations.

A regular maintenance program should be established with clearly defined roles and responsibilities, ideally in partnership with Local Government Units (LGUs), to prevent system failures and extend the operational life of the equipment. In parallel, comprehensive training and extension services must be provided to farmer associations to enhance their technical capacity in operating and maintaining SPIS systems. These should include workshops on efficient water management, solar panel upkeep, and irrigation scheduling to improve system utilization and overall performance.

Beyond technical and economic aspects for critical issues, solutions may include providing subsidized inputs, offering affordable credit through cooperatives or microfinance institutions, and facilitating bulk procurement partnerships with the Department of Agriculture (DA) or private suppliers to reduce production costs. Finally, the DA should conduct regular technical assessments of SPIS infrastructure and implement a monitoring system to track irrigation efficiency, yield outcomes, and system performance. These combined efforts will help ensure the sustainability and long-term impact of SPIS on rice production in Region XII.

The Solar-Powered Irrigation System (SPIS) is a commendable initiative and intervention by the Department of Agriculture for rice farmers in Region XII, particularly in water-scarce and remote areas lacking irrigation canals. This program has revived the lost hope of many farmers, transforming their struggles into renewed opportunities for increased productivity and sustainable livelihoods, as government officials responded to their long-standing concerns and needs, which should be replicated not only in Region XII but also in other Regions of the Philippines that have not yet established SPIS.

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