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Sustainability of Solar-Powered Pump Irrigation System (SPIS) As an Alternative Irrigation Method

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***Abstract*—** This study determines the sustainability of the Solar-Powered Pump Irrigation System (SPIS) as an alternative irrigation method, describes its implementation in Juban, Sorsogon, assesses its role in improving rice productivity, gathers farmer feedback, and proposes relevant policy outputs based on the findings. A descriptive qualitative research design was used to examine farmer experiences and system performance across two SPIS project phases. Data were collected through documentary material from NIA and interviews involving twelve purposively selected farmer-beneficiaries. Results indicated that SPIS supported more consistent water access, increased rice yield for several farmers, and enabled all respondents to plant twice annually. Many also reported higher net returns due to reduced fuel and labor costs. Despite these gains, challenges such as pump malfunctions, limited canal reach, and solar dependency during cloudy weather affected system efficiency. Farmers perceived SPIS as cost-saving, environmentally friendly, and generally easy to operate, but noted the need for better infrastructure and maintenance support. Based on the findings, the study developed a policy brief that recommended improvements in site assessment, infrastructure upgrades, technical services, and farmer capacity-building. Overall, SPIS demonstrates strong potential for sustainable, climate-resilient rice farming when paired with localized policy interventions and ongoing institutional support.

***Keywords*—** Solar-Powered Pump Irrigation System, sustainability, rice productivity, farmer feedback, policy brief.

I. INTRODUCTION

Agriculture remains a vital component of national development and rural welfare in the Philippines, closely tied to public service delivery and the broader mandates of public administration. It is not only a source of livelihood for millions of Filipinos but also a strategic sector in ensuring food security, generating employment, and reducing poverty. In this regard, the government's role in agriculture extends beyond production, it includes the provision of services, policy support, and infrastructure, particularly irrigation.

In regions like Juban, Sorsogon, rice farming is heavily dependent on traditional irrigation practices such as rainfed systems and diesel-powered pumps. These methods are inefficient, unreliable, and vulnerable to weather disturbances. Moreover, the rising cost of fuel and maintenance further burdens smallholder farmers. The introduction of Solar-Powered Irrigation Systems (SPIS) offers a promising innovation that integrates renewable energy with agricultural infrastructure. SPIS provides farmers with reliable access to water while reducing dependence on fossil fuels and enhancing productivity. This shift aligns with sustainable public administration by promoting technological solutions that address rural development needs.

Public institutions such as the National Irrigation Administration (NIA), established under Republic Act No. 3601, are tasked with developing and managing irrigation systems, including SPIS. This mandate reflects the government's commitment to inclusive and sustainable agricultural growth. These initiatives support the transformation of rural agricultural systems in line with national development goals.

The Philippine government's support for SPIS is further rooted in key legislative frameworks. Republic Act No. 9513, or the Renewable Energy Act of 2008, promotes solar energy investments, while Republic Act No. 10969, or the Free Irrigation Service Act, eliminates irrigation service fees for smallholder farmers. These policies are executed through the Department of Agriculture (DA) and NIA in collaboration with Local Government Units (LGUs). The DA formulates national strategies, allocates funding, and provides training and technology, while LGUs implement and manage SPIS projects locally.

This intergovernmental coordination ensures that SPIS projects are contextually grounded, community-responsive, and aligned with Sustainable Development Goals, specifically SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), and SDG 7 (Affordable and Clean Energy). SPIS enhances agricultural resilience, equitable water access, and low-carbon farming practices.

Climate variability continues to challenge rice production. Prolonged droughts, excessive rainfall, and typhoons threaten farming systems. Stuecker et al. (2018) linked climate variability to declining rice yields, highlighting the urgency of adaptive technologies. SPIS serves as a climate-resilient irrigation alternative. Studies from Bangladesh (Kundu, Islam, & Paul, 2021) and Bicol (Escoto, 2023) demonstrated that SPIS sustains irrigation during dry spells, mitigating crop failure.

Technologically, SPIS uses solar photovoltaic panels to run water pumps, offering a clean and cost-efficient solution for off-grid areas. Chandel et al. (2015) emphasized SPIS's advantages in reducing environmental impact and operational costs. Ashraf and Jamil (2022) highlighted its benefits in greenhouse gas reduction and energy independence, while Ashrafi Goudarzi et al. (2019) and Rezk et al. (2019) noted that hybrid solar and PV-battery systems improve efficiency, scalability, and system reliability.

Beyond irrigation, SPIS contributes to sustainable energy transitions and rural development. According to Guno and Agaton (2022), it reduces farming costs, carbon emissions, and enhances farmer income. Huang et al. (2023) found that life cycle cost analysis favors SPIS investments, especially when environmental benefits are considered. As a decentralized energy solution, SPIS addresses food insecurity, energy poverty, and environmental degradation.

However, adoption barriers remain high capital costs, technical limitations, and limited community-level data hinder effective implementation. This study addresses these challenges by examining SPIS sustainability in Juban, Sorsogon, assessing its environmental, economic, and social impacts.

The significance of this study lies in its contribution to understanding the sustainability and practical effectiveness of Solar-Powered Pump Irrigation Systems (SPIS) as an alternative irrigation method in rural agricultural settings. Conducted in Catan-agan, Juban, Sorsogon, the research provides insights into how SPIS enhances rice productivity, cropping intensity, and net returns per hectare while reducing dependence on costly, carbon-intensive pumps. By documenting the benefits and challenges faced by farmer-beneficiaries, the study guides policymakers, NIA, and development planners on how to improve and scale SPIS programs for climate-resilient, energy-efficient, and inclusive agricultural development.

Objectives

This study aimed to determine the sustainability of SPIS as an alternative irrigation method in Juban, Sorsogon. Specifically, the research sought to:

1. Describe SPIS as an alternative irrigation method
2. Assess SPIS on rice productivity in terms of: (a) yield performance, (b) cropping intensity, and (c) net return per hectare.
3. Describe the feedback of the farmer beneficiaries on SPIS.
4. Proposed policy brief based on the findings of the study.

II. METHODOLOGY

Research Design

This study utilized a descriptive-qualitative research design to assess the sustainability of the Solar-Powered Irrigation System (SPIS) as an alternative irrigation method in Juban, Sorsogon. The approach was suitable for capturing both the technical characteristics of SPIS and its socio-economic and environmental implications within an actual community context. Documentary reviews from the National Irrigation Administration (NIA), such as technical plans, maps, and system layouts, were conducted to describe the implementation scope. These were supplemented by primary data gathered through structured interviews with farmer-beneficiaries, whose responses were analyzed thematically following Braun and Clarke's (2006) framework. The integration of institutional data and user narratives ensured a grounded and policy-relevant analysis (Creswell & Plano Clark, 2018).

Sources of Data

The study drew on two key sources of data. First, documents obtained from NIA included SPIS project reports, system specifications, layout maps, and installation guidelines from 2019 to 2022, which provided contextual and technical details about the system design and rollout in Catan-agan, Juban. Second, interviews were conducted with 12 purposively selected farmer-beneficiaries representing various phases of SPIS deployment, including centrifugal and submersible pump users. These respondents provided insights on SPIS usability, cropping intensity, productivity changes, and financial returns. This combination of institutional data and grassroots data ensured a balanced understanding of SPIS implementation and outcomes.

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Research Ethics

To ensure ethical integrity, the study followed established standards in qualitative research. Informed consent was secured from all farmer-respondents after explaining the research purpose, procedures, and their right to voluntary participation. Confidentiality and anonymity were assured through secure data handling, and participants were informed they could withdraw at any time. Compliance with Republic Act No. 10173 or the Data Privacy Act of 2012 ensured the protection of all personal data throughout the research process.

Research Instrument

The main data collection tool was a structured interview guide developed by the researcher and validated by the thesis adviser. The instrument was divided into two parts: the first focused on productivity-related indicators such as yield, cropping intensity, and net return per hectare before and after SPIS implementation; the second included open-ended questions on SPIS usability, technical issues, and sustainability. The questions were aligned with the study's objectives and derived from relevant literature to ensure content relevance and clarity (Chandel et al., 2015; Escoto, 2023).

Data Collection

Data collection took place from March 31 to April 1, 2025. A formal letter of request was sent to the NIA Irrigation Management Office to secure access to both documents and farmer-beneficiaries. Project records from 2021 to 2023 were reviewed to validate SPIS coverage and identify qualified respondents. One-on-one structured interviews were conducted with 12 SPIS beneficiaries using the validated guide, administered in Tagalog to ensure clarity. Responses were manually recorded and immediately reviewed to ensure accuracy and completeness.

Data Analysis

Table 1. *Summary of SPIS Project Profile and Farmer Respondents per Phase*

Category	**Phase 1**	**Phase 2**	**Total**
Year Started	2019	2021	–
Year Turned Over	2021	2022	–
No. of SPIS Pumps/Sites	3 Pumps	3 Sites	6 Units
Type of Pump Used	Centrifugal Pump	Submersible Pump	–
Irrigable Area (Hectares)	30 ha	30 ha	60 ha
Total Project Cost	₱12,000,000	₱12,000,000	₱24,000,000
Farmer Beneficiaries	48	49	97

The study employed purely qualitative analysis. NIA documents were analyzed to outline SPIS features, infrastructure scope, and rollout phases.

Interview responses were used to compare productivity indicators before and after SPIS adoption and to capture experiential insights on SPIS implementation.

Thematic analysis, following Braun and Clarke's (2006) six-phase approach, was used to identify recurring themes such as system reliability, water access, environmental benefits, and operational challenges.

These findings informed the development of context-driven recommendations.

III. RESULTS AND DISCUSSION

The Solar-Powered Irrigation System (SPIS) implemented in Barangay Catan-agan, Juban, Sorsogon was analyzed through spatial distribution, productivity indicators, and farmer feedback to assess its sustainability as an alternative irrigation method.

The project, divided into two phases and six pump sites, served 97 farmer-beneficiaries across 60 hectares. Phase 1 utilized centrifugal pumps (surface water) and Phase 2 deployed submersible pumps (groundwater), each irrigating 30 hectares and costing ₱12 million.

Description of SPIS as an Alternative Irrigation Method

Figure 3 presents a map showing the locations of all SPIS pump sites and farmer-beneficiaries.

The area is divided into four quadrants to better understand how pump sites and farmers are spatially distributed.

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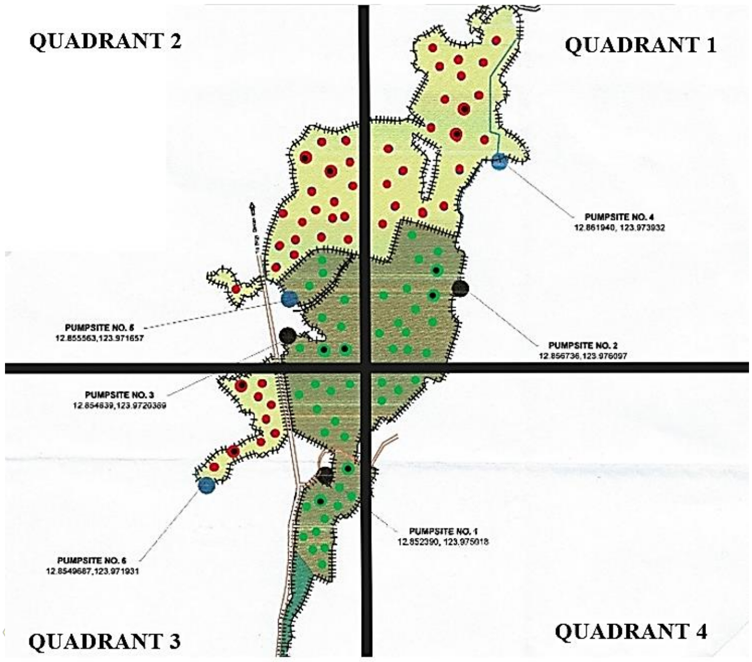

Figure 3. *Map of Solar-Powered Irrigation System (SPIS) in Barangay Catan-agan, Juban, Sorsogon*

Black dots show Phase 1 pump sites (using centrifugal pumps), while blue dots show Phase 2 sites (using submersible pumps). Green and red dots represent Phase 1 and Phase 2 farmers, respectively. Some dots are marked with black centers to indicate the 12 sampled farmer-respondents for this study.

Table 1 summarizes key project information: implementation year, pump type, irrigated area, and number of beneficiaries per phase. Both phases covered 30 hectares each, supported by three pump sites. Each pump is capable of irrigating 10 hectares. The table shows that the two phases are equal in investment and area served, but differ in pump type and possibly in water source depth and terrain suitability.

Evaluation of Rice Productivity Through SPIS

Table 2 compares rice yields before and after SPIS installation among 12 selected farmer-beneficiaries. It shows the farm area, the number of sacks harvested before SPIS, and the yield after SPIS implementation. Six out of twelve farmers recorded higher yields, some significantly, such as Farmer 8, who increased from 70 to 130 sacks. This suggests that SPIS improved irrigation reliability, especially in larger farms or those using Phase 2's submersible pumps. However, other farmers (e.g., Farmer 5 and Farmer 10) showed no yield increase, often due to issues like poor canal reach or previously having reliable irrigation sources.

Table 2. *Rice Yield of Farmers Before and After SPIS Installation.*

Farmer ID	Area (ha)	Harvest Before SPIS (sacks)	Harvest After SPIS (sacks)	Increase (+) / No Change (=)
Farmer 1	1.00	50	80	+30
Farmer 2	1.00	50	70	+20
Farmer 3	0.25	15	25	+10
Farmer 4	0.50	30	60	+30
Farmer 5	0.50	70	70	=
Farmer 6	0.25	40	40	=
Farmer 7	1.00	60	60	=
Farmer 8	1.50	70	130	+60
Farmer 9	0.33	30	30	=
Farmer 10	0.33	30	30	=
Farmer 11	0.66	30	50	+20
Farmer 12	0.50	50	50	=

Table 3 shows the number of cropping cycles (planting and harvesting seasons) per year before and after SPIS was introduced. Initially, only six out of 12 farmers planted twice per year, while the rest planted once due to water limitations. After SPIS installation, all farmers were able to plant twice yearly. This demonstrates that SPIS allowed farmers to use their land more intensively, increasing their output and potential income.

Table 3. *Cropping Intensity Before and After SPIS Installation*

Farmer ID	Cropping Cycle Year (Before SPIS)	Cropping Cycle per Year (After SPIS)	Change
F1	1	2	+1
F2	2	2	=
F3	1	2	+1
F4	1	2	+1
F5	2	2	=
F6	2	2	=
F7	1	2	+1
F8	1	2	+1
F9	2	2	=
F10	2	2	=
F11	1	2	+1
F12	2	2	=

Table 4 calculates the income per hectare that farmers earned before and after using SPIS, considering both yield and expenses. The net return was computed based on market price per kilogram of rice, sack weight, and land area. Eight farmers showed increased net returns, with some gaining over ₱30,000 due to higher yield and reduced fuel costs. The rest had no change, usually because their harvest remained the same, or SPIS did not significantly extend their water reach.

Feedback of the Farmer Beneficiaries on SPIS

Table 5 summarizes the feedback gathered from farmer-beneficiaries regarding their experience with the Solar-Powered Irrigation System (SPIS).

Table 5. *Feedback of Farmer Beneficiaries on SPIS*

Sustainability Dimension	Positive Feedback	Negative Feedback
Technical	- Easy to operate and maintain - System is user-friendly even without training	- Inconsistent performance during cloudy weather - Limited water reach in distant or elevated farms
Economic	- Zero fuel cost compared to diesel systems - Increased cropping opportunities	- Unequal water distribution due to lack of canals - Some farmers saw no increase in income
Environmental	- No smoke or air pollution from system use - Preference for clean energy over diesel	- Solar dependency limits use on overcast days - Basic maintenance, like panel cleaning required

Table 4. *Net Return per Hectare Before and After SPIS Installation*

Farmer ID	Area (ha)	Harvest Before (sacks)	Harvest After (sacks)	Net Return/ha Before (₱)	Net Return/ha After (₱)	Change (₱)
F1	1.00	50	80	42,500	68,000	+25,500
F2	1.00	50	70	42,500	59,500	+17,000
F3	0.25	15	25	51,000	85,000	+34,000
F4	0.50	30	60	51,000	102,000	+51,000
F5	0.50	70	70	119,000	119,000	=
F6	0.25	40	40	136,000	136,000	=

F7	1.00	60	60	51,000	51,000	=
F8	1.50	70	130	39,667	73,667	+34,000
F9	0.33	30	30	77,273	77,273	=
F10	0.33	30	30	77,273	77,273	=
F11	0.66	30	50	38,636	64,394	+25,758
F12	0.50	50	50	85,000	85,000	=

From a technical aspect, many farmers emphasized the ease of operating the system. Even without formal training, they reported being able to use the pump mechanisms confidently, likening the operation to that of a basic electric pump. However, several respondents raised concerns about the system's performance during overcast or rainy days, when the solar panels could not generate sufficient energy. Additionally, they noted limitations in water reach, particularly in farms located at higher elevations or farther from the pump sites, which sometimes failed to receive consistent irrigation.

Economically, the shift from diesel to solar power brought considerable relief to farmers. They cited the complete removal of fuel expenses as a major benefit, enabling them to reduce operational costs and increase income potential. With SPIS, several farmers also observed the opportunity to plant more frequently within a year, effectively maximizing land use. However, these benefits were not universally felt. Some farmers, especially those whose farms were located beyond the immediate reach of the pumps, reported that the lack of irrigation canals or sufficient water pressure resulted in no observable increase in their yields or income.

From an environmental standpoint, farmers expressed a strong preference for SPIS over diesel-powered systems. They appreciated the absence of smoke, noise, and fuel odor, describing the system as clean, quiet, and more suitable for their community. Despite these positives, they also pointed out a few challenges. The system's reliance on sunlight meant that irrigation could be interrupted during cloudy days, and basic maintenance, such as regular cleaning of the solar panels, was required to maintain efficiency. These comments reflect a general satisfaction with SPIS, tempered by specific limitations in system design, weather dependency, and infrastructure.

Policy Implications and Recommendations for Supporting SPIS Sustainability

The study translated its findings into a policy brief titled "Sustainability of Solar-Powered Irrigation in the Philippines: Evidence from Juban, Sorsogon." The policy brief was designed as an output to inform decision-makers such as the National Irrigation Administration (NIA), local government units, and agricultural policy stakeholders. It highlights SPIS's effectiveness in improving irrigation access, increasing cropping intensity, and promoting clean energy use in rice farming.

The brief also identifies practical challenges such as inconsistent pump performance during overcast conditions, lack of spare parts, and insufficient canal networks. From this analysis, five key recommendations were proposed: (1) site customization based on terrain and water source; (2) provision of technical support and training; (3) improvement of distribution infrastructure; (4) integration of farmer capacity-building programs; and (5) increased budget support for long-term SPIS viability.

By aligning with national development priorities and Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 7 (Affordable and Clean Energy), and SDG 13 (Climate Action), the policy brief demonstrates how SPIS can serve as a model for climate-resilient, sustainable agriculture in off-grid rural communities. The development of this brief affirms the role of evidence-based participatory research in shaping inclusive agricultural policies and advancing energy transition in the Philippine irrigation sector.

IV. CONCLUSION AND RECOMMENDATION

The study affirmed the potential of the Solar-Powered Irrigation System (SPIS) as a sustainable and climate-resilient alternative to traditional, fuel-dependent irrigation methods for rice farming in off-grid areas such as Catan-agan, Juban, Sorsogon.

SPIS demonstrated its capacity to lower operational costs, stabilize water supply, and enable intensified cropping, especially for farmers previously dependent on rainfed systems.

Its renewable energy basis makes it an environmentally responsible intervention aligned with national agricultural goals and global climate commitments.

Across the six SPIS pump sites assessed, half of the sampled farmer-beneficiaries experienced increased rice yield, while all were able to conduct two cropping cycles per year following SPIS installation. Financial analysis further revealed improved net returns per hectare among farmers who received adequate irrigation coverage. These findings confirm that SPIS enhances farm productivity and profitability under favorable implementation conditions.

However, the system's effectiveness was unevenly distributed. Limitations such as insufficient canal reach, low pump performance during overcast conditions, delayed repairs, and terrain-related water distribution issues were recurrent. These challenges underscore the necessity of customizing SPIS implementation based on site-specific environmental, infrastructural, and operational factors. The qualitative insights from farmer feedback highlighted the system's perceived benefits, including ease of use, cleaner operation, and fuel independence, while also emphasizing the urgent need for maintenance support, local spare parts, and technical training.

In response to these findings, the study produced a policy brief that translates empirical insights into actionable guidance for national and local implementing agencies. The brief supports a multi-sectoral, participatory framework that treats SPIS not merely as a technological fix but as a component of a broader rural development strategy. Its contributions align with Sustainable Development Goals (SDG 2: Zero Hunger, SDG 7: Affordable and Clean Energy, and SDG 13: Climate Action), reinforcing the value of SPIS in building resilient, self-sufficient agricultural communities.

To ensure the sustainability and scalability of SPIS in Juban and similar rural settings, this study recommends the following:

First, pre-installation assessments should be institutionalized by the National Irrigation Administration (NIA) and partner agencies to ensure that SPIS units are deployed in sites with favorable solar exposure, reliable water sources, and appropriate terrain. Doing so can reduce inefficiencies and maximize system output.

Second, training programs for both farmer-users and local technicians should be embedded in the implementation process. These programs must cover system operation, maintenance, and troubleshooting to build local capacity and reduce equipment downtimes. Periodic refresher sessions are also recommended to reinforce knowledge over time.

Third, establishing a regional supply chain for SPIS spare parts is vital. Local access to essential components such as inverters, breakers, and panels can minimize system interruptions. Public-private partnerships can help bridge the current gap in technical support and maintenance logistics.

Fourth, SPIS should be integrated into a broader rural development framework. This includes support for canal systems, farmer cooperatives, and clustered implementation to ensure that even remote or elevated farms benefit equitably from irrigation investments.

Fifth, future SPIS planning should adopt an inclusive and participatory approach. Farmers must be consulted and involved in project planning, monitoring, and evaluation. Their involvement ensures ownership, practical design adjustments, and long-term success.

Lastly, further studies should be conducted to assess the long-term impacts of SPIS on income dynamics, labor distribution, and water resource sustainability. A comprehensive cost-benefit analysis considering system lifespan, maintenance burden, and socio-environmental outcomes would strengthen future policy and investment decisions.

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REFERENCES

[1] Ashraf, A., & Jamil, K. (2022). A solar-powered irrigation system as a nature-based solution for sustaining agricultural water management in the Upper Indus Basin. Nature-Based Solutions, 2, 100026. https://doi.org/10.1016/j.nbsj.2022.100026

[2] Ashrafi Goudarzi, S., Fazelpour, F., Gharehpetian, G. B., & Rosen, M. A. (2019). Techno-economic assessment of hybrid renewable resources for a

residential building in Tehran. Environmental Progress & Sustainable Energy, 38(5). https://doi.org/10.1002/ep.13209

[3] Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

[4] Chandel, S. S., Naik, M. N., & Chandel, R. (2015). Review of solar photovoltaic water pumping system technology for irrigation and community drinking water supplies. Renewable and Sustainable Energy Reviews, 49, 1084–1099. https://doi.org/10.1016/j.rser.2015.04.083

[5] Creswell, J. W., & Plano Clark, V. L. (2018). Designing and conducting mixed methods research (3rd ed.). SAGE Publications. https://bayanbox.ir/view/236051966444369258/9781483344379-Designing-and-Conducting-Mixed-Methods-Research-3e.pdf

[6] Escoto, B. E., & Abundo, M. L. (2024). A framework to assess solar PV irrigation system (SPIS) for sustainable rice farming in Sorsogon, Philippines. International Journal of Renewable Energy Development, 13(5), 929-940. https://doi.org/10.61435/ijred.2024.60445

[7] Guno, C. S., & Agaton, C. B. (2022). Economic analysis of solar-powered irrigation systems for sustainable farming in the Philippines. Renewable Agriculture and Food Systems, 37(3), 303–312. https://doi.org/10.1017/S1742170521000027

[8] Huang, Y., Li, D., Wang, H., & Xu, Y. (2023). Life cycle cost assessment of solar energy systems in developing regions. Journal of Cleaner Production, 389, 136134. https://doi.org/10.1016/j.jclepro.2023.136134

[9] Kundu, P. K., Islam, M. T., & Paul, P. L. C. (2021). Low-cost solar pump irrigation system for irrigated rice production. Bangladesh Rice Journal, 25(2), 1–10. https://www.researchgate.net/publication/366249308

[10] Rezk, H., Abdelkareem, M. A., Al-Dhaifallah, M., & Miqdam, T. (2019). Performance of solar PV-based water pumping system using artificial intelligence techniques: A comprehensive review. Solar Energy, 192, 537–556. https://doi.org/10.1016/j.solener.2019.09.030

[11] Stuecker, M. F., Tigchelaar, M., & Kantar, M. B. (2018). Climate variability and rice yield: The Philippines case. Environmental Research Letters, 13(5), 054011. https://doi.org/10.1088/1748-9326/aab1e4

[12] Republic Act No. 3601. An Act Creating the National Irrigation Administration. (1963). https://www.officialgazette.gov.ph

[13] Republic Act No. 9513. Renewable Energy Act of 2008. https://lawphil.net/statutes/repacts/ra2008/ra_9513_2008.html

[14] Republic Act No. 10173. Data Privacy Act of 2012. https://lawphil.net/statutes/repacts/ra2012/ra_10173_2012.html

[15] Republic Act No. 10969. Free Irrigation Service Act of 2017. https://lawphil.net/statutes/repacts/ra2017/ra_10969_2017.html