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Design and Development of a Solar-Powered Deep Learning-based Rice Pest Detection and SMS Alert System in CarCanMadCarLan

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ABSTRACT: The Solar-Powered AI-Based Rice Pest Detection and Monitoring System with SMS Alerts was developed to address the challenges faced by rice farmers in detecting and monitoring pests in remote agricultural areas of CarCanMadCarLan, Surigao del Sur. The system integrates YOLOv8 deep learning, Raspberry Pi, GSM communication, GPS tracking, and solar energy technologies to provide real-time pest detection and automated SMS notifications. The developed system successfully identified common rice pests with high accuracy and enabled continuous field monitoring through renewable energy. Results demonstrated improved pest management efficiency, faster response time, and reliable monitoring support for sustainable smart farming practices.

KEYWORDS: Rice Pest Detection, YOLOv8, Smart Agriculture, Raspberry Pi, Solar-Powered Monitoring System

I. INTRODUCTION

Rice farming remains one of the primary sources of livelihood in CarCanMadCarLan, Surigao del Sur. However, pest infestations continue to threaten rice productivity and farmer income due to delayed detection and inefficient monitoring methods. Traditional pest management practices rely heavily on manual inspection, which is time-consuming, labor-intensive, and often ineffective in identifying pests during their early stages of infestation. In remote farming communities, the lack of stable electricity and internet connectivity further limits the use of advanced agricultural technologies.

The development of smart agricultural technologies has introduced new opportunities to improve crop monitoring and pest management. Artificial Intelligence (AI), Internet of Things (IoT), and deep learning technologies have shown significant potential in automating agricultural processes and providing real-time monitoring solutions. According to Wang et al. (2023) [5], AI-powered pest detection systems can significantly reduce crop damage by enabling early



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intervention. Similarly, Zhang et al. (2024) [7] emphasized that edge-based AI systems using Raspberry Pi devices provide practical solutions for remote agricultural environments.

This study developed a Solar-Powered AI-Based Rice Pest Detection and Monitoring System integrated with SMS alerts to assist rice farmers in CarCanMadCarLan. The system combines YOLOv8 deep learning, Raspberry Pi, camera modules, GPS tracking, GSM communication, and solar energy technologies to deliver real-time pest monitoring and automated notifications. The study aims to provide a sustainable, cost-effective, and intelligent agricultural solution that improves pest management and supports smart farming practices.

II. LITERATURE REVIEW

A critical review of related studies was conducted to establish the relationship between the present study and previous research regarding AI-based agricultural monitoring systems and smart farming technologies.

Recent advancements in artificial intelligence and IoT have significantly improved agricultural monitoring systems. Bijlwan (2025) [1] developed a real-time crop pest detection framework that integrates deep learning models with Raspberry Pi devices. The study demonstrated that AI-based detection systems can improve monitoring accuracy and reduce manual labor in agricultural operations.

Wang et al. (2023) [2] proposed an IoT-based pest monitoring system integrated with machine learning and SMS notifications for real-time agricultural monitoring. Their study highlighted the importance of automated communication systems in providing immediate alerts to farmers regarding pest infestations.

Barman et al. (2024) [3] introduced a YOLO-based rice pest detection system using drone imagery and object detection techniques. The researchers achieved high detection accuracy under varying environmental conditions, demonstrating the effectiveness of deep learning approaches in agricultural applications.

Telaumbanua et al. (2025) [4] developed a solar-powered AI-integrated pest trap system capable of operating continuously in remote farming environments. Their findings emphasized the importance of renewable energy integration in agricultural monitoring technologies.

Linker (2025) [5] proposed a hybrid YOLOv5 and CNN-based pest detection framework optimized for Raspberry Pi deployment in rice fields in the Philippines. The study confirmed that lightweight AI models can effectively operate on low-power edge devices for real-time field monitoring.

Table.1. Summary of Relevant Literature

No.	Paper Title	Author(s)	Key Points	Remark
1	Real-Time Crop Pest Detection Using Deep Learning Models	Bijlwan (2025)	Developed an AI-based pest detection system using deep learning and Raspberry Pi for real-time agricultural monitoring.	Demonstrated the effectiveness of AI-powered pest detection in improving monitoring accuracy and reducing manual inspection.
2	IoT-Based Pest Monitoring System Using Machine Learning and SMS Alerts	Wang et al. (2023)	Integrated IoT devices, machine learning, and GSM communication for automated pest monitoring and SMS notification.	Highlighted the importance of real-time alerts and automated communication in smart agriculture.
3	YOLO-Based Rice Pest Detection Using Coordinate Attention Mechanisms	Barman et al. (2024)	Applied YOLO-based object detection techniques for accurate rice pest identification	Provided a strong foundation for implementing YOLOv8 in rice pest detection



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			under varying environmental conditions.	systems.
4	Solar-Powered AI-Integrated Automatic Pest Trap Systems	Telaumbanua et al. (2025)	Developed a renewable energy-powered pest monitoring system capable of continuous field operation.	Supported the integration of solar energy technologies in sustainable agricultural monitoring systems.
5	Hybrid YOLOv5 and CNN-Based Pest Detection Framework for Philippine Rice Fields	Linker (2025)	Proposed a lightweight AI framework optimized for Raspberry Pi deployment in rice farming environments.	Confirmed the suitability of edge AI technologies for rural agricultural applications.

In summary, previous studies demonstrated the effectiveness of AI, IoT, and renewable energy technologies in agriculture. However, limited studies have focused on integrating these technologies into a localized, solar-powered pest monitoring system specifically designed for rural rice farming communities in the Philippines. This study addresses these gaps by combining AI-based pest detection, SMS alerts, GPS tracking, and solar-powered operation into a single integrated system.

III. METHODOLOGY

Research Design

The study utilized a developmental research design to develop a solar-powered, AI-based rice pest detection and monitoring system with SMS alerts for rice farmers in CarCanMadCarLan, Surigao del Sur. The system was designed, developed, tested, and continuously refined through iterative processes to ensure stable performance under real agricultural field conditions.

Research Respondents

The respondents of the study consisted of fifty (50) individuals, composed of five (5) hardware and software professionals and forty-five (45) rice farmers from CarCanMadCarLan. The technical experts evaluated the system's design, functionality, and reliability, while the farmers assessed the system's usability and effectiveness in real-world farming conditions.

Research Instrument

The study used the System Usability Scale (SUS) developed by John Brooke (1986) as the primary evaluation instrument for measuring the usability and acceptability of the developed system. The SUS questionnaire contains 10 items rated using a five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5). The instrument evaluated the system's usability, ease of use, learnability, consistency, and overall user satisfaction.

Data Gathering Procedure

The researchers collected and labeled rice pest images from selected rice fields in CarCanMadCarLan, Surigao del Sur. The dataset included common rice pests such as freshwater snails, green leafhoppers, and rice bugs. The images underwent preprocessing, augmentation, training, validation, and testing using the YOLOv8 deep learning model. The developed system was then deployed in actual field conditions for monitoring and evaluation.

Data Analysis

The quantitative and technical data gathered from the evaluation and testing of the Solar-Powered AI-Based Rice Pest Detection and Monitoring System were analyzed using the following statistical and performance evaluation methods:

1. Weighted mean was used to determine the average evaluation score for the system's functionality, reliability, accuracy, and efficiency based on the responses of the evaluators.
2. Verbal Interpretation used to compute mean scores was interpreted using a qualitative scale to describe the performance and acceptability of the developed system.
3. Precision was used to measure the accuracy of the AI model in correctly identifying rice pests while minimizing false positive detections.



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4. Recall measured the ability of the system to correctly detect actual rice pests present in the captured field images.
5. The F1-Score was used to evaluate the balance between precision and recall in assessing the overall performance of the AI model.
6. Mean Average Precision was utilized to assess the object detection capability and classification performance of the YOLOv8 model across different Intersection over Union (IoU) thresholds.
7. Intersection over Union was used to evaluate the overlap accuracy between predicted bounding boxes and actual annotated pest locations.
8. The System Usability Scale (SUS) developed by John Brooke was used to evaluate the usability, learnability, and overall user satisfaction of the developed monitoring system.
9. Inference speed analysis was conducted to determine the real-time processing capability and performance efficiency of the system during field operation using Raspberry Pi 4.

IV. RESULTS AND DISCUSSION

System Performance Evaluation

The developed Rice Field Pest Detection and Monitoring System demonstrated high performance in detecting and classifying rice pests under actual field conditions. The system achieved an overall precision of 97.8% and a recall of 94.3%, indicating that the model can accurately identify rice pests while minimizing false positives and false negatives. Additionally, the system achieved a mean Average Precision (mAP50) of 97.6%, confirming its effectiveness in localizing and classifying pests in real time.

The freshwater snail class achieved the highest detection accuracy with 99.2% precision and 97.5% recall, while the rice bug class showed slightly lower performance due to background complexity and field variability.

The speed analysis of the system showed that image preprocessing required 0.4 milliseconds, inference required 2.9 milliseconds, and post-processing required 0.8 milliseconds per image, demonstrating the capability of the system for real-time agricultural monitoring.

Functionality Evaluation

Evaluation Criteria	Mean	Interpretation
Functionality	4.606	Outstanding

The functionality evaluation revealed that the system effectively detects rice pests, sends SMS alerts, displays monitoring results on the dashboard, and integrates all system components properly. Respondents confirmed that the system successfully performs its intended functions in real-world agricultural settings.

Reliability Evaluation

Evaluation Criteria	Mean	Interpretation
Reliability	4.264	Very Satisfactory

The reliability evaluation demonstrated that the system operates consistently during long hours of operation and maintains stable SMS communication and solar-powered performance under rural field conditions.

Accuracy Evaluation

Evaluation Criteria	Mean	Interpretation
Accuracy	4.212	Very Satisfactory

The accuracy evaluation showed that the system effectively identifies rice pests, minimizes incorrect classifications, and accurately determines pest locations in the field.



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Efficiency Evaluation

Evaluation Criteria	Mean	Interpretation
Efficiency	4.50	Outstanding

The efficiency evaluation confirmed that the system provides fast pest detection, real-time dashboard updates, energy-efficient operation, and reliable performance under varying environmental conditions.

V. CONCLUSION

The development of the Solar-Powered AI-Based Rice Pest Detection and Monitoring System represents a significant advancement in smart agriculture technologies for rural farming communities in CarCanMadCarLan, Surigao del Sur. The integration of YOLOv8 deep learning, Raspberry Pi, GSM communication, GPS tracking, and solar energy technologies enabled accurate real-time pest detection and continuous field monitoring.

The system successfully addressed the limitations of traditional manual pest monitoring by providing automated detection and SMS notifications. The high detection accuracy and reliable field performance demonstrate the viability of AI-powered agricultural monitoring systems in improving rice pest management and reducing crop losses. Ultimately, the study highlights the potential of integrating AI, IoT, and renewable energy technologies to support sustainable and intelligent farming practices in the Philippines.

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