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Rice Hull Management System: A Mobile-based Application Tool for Cooperatives

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Abstract – *This study focuses on the design and evaluation of the Rice Hull Management System (RHMS), a mobile application for cooperatives in Occidental Mindoro, Philippines, to improve rice hull waste management. Developed using the RAD methodology with React Native and Firebase, enabling the system to be responsive, scalable, and secure. RHMS enables efficient transaction processing, real-time data updates, and automated reporting, addressing inefficient manual practices that pose environmental risks. The system usability, reliability, safety, and mobility were assessed through surveys, usability tests, and performance benchmarks involving IT experts, cooperative staff, and members. System reliability was demonstrated to be high, with a Cronbach's alpha greater than 0.80, and high user satisfaction, as indicated by grand mean scores ranging from 4.08 to 4.23 ("Very Good"). Results indicate high user satisfaction and system effectiveness with positive ratings across criteria. RHMS promotes sustainable agricultural practices by facilitating eco-friendly waste recycling, reducing environmental hazards, and supporting data-driven decision-making. The RHMS showcases considerable promise for development and implementation across agricultural supply chains, given its secure, easy-to-use, and flexible interface for users, administrators, and cooperatives. While the results demonstrate significant operational improvements, future research should focus on integrating advanced analytics, expanding system interoperability, and evaluating long-term environmental and economic impacts to enhance sustainability and scalability in a broader agricultural context.*

Keywords*: cooperatives; mobile application; rice husk; real-time; sustainability*

I. INTRODUCTION

Rice (Oryza sativa L.) is a vital crop for global food security, providing the primary source of calories and nutrients for more than half of the world's population (Bandumula, 2018). In many Asian countries, rice not only meets dietary needs but also significantly contributes to poverty reduction and nutritional stability in developing economies. Globally, rice accounts for nearly 50% of caloric intake, with production exceeding 513 million metric tons in 2021 (Verma et al., 2021; Mohidem et al., 2022).

One of the major by-products of rice cultivation is rice hulls (husks), which constitute appropriately 20% of the total paddy weight, generating between 80 and 134 million metric tons annually (Quispe et al., 2017). Rice hulls are disposed of unsustainably and even burnt in the open, contributing to greenhouse gas emissions and air and soil pollution. Unsustainable disposal methods, such as the open burning of rice hulls, lead to emissions of greenhouse gases, air pollution, and soil degradation (Goodman, 2020; Jandrić et al., 2020). That said, the lack of eco-friendly methods to manage the waste rice hulls produced is concerning.

There are, however, eco-friendly and value-improving alternatives on the horizon, such as the production of biochar, water management, and the recovery of waste hulls as biomass energy (Kumarathilaka et al., 2021; Xing et al., 2020). Limited integration systems for traceability, the circular economy, and resource efficiency are the main reasons these alternatives have not been widely adopted (Gowlla et al., 2025). This statement is particularly true for the Philippines, where rice farming is the primary source of income for families in rural areas and is crucial for the country's food security. The Philippines is also a country that, having issues with self-sufficiency in rice, should aim to improve the value of its rice hulls as a waste by-product of rice (Mamiit et al., 2020).

Innovations in technology, including the Internet of Things (IoT), cloud computing, and mobile apps, are changing the world of agriculture (Nenga Riki & Tata Sutabri, 2024; Tyagi et al., 2024), but little research focuses on the application of these technologies in managing rice hull wastes, especially in the cooperatives' context. Other studies focus on environmental impacts or technology use, but fail to integrate digital technology into the operational and social aspects of smallholder cooperatives. Likewise, no comprehensive and straightforward integrated platforms are available to allow real-time monitoring, automated processes, and analytics to support rice hull waste management.

Pag-Asa Renewable Energy Corporation (PRECO) in Occidental Mindoro, Philippines, is an outstanding example of the problem. PRECO is the only company in the Philippines that purchases rice hulls from local cooperatives to produce clean energy. Low-tech manual systems, as cited by Herpiah et al. (2024) in their research, create inefficiencies in transactions and record-keeping, leading to delays, poor traceability, and limited transparency that impact the inefficient management of sustainable resources (Prochazka et al., 2024).

In response to these gaps, this study develops the Rice Hull Management System (RHMS), a mobile-based application built with React Native and Firebase. The real-time system monitoring, automated sales tracking, payment processing, and analytical features of RHMS promote transparency, operational efficiency, and sustainability on a global scale, leveraging mobile and cloud technology and shifting towards waste management of rice hulls (Farooq et al., 2023; Peng et al., 2022). As recognized, RHMS aims to make the management of waste rice hulls eco-friendly, traceable, and cooperative (Ghodake, 2024). Real-time automated monitoring, central cloud analytics, and integrated control, as described by Dhal et al. (2024) and Kumarathilaka et al. (2021), focused on precision agriculture using IoT and AI technology on smart sensors and cloud infrastructure.

Although studies have been conducted on the use of mobile technology and IoT in agriculture, particularly in precision farming and decision support systems (Dhal et al., 2024; Kumarathilaka et al., 2021), research on integrated mobile-based systems for rice hull waste management at the cooperative level is scarce. There is also very little research on the cooperative context and how the use of digital technology addresses the three pillars of operational efficiency, financial transparency, and environmentally sustainable practices. This study fills this gap by designing, developing, and evaluating RHMS, explicitly tailored for cooperatives in Occidental Mindoro, Philippines, thereby contributing both a technological innovation and a model for sustainable agricultural by-product management.

II. METHODS

2.1 Research Design

This research implemented a mixed-methods approach to mobile-based rice hull management. It combines quantitative assessments with qualitative feedback to develop and evaluate the managed system. It also facilitated iterative refinement, thorough testing, and comprehensive assessment of the rice hull management systems within Occidental Mindoro rice cooperatives.

2.2 System Development Approach

The development model followed RAD (Rapid Application Design), which allows for the creation of prototypes at a faster rate. Mobile applications for both Android and iOS were created using React Native. To facilitate cloud-based requirements and provide services such as real-time database syncing, user authentication, and analytics, Firebase is utilized as the backend. This tech stack balanced system responsiveness and development speed while providing ample room for scaling.

2.3 System Architecture

The diagram illustrates the integration of mobile devices, the central processing system, and Firebase cloud infrastructure, detailing data flow, user interactions, and system components, as shown in Figure 1. This system addresses manual inefficiencies and environmental challenges, while streamlining real-time data management for PRECO and the Rice Millers Cooperatives. It comprises mobile devices, a central process (Rice Hull Management System), and a Firebase Database. The employee manages daily operations, including recording transactions, monitoring deliveries, and accessing reports. The application has a secure user interface with transaction logging, payment processing, and real-time tracking features. Data flow involves inputs from the system and outputs via the Firebase Database. The central process, "Rice Hull Coop," processes data inputs, manages transactions, and generates outputs like reports and analytics. The Firebase Database is the central repository for all rice hull data, ensuring secure, scalable, and real-time storage and retrieval. The system's background is a light beige or rice field texture, reinforcing the agricultural context of rice hull management in Occidental Mindoro.

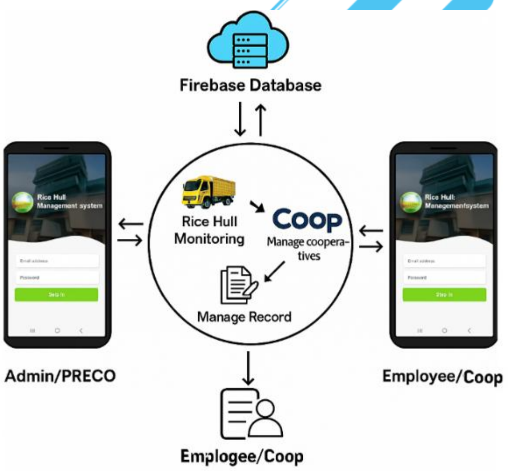

Figure 1. System Architecture of the Rice Hull Management System (RHMS)

2.4 Project Development

The "Mobile-Based Application Tool for Rice Hull Management" project was developed for PRECO and rice millers' cooperatives in Occidental Mindoro. The iterative process involved five phases: Planning and Analysis, User Design, Development, Testing, and Deployment. The project aimed to address rice hull challenges and manual inefficiencies by providing real-time tracking, data analytics, and payment processing. The user design was translated into a mobile-first UI and functional design using React Native and Firebase, guided by Data Flow Diagrams and process flowcharts. Coded in React Native, integrated with Firebase for real-time data storage, and implemented features for transaction logging, sales monitoring, and report generation. The system was tested using ISO 9126 parameters to ensure data accuracy, performance, and security. The application was launched for PRECO and cooperatives, enabling the distribution of rice hulls for energy production, with ongoing maintenance to ensure operational stability. The application is expected to enhance operational stability, reduce waste, improve decision-making, and promote sustainability, with a 70% efficiency improvement in waste management.

2.5 Participants and Sampling

The evaluation phase involved 50 respondents, including IT experts, cooperative personnel, and cooperative members involved in rice hull transactions. They were selected using stratified random sampling to ensure representation across key stakeholder groups. Participants were required to be familiar with cooperative operations and have basic digital literacy to assess system usability and functionality.

2.6 Data Collection Procedures

The system underwent iterative usability testing and performance benchmarking, with participants performing standardized tasks. Usability was evaluated using Nielsen heuristics, focusing on learnability, efficiency, memorability, error prevention, and satisfaction. Performance benchmarking is done by recording system response times, transaction speeds, and uptime metrics under simulated operational loads. Post-test surveys were administered to gather user perceptions on system functionality, ease of use, security, and reliability. Transaction logs, system analytics, and error reports provided objective measures of system performance.

2.7 Data Validity and Reliability

To ensure data validity, the survey instruments were reviewed by experts in information systems and agricultural management, ensuring content relevance and clarity. A pilot test involving five participants was conducted to refine survey items and testing protocols. Construct validity was confirmed through factor analysis, ensuring that survey items accurately measured intended constructs.

The reliability of survey responses was assessed using Cronbach's alpha, which exceeded 0.80 across different scales, indicating high internal consistency. Data collection procedures were standardized across participants to minimize variability, and multiple testing rounds were conducted to verify system stability.

2.8 Data Analysis

Quantitative data from usability tests, performance benchmarks, and surveys were analyzed using descriptive statistics, such as mean scores. Qualitative feedback from open-ended survey responses and system logs was analyzed thematically. Recurring themes and issues were identified, categorized, and utilized to inform iterative system improvements.

2.9 Ethical Considerations

Participation was voluntary, and all respondents provided informed consent prior to engagement. Data confidentiality and participant anonymity were maintained throughout the study in accordance with ethical research standards. The relevant institutional review board approved the research protocol to ensure compliance with ethical guidelines for human subjects.

III. RESULTS AND DISCUSSION

3.1 Project Structure

The Rice Hull Management System comprises various essential elements. The Login Page requires users to enter their specified usernames and passwords, utilizing separate approaches for employees and administrators to enhance data security. The Home/Dashboard Page is the main screen from which the user can view their accounts, payment methods, reports, and settings. The payment transaction section is specially tailored to support cooperative transactions. User accounts contain the personnel data of members. The settings enhance the user-friendliness of system navigation, whereas administrators handle report generation. Through the Management Account Page, administrators can easily manage cooperative and employee accounts, assist in onboarding new cooperatives into the system, and grant platform access to designated staff members. The History of Payments section enables users to view and analyze the detailed transaction history of rice hulls, including all paid and unpaid transactions, which improves transparency in the system.

Furthermore, the Summary Report outlines the rice hulls collected from various cooperatives, categorized by their payment history. The last section of the application is the Settings Menu Page. The page allows the modification of personal details, displays system summaries at various levels of granularity, and facilitates logging out. This system features several components that cater to the diverse needs of users and system administrators. It features a user interface designed to simplify the processing of rice hulls.

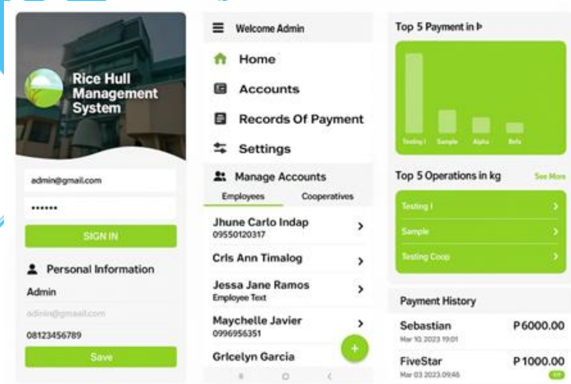

Figure 2. Rice Hull Management System App Environment

3.2 Project Evaluation

The Rice Hull Management System is a mobile-based application tool developed using Rapid Application Development (RAD) to address the challenges of managing rice hulls, a significant agricultural waste product in the Philippines, particularly in Occidental Mindoro. The system, built with React Native and Firebase, aims to eliminate manual inefficiencies, mitigate environmental risks, and improve operational efficiency, sustainability, and decision-making.

The evaluation involved fifty (50) randomly selected respondents, including IT experts, personnel (Administrators and Employees), and cooperative members. Data collected through surveys, usability tests, and performance benchmarks during the system's development and testing phases. The system effectively covers all specified tasks, such as real-time tracking of rice hull deliveries, inventory management, sales monitoring, payment processing, and report generation. It provides accurate results, facilitates task accomplishment, and meets user expectations for functionality. However, some respondents noted minor gaps in handling complex disposal risk analyses, suggesting the need for additional features in emissions tracking. The system's performance efficiency is excellent. It provides appropriate response times, processing speeds, and resource utilization to meet requirements under normal conditions. Response times and throughput rates meet requirements, ensuring quick access for stakeholders. Resource usage is efficient, supporting scalability for PRECO and cooperatives.

The system delivers outstanding performance, saving time, providing accurate data, and enhancing productivity. Compatibility is the system's ability to coexist and interoperate with other systems without adverse effects, ensuring seamless data exchange with PRECO's energy systems or cooperative software. The system performs its functions without harming other systems, achieving a mean of 4.20 (Very Good) and supporting integration with the organization's operations. It exchanges information effectively with external systems, enhancing transparency. Usability refers to the extent to which a system is easy to learn, use, and operate, thereby ensuring effectiveness, efficiency, safety, and user satisfaction for diverse users. Users learn the system quickly, achieving effectiveness, efficiency, safety, and satisfaction. The system is easy to operate and control, protecting users against errors and accommodating many users. Reliability is the system's ability to perform consistently under regular operation, remain accessible, and operate as intended despite faults or malfunctions. Under normal circumstances, the system functions effectively; thus, PRECO and the cooperatives have reliable systems for managing rice hulls.

The system's functionality accuracy overlaps with its uptime reliability and recovery from hardware or software failures. Uptime reliability protection refers to the system's readiness, while accuracy relates to its functionality within the operational window. The rice hull management system operates securely within established boundaries, preserving confidentiality and protection from unauthorized access or tampering. Users accessing the system from multiple privileged accounts have limited options, which allows them to view or use data while protecting data integrity. Actions taken through accounts form a signature that fortifies accountability and transparency. Concerning the remarkable performance appraisal of the Rice Hull Management System, IT experts and cooperative members documented an overall score of 4.18, classifying the performance as 'very good.'

This study demonstrates how the Rice Hull Management System addresses the challenges of handling rice hulls, particularly in Occidental Mindoro. Unfortunately, manual operations often result in more environmental abuse, damage, and ineffectiveness. Automation in sales monitoring, payment verification, and record-keeping, the Rice Hull Management System (RHMS) enhances efficiency in cooperative transactions. Cooperative members appreciated the streamlined system, which resulted in improved payment verification and enhanced traceability of rice hull deliveries. These deliveries had previously been challenging to track and trace in the manual systems. The integration of Firebase Cloud Storage and the React Native interface also facilitated immediate access to transaction histories, supporting transparency and accountability among stakeholders.

However, certain features, such as risk analysis of disposal and emission tracking, remain underdeveloped. At present, the system can only record and categorize disposal methods, without quantifying emission outputs or simulating environmental risks associated with improper rice hull management. The limitation is primarily due to the absence of a standardized dataset on localized emission factors and disposal practices in Occidental Mindoro. Furthermore, integrating IoT-enabled sensors for real-time monitoring of combustion or storage conditions was beyond the scope of this initial implementation.

Table 1. Summary Table of The Rice Hull Management System Evaluation

Category	Grand mean	Interpretation	Key strengths	Areas for improvement
Functionality	4.22	Very Good	Covers all tasks, provides accurate results, and facilitates objectives.	Enhance disposal risk analysis features.
Performance Efficiency	4.23	Very Good	Quick responses, efficient resources, and high productivity.	Optimize for peak traffic (e.g., harvest seasons).
Compatibility	4.08	Very Good	Coexists with other systems and exchanges information effectively.	Develop APIs for seamless integration with cooperative systems.
Usability	4.10	Very Good	Easy to learn, user-friendly, error-reducing, satisfying.	Provide training for users with limited digital literacy.
Reliability	4.32	Very Good	Consistent, accessible, fault-tolerant.	Implement redundancy for update downtimes.
Security	4.12	Very Good	Secure access prevents unauthorized changes and provides a clear audit trail of actions.	Strengthen encryption and user training to address vulnerabilities.
Grand Mean	4.18	Very Good	Efficient, user-friendly, and secure system.	Focus on security, compatibility, and scalability enhancements.

When compared with similar research, RHMS highlights both commonalities and distinctive contributions. Farooq et al. (2023) examined the integration of blockchain in rice supply chains, emphasizing the immutability and security of transactions across multi-stakeholder networks. While blockchain-based systems ensure tamper-proof records and high levels of trust, they often require significant computational resources and complex onboarding processes for smallholder cooperatives. In contrast, RHMS prioritizes usability, cost-effectiveness, and accessibility through mobile interfaces and cloud-based storage, making it more adaptable for resource-limited cooperatives in developing regions. Still, incorporating blockchain technology into RHMS is another focus for the future, especially for reinforcing the integrity of the data. Additionally, it would help strengthen trust among stakeholders outside localized cooperatives.

These findings align with other studies on the use of mobile-based agricultural platforms for efficient knowledge sharing and streamlined business operations (Kumhe et al., 2022; Chandran et al., 2022). While other general agricultural applications focus on the broader picture, RHMS zeroes in on the rice hull waste management niche, which carries great environmental and economic value, yet remains largely unrecognized. This level of specialization underscores the need for technology developed for agriculture, not just for primary production stages, but also for waste management and the sustainability of the entire process.

IV. CONCLUSION

A comprehensive analysis of the mobile application for PRECO and the cooperatives in Occidental Mindoro, the Rice Hull Management System, has been conducted. Achieved through an unambiguous system architecture, robust cybersecurity, multiconnectivity, and advanced information processing. This research enhances the understanding of the digital technological integration in the management of rice hulls in cooperatives. The Rice Hull Management System (RHMS) has significantly enhanced transaction management, offering increased precision and agility. It showcases the potential of mobile systems in managing waste processes, significantly reducing the need for manual intervention. The system incorporates features that promote waste monitoring during disposal and analyze gas emissions, thereby encouraging eco-friendly and sustainable practices. It aids in the eco-friendly conservation of agricultural operations and resources. The RHMS represents the digital transformation of management practices within cooperatives and the increased visibility of their operations. It is scalable and has potential applications in other regions and for various crops in agriculture. In brief, the research makes a valuable contribution to understanding how mobile technology is applied to managing agricultural waste, and it also lays a foundation for the further digitalization of rural cooperatives. As such, future development should focus on three aspects: 1) connecting the RHMS to emission/ carbon accounting at a local level, 2) incorporating predictive analytics for the assessment of environmental risks, and 3) the potential use of the IoT for automated data collection. With these additions, RHMS would go beyond being a transactional and monitoring tool to an environmental support system for decision-making.

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