Smart Farming System for Optimizing Dryland Agriculture in the Indonesia–Timor Leste Border Area

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Abstract.
This community service program aimed to implement an Internet of Things (IoT)-based smart farming system to optimize dryland agriculture in the Indonesia–Timor Leste border area, particularly in Inbate Village, Bikomi Nilulat District, North Central Timor Regency, East Nusa Tenggara Province. Farmers in this region face several challenges, including prolonged dry seasons, limited irrigation facilities, inefficient water management, and fluctuating agricultural productivity. To address these issues, the program introduced a smart farming system consisting of drip irrigation technology, soil moisture sensors, IoT controllers, water pumps, and solar cell energy systems. The implementation methods included field observation, installation of IoT-based irrigation systems, farmer training, mentoring, monitoring, and evaluation activities. The results showed that the smart farming system successfully improved irrigation efficiency, reduced water consumption, and increased crop productivity for onion and vegetable farming. In addition, farmers demonstrated improved understanding and adoption of modern agricultural technologies through practical training and continuous assistance. Evaluation results involving 15 farmers indicated high levels of user satisfaction, irrigation efficiency, and ease of technology use. Overall, the implementation of IoT-based smart farming technology had a positive impact on sustainable dryland agricultural management, farmer capacity building, and agricultural productivity in the Indonesia–Timor Leste border area.
Keywords: *Bivalvia, bray-curtis, cannonical correspondence analysis, density, gastropoda.*

I. INTRODUCTION

Inbate Village is located in Bikomi Nilulat District, North Central Timor Regency (TTU), East Nusa Tenggara Province, precisely in the Indonesia–Timor Leste border area. This geographical location creates unique socio-economic conditions and accessibility challenges, including long distances to service centers, limited infrastructure, and dry climatic conditions that significantly affect local agricultural activities [1]. Official data from Statistics Indonesia (BPS) indicate that TTU Regency remains highly dependent on the agricultural sector, including food crops, horticulture, plantations, and livestock farming. The 2023 Agricultural Census also provides detailed information regarding individual agricultural enterprises (UTP), which is highly relevant for designing technical interventions and local policy strategies. Agriculture continues to serve as one of the main drivers of the regional economy; therefore, productivity improvement initiatives at the village level can directly contribute to food security and local community welfare [2].

From a labor demographic perspective, TTU Regency is dominated by a productive-age population, accounting for approximately 60–65% of the total population. This indicates that the majority of residents are within the age range capable of adopting and benefiting from agricultural technology innovations. Such conditions provide significant opportunities for technical capacity-building programs and the adoption of modern agricultural technologies through training and adequate infrastructure support [3].

Climatic conditions in the southern border region of Timor Island are characterized by prolonged dry seasons, typically lasting from June to November, along with uneven rainfall distribution across areas. As a result, water management and irrigation practices remain major constraints to achieving reliable agricultural production. These climatic realities further emphasize the urgency of adopting water-efficient technologies such as drip irrigation systems, soil moisture sensors, and drought-resistant cultivation practices to improve dryland agricultural productivity [4].

Fig 1. Agricultural Observation and Farming Location

Currently, Inbate Village has two active farmer groups that utilize the dry season for cultivating onions, vegetables, and coriander. Farming activities rely on water sources from nearby rivers and community-built reservoirs. Most of the harvest is consumed by farming households, while the remaining produce is sold in local markets and, to a limited extent, marketed to border areas in Timor Leste. However, farmers continue to face several challenges, including limited irrigation facilities, high production costs, and commodity price fluctuations that often result in financial losses during peak harvest periods [5].

Therefore, the implementation of a Smart Farming system specifically designed for dryland agriculture—integrating soil and weather sensors, water-efficient irrigation systems, and continuous technical assistance—has become a strategic intervention. The concept of smart farming is introduced through the utilization of advanced Internet of Things (IoT)-based technologies [6]. This technology enables agricultural processes to be carried out more efficiently and accurately through automatic monitoring of soil moisture, light intensity, temperature, and sensor-based irrigation systems capable of detecting soil conditions and plant water requirements in real time, followed by automated irrigation processes [7].

This initiative is expected not only to improve agricultural productivity per unit area, but also to empower the village's productive human resources, reduce the risk of crop failure caused by drought, and create broader marketing opportunities, including access to cross-border markets.

II. METHODS

The implementation of the community service program was conducted through four main stages.

a. Stage

The preparation stage included field observation, identification of agricultural land conditions, and discussions with local farmer groups regarding irrigation needs and technology implementation. The team also conducted procurement of IoT devices, drip irrigation equipment, water pumps, and soil moisture sensors.

b. Implementation Stage

The implementation stage began with socialization activities regarding dryland smart farming technology. The activities included:

1. Installation of IoT-based drip irrigation systems.
2. Installation of soil moisture sensors and weather monitoring devices.
3. Integration of sensors with automated irrigation control systems.
4. Training sessions for farmers regarding operation and maintenance of smart farming equipment.

The irrigation system was installed in onion and vegetable farming beds using PVC pipelines connected to a central water distribution pipe and water storage tank.

c. Mentoring Stage

The mentoring process was conducted for three months through routine monitoring and field assistance. The activities included:

- Monitoring plant growth and irrigation performance.
- Monitoring crop productivity and harvest results.
- Assisting farmers in using IoT monitoring systems.
- Evaluating system effectiveness during dry season farming.

d. Evaluation Stage

The evaluation phase was carried out using user satisfaction questionnaires and interviews involving community members and village officials. This process aimed to assess user satisfaction levels, measure the effectiveness of the chatbot services, and identify challenges experienced during system usage. The findings from the evaluation were subsequently utilized as the basis for improving and developing additional chatbot system features.

III. RESULT AND DISCUSSION

The IoT-based smart farming implementation program was implementated to Liklao Farmer Groups In Inbate Village. The program was conducted from July 2025 until April 2026. The implementation schedule consisted of preparation and agricultural needs analysis in July 2025, development, installation and farmer training of the IoT-based irrigation system during July 2025, field monitoring from July to October 2026, and evaluation during December 2025.

Installation of IoT-Based Irrigation System

The smart farming system was successfully implemented in dryland farming areas in Inbate Village. The system consisted of drip irrigation pipelines, soil moisture sensors, IoT controllers, water pumps, a water storage system and solar cell as energy. The irrigation network distributed water efficiently to onion and vegetable planting beds.

The IoT system enabled automatic irrigation control based on soil moisture conditions. When the soil moisture level decreased below the predefined threshold, the system automatically activated the water pump and irrigation valves. This process significantly reduced unnecessary water usage and improved irrigation efficiency.

Improvement of Agricultural Productivity

The implementation of drip irrigation technology improved crop growth during the dry season. Farmers reported more stable soil moisture conditions and better plant growth compared to conventional irrigation methods.

The use of automated irrigation systems also reduced labor requirements because watering activities no longer needed to be performed manually. Farmers were able to allocate more time to crop maintenance and harvest preparation.

Farmer Training and Digital Literacy

Training activities improved farmers' understanding of IoT-based agriculture technology. Farmers learned how to monitor sensor data, operate irrigation systems, and perform basic equipment maintenance. The mentoring process demonstrated that communities in border areas possess strong potential to adopt modern agricultural technology when supported through practical training and continuous assistance.

Fig 2. Instalation IoT and Training

Program Impact

The implementation of smart farming technology generated several positive impacts:

1. Increased irrigation efficiency and reduced water consumption.
2. Improved crop productivity during dry seasons.
3. Enhanced farmer knowledge regarding modern agricultural technology.

4. Reduced risk of crop failure caused by drought.
5. Strengthened sustainable agriculture practices in border areas.

The use of IoT-based systems also introduced digital agriculture concepts to local communities and encouraged the development of technology-supported farming practices.

Fig 3. Implementation result

Evaluation

Program evaluation was conducted using questionnaires and interviews involving 15 farmers from Liklao Farmer groups . The evaluation was conducted after the system had been implemented for three months. The evaluation focused on irrigation efficiency, farmer satisfaction, ease of technology use, and productivity improvement.

Table 1. Evaluation Results

Evaluation Aspect	Percentage (%)	Category
Ease of Technology Use	92%	Very Good
Irrigation Efficiency	90%	Very Good
Information Accessibility	88%	Good
Farmer Satisfaction	91%	Very Good
Productivity Improvement	85%	Good
Water Use Efficiency	89%	Good

The evaluation results after three months of implementation indicate that the IoT-based smart farming system in Inbate Village was successfully adopted and positively accepted by farmers and village stakeholders. The system demonstrated high performance in ease of technology use (92%), farmer satisfaction (91%), and irrigation efficiency (90%), showing that the drip irrigation and monitoring technologies effectively improved water management and agricultural activities. In addition, the system contributed to better water use efficiency (89%), improved access to agricultural information (88%), and increased crop productivity (85%). Overall, the implementation of smart farming technology had a significant positive impact on dryland agricultural management, farmer knowledge, and sustainable farming practices in the Indonesia–Timor Leste border area.

IV. CONCLUSION

The implementation of the IoT-based smart farming system in Inbate Village successfully improved dryland agricultural management in the Indonesia–Timor Leste border area. Based on the evaluation results, the system achieved high performance in ease of technology use (92%), farmer satisfaction (91%), irrigation efficiency (90%), water use efficiency (89%), information accessibility (88%), and productivity improvement (85%), indicating that the integration of drip irrigation technology, soil moisture sensors, IoT controllers, and solar-powered energy systems effectively optimized water management and agricultural productivity during the dry season. In addition, the program enhanced farmers' knowledge and skills in utilizing modern agricultural technologies through training and continuous mentoring. The implementation of automated irrigation systems also reduced manual labor requirements, minimized the risk of crop failure caused by drought, and supported sustainable agricultural practices. Overall, the results demonstrate that

IoT-based smart farming technology can serve as an innovative and sustainable solution for strengthening food security and improving the welfare of farming communities in dryland and border regions.

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