



# Advancing Sustainable Agriculture through Smart Farm Tagging and AI-Driven IoT Dashboards

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DOI:

<https://doi.org/10.47134/jtsi.v2i3.4859>

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Received: 30-05-2025

Accepted: 30-06-2025

Published: 30-07-2025



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**Abstract:** The paper introduces Smart Farm Tagging with Basic, Pro, and Advanced versions, a smart livestock monitoring system that integrates Artificial Intelligence (AI), Internet of Things (IoT), Near Field Communication (NFC), barcode technologies, and Global Positioning System (GPS). The system enables real-time tracking and monitoring of key parameters such as species type, gender, health status, body weight, and production output. Initial field data include cattle profiles labeled by health status (“Healthy”), gender (“Female” or “Male”), and weight, with birth date validation ongoing. Furthermore, the AI-powered dashboard integrates operational logs with external weather inputs such as temperature, humidity, and light rain conditions recorded in Sayan, Bali, to predict livestock health trends and recommend timely interventions. Statistical models analyze historical and real-time data to detect diseases, optimize breeding schedules, and enhance resource allocation. By integrating AI, IoT, NFC, and barcode technologies, Smart Farm Tagging presents a scalable, cost-effective, and efficient solution for modern smart farming systems.

**Keywords:** Smart Farming, Livestock Monitoring, Artificial Intelligence (AI), Internet of Things (IoT), NFC and Barcode Integration

## Introduction

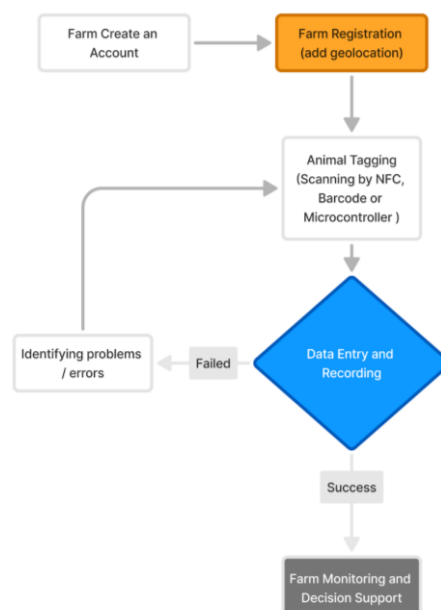
The livestock industry plays a pivotal role in ensuring global food security and supporting economic stability (Banda & Tanganyika, 2021) (Godber & Wall, 2014). However, traditional livestock management practices are increasingly being challenged by limitations in data accuracy, inefficient tracking, and a lack of automation (Berckmans, 2017) (Mulla, 2013) (Pendyala et al, 2021). As the demand for higher productivity, better animal welfare, and sustainable operations grows, modern farms are under pressure to adopt smarter technologies (Dawkins, 2021) (Dayoub et al, 2024) (Gaworski & Kic, 2024) (Michie et al, 2020). Recent studies have shown that the integration of technologies such as the Internet of Things (IoT), Near Field Communication (NFC), artificial intelligence (AI), and automated data collection devices can significantly enhance livestock productivity and decision-making (Akhigbe et al, 2021) (Mishra & Sharma, 2023) (Sharma et al, 2023). These innovations allow for real-time monitoring, labor reduction, and timely interventions critical components in advancing precision agriculture (Aarif et al, 2025).

Despite these advancements, many livestock farms, particularly in rural and developing areas, still rely on manual methods for tracking animal health, vaccination, reproduction, and birth records (Donadeu et al, 2019) (Islam et al, 2025). These manual systems are susceptible to human error, inconsistent updates, and data loss (Banhazi & Black, 2009) (Curti et al, 2023). Without accurate and real-time information, farm managers face difficulties in making informed decisions, which can result in reduced animal health, inefficient breeding cycles, and suboptimal resource usage. Furthermore, the lack of integration between health records and environmental factors such as local climate and weather poses additional risks, especially in regions where external conditions heavily influence livestock health outcomes (Cheng et al, 2022) (Escarcha et al, 2018) (Narayan et al, 2021).

To address these challenges, this paper proposes Smart Farm Tagging, a modular livestock monitoring solution available in Basic, Pro, and Advanced versions. The system leverages AI and IoT technologies alongside NFC and barcode scanning. It enables real-time tracking of livestock attributes such as species, health status, gender, body weight, and production output. The collected data is processed through an AI-powered dashboard that integrates operational logs with local weather inputs such as temperature, humidity, and rainfall recorded in Sayan, Bali. This integration supports predictive analytics to detect disease risks, optimize breeding schedules, and enhance resource allocation. This research contributes a scalable and cost-efficient approach to precision livestock farming by showcasing the practical implementation of AI, IoT, NFC, and environmental sensing technologies within a unified smart farming framework.

## Methodology

The Smart Farm Tagging system offers an intuitive workflow for farmers and livestock managers, beginning with farm registration via a web-based dashboard where users input farm location, name, and livestock type shown in Figure 1.



**Figure 1.** Workflow of Smart Farm Tagging

## System Architecture

The Smart Farm Tagging system was developed as a hybrid AI-IoT solution to support real-time livestock management, particularly for cattle and poultry farming. The system architecture consists of three major components: a cloud-based dashboard powered by AI analytics, a progressive web application (PWA) for farmers' mobile devices, and field tagging devices utilizing Near Field Communication (NFC) and barcode technologies. This design ensures seamless data synchronization, minimizes device dependency, and promotes accessibility across both Android and iOS platforms.

The decision to implement a PWA was based on its cross-platform capabilities, allowing the system to be installed on any smartphone without the need for specific app stores, ensuring broader farmer adoption in rural and semi-urban areas.

## Field Site Selection

The field implementation was conducted in Sukasada Subdistrict, located in Buleleng Regency, Bali Province, Indonesia. Bali Island was selected due to its international reputation for Balinese cattle (*Bos javanicus domesticus*), a prominent and genetically significant livestock breed known for its adaptability and economic importance. Sukasada was chosen as one of the representative farming areas where cattle farming is prevalent. In addition to cattle farms, initial tests were also performed on poultry farms in the same region to evaluate the flexibility and generalizability of the Smart Farm Tagging system across different types of livestock.

## Animal Identification System

Each animal is assigned a unique identifier based on a structured naming convention showing Figure 2. Identifiers are encoded onto both NFC tags and barcode labels, attached appropriately to cattle collars or poultry housing units.

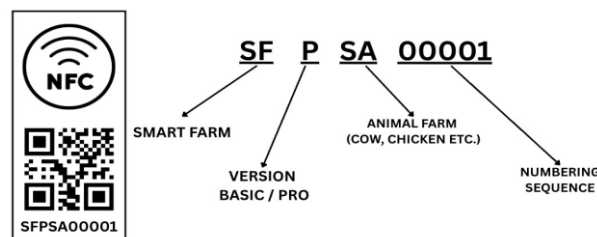


Figure 2. Formatting the numbering of Smart Farm Tagging

SFPSA00001, where:

- SF: Represents the "Smart Farm" project origin.
- P: Denotes the "Pro" version, which supports advanced features such as 3D data integration.
- SA: Stands for "Sapi," meaning "cow" in Indonesian.
- 00001: A sequential five-digit number representing individual animals.

## NFC and Barcode Technology Implementation

NFC technology was selected for its ease of use, requiring only a simple tap to retrieve information, making it highly suitable for farm environments. Farmers can instantly access an animal's complete profile via their NFC-enabled smartphones.

However, recognizing that not all smartphones are equipped with NFC capabilities, barcode technology was also implemented. Barcodes corresponding to each animal's unique ID were printed on durable, weather-resistant materials, ensuring compatibility with standard smartphone cameras without requiring additional hardware.

The dual-technology approach guarantees that Smart Farm Tagging remains inclusive, fast, and easy to accommodate varying technological infrastructures among farmers.

## Dashboard and Data Processing

The PWA and cloud dashboard collect and manage key livestock parameters, including:

- 1) Species type
- 2) Health status
- 3) Gender
- 4) Body weight
- 5) Production output
- 6) Reproductive cycle (for cattle)
- 7) Vaccination records
- 8) Birth events

All data entries are time-stamped and, where possible, geotagged. The AI engine processes operational logs and integrates external weather inputs such as temperature, humidity, and precipitation data to predict livestock health risks and recommend timely interventions shown in Figure 3.



Figure 3. Smart Farm Tagging historical dashboard

Real-time and historical data are used to train machine learning models for disease detection, breeding optimization, and resource allocation strategies. Offline operation is supported through data caching, with automatic synchronization once internet connectivity is restored.

## Result and Discussion

### System Performance and Data Collection

The Smart Farm Tagging system was successfully deployed in Sayan, Mengwi, Badung, Bali. A total of four unique records were collected during the pilot deployment, consisting of two cattle entries and two poultry entries. The system effectively logged key parameters, including animal ID, gender, birth date, health status, vaccination history, and body weight. The data collected are summarized in Table 1.

**Table 1.** An example of a table (font size 10pt)

Animal ID	Species	Gender	Age (year)	Body Weight (kg)	Last Vaccination Date	Health Status
SFPSA00001	Cow	F	1.3	300	2024-12-01	Healthy
SFPSA00002	Cow	M	1	200	2024-12-01	Healthy
SFPAB00001	Chicken	M	1	1.5	2025-04-26	Healthy
SFPAB00002	Chicken	M	1	1.5	2025-04-26	Healthy

### Livestock Monitoring Effectiveness

The Smart Farm Tagging system demonstrated tracking of individual animal records, particularly in terms of vaccination status, age, and growth metrics in line with Bernard. I. Akinade et al. The cattle records (SFPSA00001 and SFPSA00002) showed consistent health data, with regular vaccination and reliable age and body weight entries. SFPSA00001, a 1.3-year-old female cow, recorded a body weight of 300.0 kg, while SFPSA00002, a 1-year-old male, registered 200.0 kg. These data confirm the system's ability to track both growth progression and health readiness, supporting long-term breeding and health management strategies.

In poultry, the system captured entries for two broiler-type chickens, SFPAB00001 and SFPAB00002, each at approximately 1 year of age. However, due to rounding or simplified entry practices, body weights were uniformly recorded as 1.5 kg in Table 1. Moreover, the system correctly logged recent poultry vaccination dates (e.g., 26 April 2025), reflecting proper scheduling adherence. This is particularly important for broiler chickens, which may follow frequent vaccination cycles depending on farm management practices.

### Technology Usability and Data Integrity

The Smart Farm Tagging system demonstrated strong usability and adaptability through its dual-mode scanning technology. Farmers with NFC-enabled smartphones benefited from quick tap-based interactions, while others relied on barcode scanning via

built-in cameras. This dual approach ensured compatibility across diverse device types commonly found in rural agricultural settings. Moreover, the use of a Progressive Web App (PWA) enabled seamless access on both Android and iOS platforms without requiring app store installations, removing barriers to adoption and simplifying deployment.

While field usage confirmed that the system was accessible and easy to operate, several data integrity issues were observed. Early entries included missing weights and invalid birth dates, indicating a need for improved input validation and error prompts within the interface. Additionally, chicken weights were later simplified to a rounded value (1 kg), diverging from previous detailed entries of 3.0–3.2 kg. This suggests the need for stronger version control and historical record tracking within the system. Furthermore, all milk or egg production values were recorded as zero, which aligns with the non-lactating status of the observed cows. However, future iterations of the system should incorporate contextual logic that adjusts expected outputs based on species type, gender, and lifecycle stage, enhancing the accuracy of analytics and AI-driven recommendations.

### *Discussion*

The pilot deployment of the Smart Farm Tagging system in Sayan, Bali, highlights both its strengths and areas for refinement. The system successfully demonstrated its capacity to capture essential livestock parameters such as identification, age, body weight, vaccination history, and health status through dual NFC and barcode scanning modes integrated into a Progressive Web App, ensuring accessibility across diverse devices. The accurate and timely recording of cattle growth metrics and poultry vaccination schedules confirms its effectiveness in supporting routine health monitoring and breeding management, consistent with findings by Bernard I. Akinade et al. Moreover, our experience echoes the broader literature: Terence (2024) points out that many IoT livestock implementations still under-address security, scalability, and data analytics capabilities; Neethirajan (2025) underscores persistent concerns with data authenticity, privacy, and availability; Hossain et al. (2025) demonstrate the effectiveness of threat detection using collaborative filtering techniques; and Das, Roy, and Sahoo (2025) highlight the transformative potential of IoT-based remote monitoring for livestock tracking, production optimization, and sustainability. Nevertheless, challenges were observed in data integrity, including simplified or inconsistent weight entries, occasional missing values, and the lack of contextualized production outputs, indicating the need for enhanced input validation, historical record tracking, and AI-driven contextual logic. These findings suggest that while the system is highly usable and scalable for rural agricultural contexts, further refinement is required to strengthen data reliability and fully unlock its potential in advancing precision livestock farming and sustainability.

## Conclusion

This study introduced and evaluated the Smart Farm Tagging system, a hybrid IoT solution designed to enhance livestock monitoring through integrated NFC and barcode technologies. Field deployment in Sayan, Bali, demonstrated the system's effectiveness in recording and managing vital animal data such as age, body weight, gender, health status, and vaccination history. The use of both NFC and barcode ensured compatibility across various smartphone types, while the progressive web application (PWA) enabled flexible access independent of platform constraints.

Results showed that the system supported consistent tracking of both cattle and poultry, with real-time updates contributing to operational transparency and improved health management. Additionally, the incorporation of weather data and AI-ready log structures laid a foundation for future predictive modeling of livestock health and productivity. However, several areas for enhancement were identified, including data input validation, record versioning, and lifecycle-aware analytics logic. Future work will focus on expanding the system's capabilities to include blockchain integration for secure data recording, ensuring transparency in livestock history, vaccination records, and traceability across the supply chain.

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