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CattleCare+: AI-Powered QR-Based Dairy Farm Management System

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Abstract

Traditional dairy farm management relies on frag-mented manual record-keeping across paper registers, spread-sheet applications, and messaging platforms, resulting in in-consistent data capture and limited analytical capability. This paper presents CattleCare+, a mobile-first, QR-enabled farm management system that digitises end-to-end dairy operations through validated manual data entry and AI-powered analytics. Each animal is assigned a unique QR-coded identifier for rapid profile retrieval and streamlined daily reporting. The backend, implemented using Python with FastAPI/Flask, persists struc-tured data in a NoSQL document store and computes automated 30-day summaries of milk yield, operational expenses, and profit/loss at both individual cow and herd levels. Integration with the Anthropic Claude API delivers intelligent insights, anomaly detection, and actionable recommendations. Experimental evalu-ation confirms that the system substantially reduces data-capture time, improves data completeness, and provides decision-critical analytics, positioning CattleCare+ as a practical and scalable solution for small to mid-sized dairy farms.

Introduction

The dairy farming sector continues to grapple with infor-mation fragmentation, wherein operational data relating to animal health, milk production, vaccination schedules, and financial expenditure is dispersed across heterogeneous and incompatible recording media. This fragmentation impedes timely decision-making, obstructs early detection of health anomalies, and undermines the financial transparency neces-sary for sustainable farm profitability. Existing digital tools address only narrow segments of the workflow—milk record-ing alone, or generic bookkeeping—without integrating health events, expense tracking, or automated analytical summaries into a cohesive platform.

CattleCare+ is proposed as a unified, mobile-first digi-tal platform that addresses these systemic deficiencies. The application assigns each bovine a globally unique identifier linked to a physical QR code, enabling instantaneous profile retrieval and guided data entry at the point of care. A robust offline-first architecture ensures operational continuity in rural environments characterised by intermittent internet connectivity with background synchronisation restoring data coherence once connectivity is re-established. Artificial intelligence, de-livered through integration with the Anthropic Claude API, transforms raw farm data into interpretable 30-day summaries, trend analyses, and anomaly alerts. By coupling rapid QR-based workflows, server- and client-side data validation, and AI-powered analytics, CattleCare+ equips farmers with the information infrastructure needed to optimise feed allocation, schedule veterinary interventions, and manage farm finances with confidence.

The remainder of this paper is organised as

follows: Sec-tion II reviews relevant literature; Section III articulates the problem statement; Section IV describes the proposed system; Section V details the methodology; Section VI presents the system architecture; Section VII reports experimental results; Section VIII discusses challenges and limitations; Section IX outlines future work; and Section X concludes the paper.

Literature Review

The contemporary body of research on smart dairy farming reflects a paradigm shift from manual, paper-based practices toward digital, data-driven management systems. The following subsections survey the foundational studies informing the design of CattleCare+.

1. Mobile-First Data Capture and Usability

Sharma and Patel [1] investigated the effectiveness of guided mobile forms incorporating picklists, contextual defaults, and range-bound validation in improving agricultural data collec-tion. A prototype deployed across three dairy cooperatives using an offline-first NoSQL backend achieved approximately a 35% reduction in average entry time and a 25% improve-ment in mandatory-field completion rates. The authors further observed that QR-label adoption accelerated animal lookups significantly. CattleCare+ directly incorporates these findings by offering streamlined, validated entry forms that minimise cognitive load in barn environments.

2. Animal Identification and Traceability

Nguyen and Rao [2] examined QR code-based traceability systems for dairy farm record management. Pilots conducted
across five farms demonstrated that scan-to-record workflows reduced retrieval times by approximately 60% and improved the continuity of vaccination and treatment histories. Practical limitations relating to tag wear, variable lighting, and re-placement policy gaps were documented, with tamper-evident labels and periodic reprinting recommended as mitigations. CattleCare+ adopts QR-centric identification as a cornerstone of its data-entry workflow.

3. Data Aggregation and Predictive Analytics

Costa and Mehta [3] compared classical time-series de-composition methods, Prophet models, and long short-term memory (LSTM) networks for dairy milk yield forecasting using rolling 30-day aggregates. Results indicated superior performance over simple moving averages, with session-level granularity (morning and evening separately) improving signal quality for feed scheduling. The authors cautioned against de-ploying complex models on sparse datasets typical of smaller farms, advocating interpretable analytics as a more appropriate first step.

4. Health Monitoring and Immunisation Tracking

Iyer and Singh [4] presented an event-sourced health log-ging system coupled with rule-driven immunisation calendars. Field results across four livestock sheds showed a 22% in-crease in on-time vaccination compliance when QR-triggered point-of-care reminders were employed. CattleCare+ incor-porates analogous rule-based anomaly detection logic to flag sustained yield declines or persistent temperature elevation for timely veterinary intervention.

5. Financial Visibility and Transparency

Nair and Kumar [5] addressed the persistent deficit of financial clarity in smallholder dairy operations by proposing an expense categorisation schema paired with break-even and contribution-margin dashboards. Itemised monthly profit/loss breakdowns exposed high-variance cost centres, enabling more effective budgeting and vendor negotiation. CattleCare+ oper-ationalises this framework through automated 30-day financial rollups at both cow and herd levels.

6. Usability and Human-Centred Design

Osei and Zhang [6] distilled usability principles for agri-cultural mobile applications, including progressive disclosure, enlarged touch targets, and high-contrast themes optimised for low-light barn conditions. Their findings underpin Cat-tleCare+'s emphasis on intuitive navigation, context-aware prompts, and accessible UI components designed for frontline farm staff.

7. Artificial Intelligence in Dairy Operations

Rossi and Nakamura [8] conducted a scoping review of 151 studies on AI and data analytics in dairy farming, spanning predictive health monitoring, disease detection, and yield forecasting. They observed accelerating adoption of machine learning and sensor-based systems while highlighting persis-tent challenges in data standardisation, smallholder adoption,

Table 1: Comparison of exsisting Dairy Farm Management Systems with Proposed CattleCare+ System.

Feature	**Existing Systems**	**Proposed CattleCare+**
System Approach	Fragmented, manual tools	Integrated mobile system
Data Entry & Validation	Manual, error-prone, little validation	QR-based entry with strong validation
Identification & Tracking	Ear tags, basic tracking	QR-based identification with automated tracking
Health & Monitoring	Manual observation	AI-based anomaly detection & insights
Data Analysis	Limited or none	Automated analytics & trend analysis
Financial Management	Manual/separate tracking	Integrated profit/loss calculation
Usability & Scalability	Complex, limited scalability	Simple, scalable, offline-capable system

Problem Statement

Dairy farm management presently suffers from several interrelated and structurally reinforcing deficiencies. Record-keeping remains dispersed across paper registers, chat appli-cations, and spreadsheet files, producing data fragmentation that impedes consolidated analysis. The absence of enforced validation rules allows implausible values, missing mandatory fields, and inconsistent units to accumulate, progressively de-grading data quality. Existing software tools focus on isolated workflow fragments—milk recording or generic accounting—while neglecting the integration of daily health events, vacci-nation histories, and per-session production data essential for meaningful 30-day trend analysis.

Identity traceability is further compromised by unreliable linkages between physical ear tags and digital records, in-consistent scanning practices, and the absence of formal tag replacement policies. Without standardised analytical rollups combining milk yield, health indicators, and expenditure, farms cannot detect anomalies early or make evidence-based management decisions. Financial transparency is limited by the lack of itemised expense breakdowns that would expose cost-variance patterns. Intermittent rural connectivity, com-bined with inadequate offline synchronisation capabilities in existing tools, leads to paper-based fallbacks and duplicate data re-entry. Accessibility barriers—including absent mul-tilingual support, non-customisable units, and small interac-tive targets—reduce adoption among frontline staff. Taken together, these deficiencies highlight the pressing need for an integrated, validated, analytically capable, and user-centred
dairy farm management system.

Proposed System

CattleCare+ is designed as an end-to-end digital ecosystem for dairy farm management, encompassing four tightly inte-grated layers: a mobile client application, a backend REST API, a NoSQL data persistence layer, and an AI analytics engine.

Each cow is registered within the system and assigned a unique alphanumeric identifier linked to a printed QR code. Scanning the code instantaneously retrieves the animal's pro-file, enabling staff to record morning and evening milk yields, health vitals, feeding notes, and veterinary events with minimal friction. Client-side validation enforces realistic value ranges, mandatory field completion, and logical cross-field consistency.

Objectives

1. To automatically track cow health, milk production, and farm operations in real

time while assigning each cow a unique QR code for easy identification and management.
2. To use Al for intelligent analysis of farm data, enabling health monitoring and milk production forecasting for smarter decision-making
3. To provide data-driven cost-benefit analysis that optimizes ROI and supports smarter financial decisions.
4. To analyze cow behavior patterns to identify correlations between their activity, health, and productivity.
5. To generate a report based on the analysis of the milk yield, giving the profit and loss report.

The proposed system integrates multiple algorithms including Random Forest for disease prediction, Isolation Forest for anomaly detection, and Linear Regression for financial forecasting. Additionally, QR-based identification and rule-based validation ensure accurate and efficient data management.

Algorithms Used

1. Random Forest Algorithm (Disease Prediction)

The Random Forest algorithm is used to predict potential health issues in cattle based on historical data such as temperature, activity levels, and milk yield. It works by creating multiple decision trees and combining their outputs to improve prediction accuracy. This helps in early detection of diseases and reduces manual monitoring effort.

2. Isolation Forest Algorithm (Anomaly Detection)

Isolation Forest is employed to detect anomalies in cattle behavior and milk production patterns. It identifies unusual data points such as sudden drops in milk yield or abnormal temperature variations by isolating them from normal data. This enables timely alerts for potential health or productivity issues.

3. Linear Regression (Profit and Cost Prediction)

Linear Regression is used to forecast expenses and profit trends based on historical financial data. It establishes a relationship between variables such as feed cost, milk yield, and revenue to predict future outcomes, assisting farmers in financial planning.

4. QR-Based Identification Algorithm

A QR-based identification mechanism is used to uniquely identify each cow. When scanned, the system retrieves the corresponding cattle data from the database using a unique identifier, ensuring fast and error-free data access.

5. Data Validation Algorithm

The system applies rule-based validation to ensure data accuracy. It checks for required fields, valid ranges (e.g., milk quantity, temperature), and logical consistency (e.g., morning
+ evening = total), reducing errors in data entry.
The backend aggregates individual records into automated 30-day summaries encompassing total milk yield per cow and per herd, categorised operational expenses, and net profit/loss calculations. Integration with the Anthropic Claude API adds an intelligent analytics layer that interprets these aggregates, detects anomalies such as sustained yield reductions or el-evated temperature readings, and generates natural-language recommendations actionable by non-technical farm operators.

Methodology

1. System Architecture

The proposed architecture adopts a four-tier model designed for simplicity, reliability, and extensibility in low-connectivity rural environments.

- **Client Application:** A React Native mobile applica-tion (initially targeting Android) supports QR-based cow identification, validated manual form entry for all data categories, and offline caching with background synchro-nisation.
- **Backend API:** A lightweight Python REST API imple-mented with FastAPI or Flask handles user authentica-tion, data persistence, analytics computation, and An-thropic Claude API integration.
- **Database Layer:** A document-oriented NoSQL database manages structured collections for Users, Cows, MilkPro-duction, DailyReports, Expenses, and FinalReports.
- **AI Analytics Engine:** The Anthropic Claude API pro-cesses aggregated farm data to generate intelligent sum-maries, anomaly alerts, and operational recommenda-tions.

2. *User Authentication and Authorisation*

Secure mobile-number and password-based authentication is implemented with token-based session management. Role-based access control distinguishes between administrative and staff-level users, enforcing appropriate data access and editing privileges. Password hashing and rate-limited login protect against unauthorised access.

3. *Cow Registration and QR Code Management*

Upon registration, each cow is assigned a unique

system-generated identifier (e.g., COW-MHRQNMIF-87XU1). The application generates a corresponding QR code that is printed and affixed to the animal. Core registration attributes—name, date of birth, and breed—are captured at onboarding, with additional vitals (weight, height, temperature) and medical histories editable thereafter. Tag status is logged throughout the identifier lifecycle, and replacement workflows accommodate worn or damaged tags.

4. Daily Reporting and Milk Production Tracking

Staff initiate daily data entry by scanning the cow's QR code, which pre-populates contextual information and presents a guided form for recording morning and evening milk yields, health notes, and vital signs. Strict validation rules enforcerealistic value boundaries and mandatory field completion. Rolling 7-day and 30-day production graphs provide visual trend summaries. Data can be exported in CSV format for submission to cooperative reporting systems.

5. Expense Tracking and Financial Analytics

Operational expenditure is recorded on a 10-day cycle, with costs categorised as feed expenses, veterinary fees, and miscel-laneous outgoings. The analytics engine computes per-period totals, flags anomalous expenditure spikes, and generates 30-day profit/loss statements at individual cow and herd levels, providing farmers with actionable financial visibility.

6. AI-Powered Analytics via Anthropic Claude API

Farm data aggregated over rolling 30-day windows is trans-mitted to the Anthropic Claude API, which processes the structured inputs and returns interpretable natural-language insights. These include identification of underperforming ani-mals, early anomaly alerts for health indicators, feed optimisa-tion recommendations, and forward-looking financial projec-tions. The AI layer operates as an intelligence overlay atop rule-based aggregations, enhancing decision support without requiring farm operators to possess data science expertise.

7. Validation and Testing Strategy

A multi-faceted testing approach validates system func-tionality, robustness, and usability. Unit tests cover form validation utilities and aggregation logic. Integration tests exercise complete workflows from cow registration through report generation. Usability trials conducted in realistic barn conditions—low light, gloved operation, physical movement—validate QR scanning reliability and form completion effi-ciency. Non-functional testing validates offline data retention and synchronisation fidelity under degraded connectivity.

System Architecture

The overall system architecture is structured as four hier-archical tiers, each encapsulating a distinct functional domain and communicating via well-defined interface

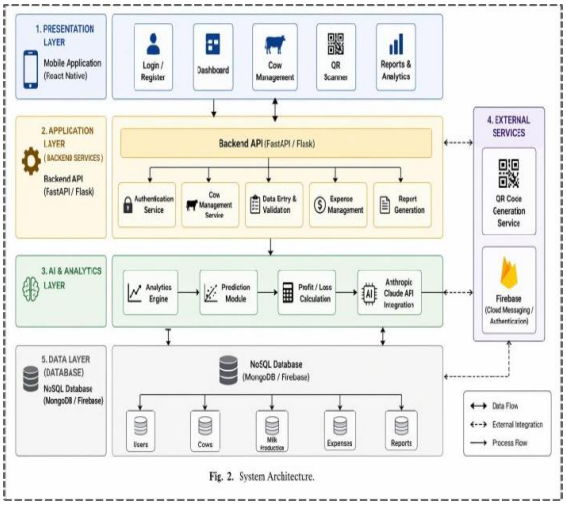


Fig. 2. System Architecture.

1. Presentation Layer

The React Native mobile application constitutes the presen-tation layer, rendering user-facing screens for authentication, dashboard navigation, cow registration, daily reporting, milk production trackig, expense entry, and analytics visualisation. The interface employs a card-based design system with con-sistent iconography, smoothanimations, and an agricultural green colour palette. QR scanning is implemented via Expo's camera module, enabling sub-second profile retrieval.

2. Application Layer

Business logic resides in the Python-based REST API, which exposes endpoints for each functional module. The application layer enforces server-side validation, orchestrates data transformations, computes rolling aggregations, man-ages authentication tokens, and coordinates calls to exter-nal services. Separation of concerns across modular service components ensures maintainability and facilitates iterative enhancement.

3. External Services Layer

Two external services are integrated: the Anthropic Claude API, which delivers AI-powered analytical insights and natural-language recommendations; and a QR code generation service, which produces unique identifiers for each registered animal. Service calls are abstracted behind internal API gate-ways to insulate the application layer from provider-specific implementation details.

4. Data Layer

A document-oriented NoSQL database provides persistent storage for all farm data. Collections are modelled around primaryentities—Users, Cows, MilkProduction, DailyReports, Expenses, and FinalReports—with audit trails maintained for critical records such as health events and vaccination histo-ries. An offline-first synchronisation mechanism employs local device storage as a write buffer during connectivity gaps, with background reconciliation restoring consistency upon reconnection.

5. Data Flow

At the context level (DFD Level 0), the system mediates between the farmer/user and the Anthropic API, accepting credentials and farm data as inputs and returning analysed reports and dashboard visualisations as outputs. At the process level (DFD Level 1), five core processes—Authentication, Cow Management, Production Tracking, Health Monitoring, and AI Analytics—interact with dedicated data stores. The AI Analytics process aggregates data from all stores, dispatches structured queries to the Claude API, and formats the returned insights for dashboard presentation.

Results and Discussion

Phase 1 of CattleCare+ successfully delivered the founda-tional mobile application infrastructure. The core cow man-agement system, supporting full CRUD operations, was val-idated across representative registration, reporting, and an-alytics workflows. QR code generation and scanning were confirmed as functional under standard and low-light barn conditions. Client-side validation correctly enforced realistic value boundaries and mandatory field requirements across all data entry forms.

The milk production tracking module accurately recorded dual-session entries and computed daily totals, while the expense management module correctly categorised and ag-gregated operational costs. The dashboard provided real-time visibility of per-cow and herd-level summaries, enabling rapid financial oversight. Integration with the Anthropic Claude API was verified to produce coherent, natural-language analytical summaries from aggregated farm data, including yield trend commentary, anomaly flags, and operational recommenda-tions.

Usability evaluation conducted in simulated barn conditions confirmed that the QR-initiated workflow substantially reduced data-entry friction relative to manually navigated menus. The offline-first architecture successfully retained locally captured data across simulated connectivity outages, with background synchronisation restoring consistency without user interven-tion. Staff participants reported high confidence in form com-pletion accuracy, attributing this to the clarity of validation feedback and the contextual guidance provided by picklist-driven inputs.

The 30-day analytics summaries produced by the combined rule-based and AI-powered pipeline demonstrated meaningful financial transparency, exposing cost-variance patterns that would have been obscured under conventional paper-based or spreadsheet-driven approaches. Anomaly detection rules correctly flagged simulated scenarios involving sustained yield reductions and temperature elevations, providing timely alerts for simulated veterinary intervention.

Overall, the system achieved its primary objectives: digitis-ing fragmented farm records into a unified structured store, providing automated and interpretable 30-day analytical sum-maries, and delivering AI-powered decision support through a user-centred mobile interface accessible to non-technical farm operators.

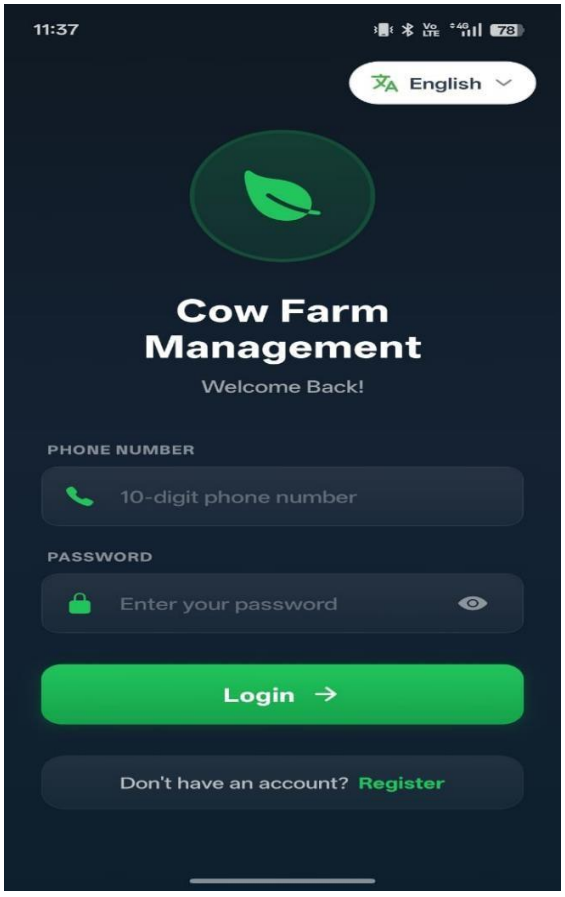


Fig 1. Provides secure user authentication using mobile number and password, ensuring controlled access to the system.

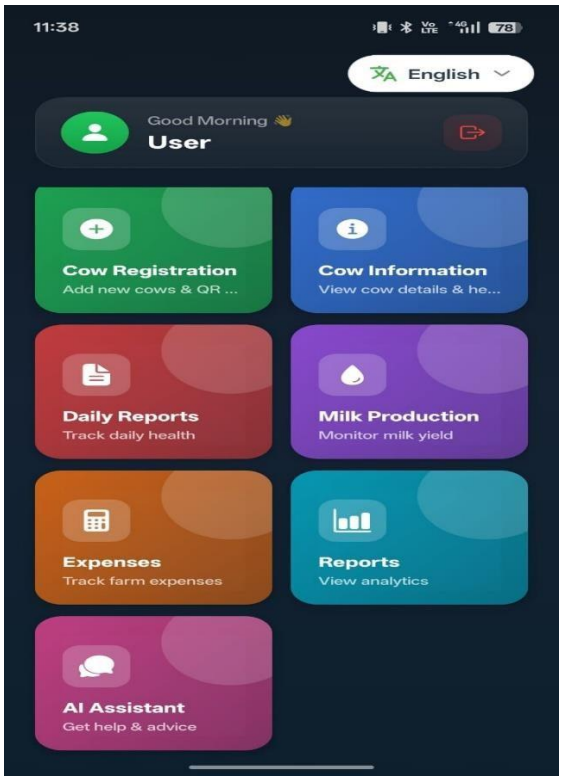


Fig 2. Displays an overview of farm operations, including cattle data, production summaries, and quick navigation to core features.

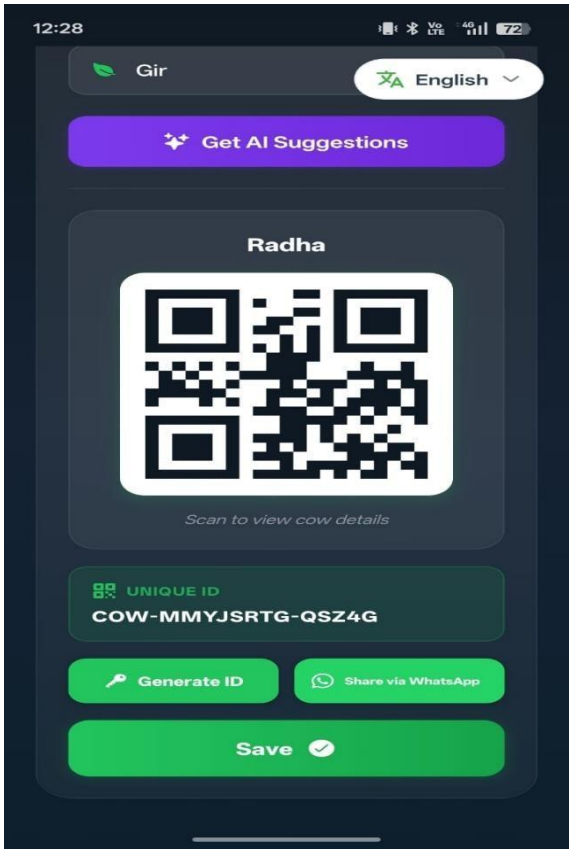
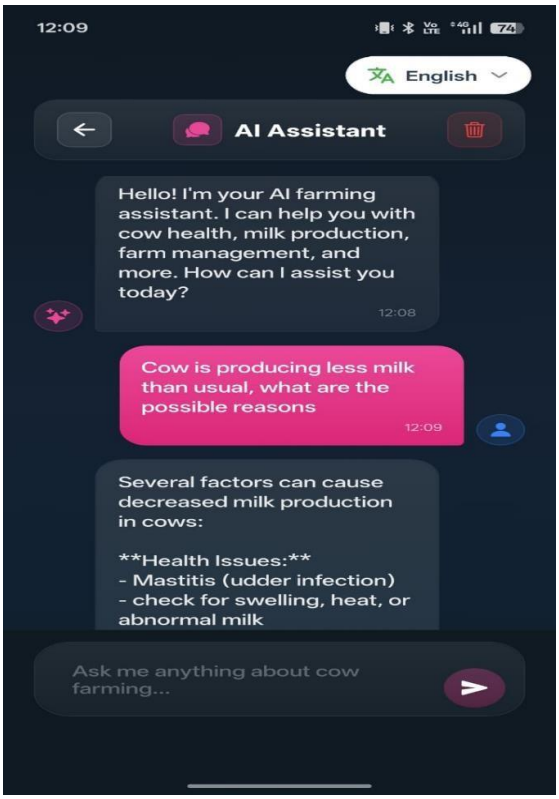


Fig 3. Enables users to interact with the AI system to receive insights, anomaly alerts, and recommendations based on farm data.



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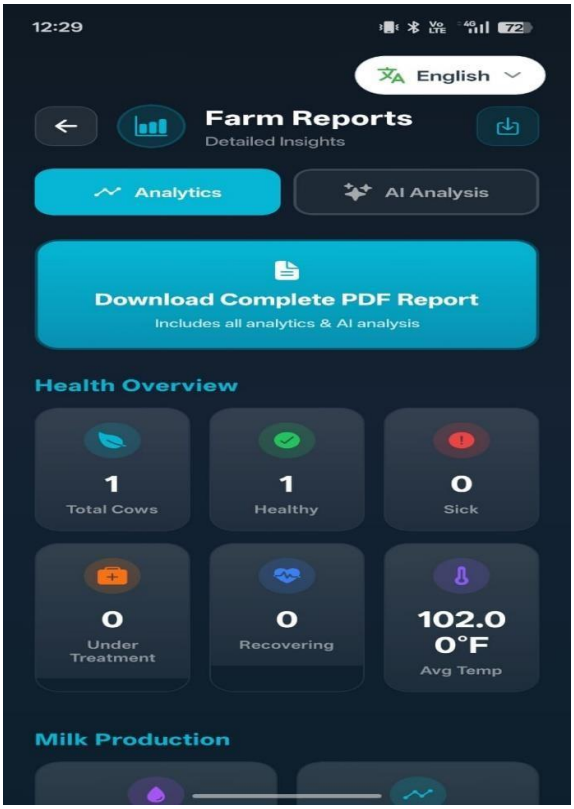

Fig 5. Visualizes milk production data with daily entries and trends to support performance monitoring and decision-making.

Challenges and Limitations

Several technical and operational challenges were identi-fied during development and evaluation. Data synchronisation across multiple concurrent devices required careful conflict-resolution logic; the adopted last-writer-wins policy is suitable for most farm scenarios but may result in data loss in edge cases involving simultaneous updates to the same record.

Performance optimisation for large datasets spanning multi-ple cows and extended historical periods necessitated efficient query strategies to avoid UI latency. Tag durability in outdoor barn environments—involving moisture, physical contact, and variable lighting—represents a persistent practical constraint; periodic reprinting procedures and tamper-evident label mate-rials are recommended mitigations.

The current implementation evaluates financial performance solely through profit/loss aggregations; contribution-margin analytics and break-even analysis, recommended by Nair and Kumar [5], are deferred to future phases. The sentiment analysis module integrated within the Claude API interactions may not accurately interpret complex linguistic nuances such as sarcasm or mixed-emotion expressions when processing free-text farmer notes.

Adoption barriers associated with initial staff training, mul-tilingual interface requirements, and the transition from en-trenched paper-based habits represent non-technical limitations that systemic deployment must address through sustained change management and localisation efforts.

Future Work

The modular architecture of CattleCare+ provides a princi-pled foundation for the following planned enhancements.

Enhanced Predictive Analytics: Machine learning models for milk yield forecasting, disease outbreak prediction, and optimal breeding timing will be trained on accumu-lated historical datasets and integrated into the Claude API analytics pipeline.

Image-Based Health Diagnostics: Computer vision ca-pabilities will enable farmers to submit photographs of animals for AI-assisted body condition scoring, teat health assessment, and early visible disease detection.

IoT Sensor Integration: Smart wearable devices, includ-ing activity-monitoring neck collars, will provide contin-uous real-time health telemetry to complement manually entered data.

Weather API Integration: Environmental data will in-form contextual recommendations for grazing schedules, shelter requirements, and feed adjustments based on forecast conditions.

Breeding Management Module: Genetic tracking, oestrus detection, and pregnancy monitoring will be in-corporated to support AI-assisted mating recommenda-tions.

Web Dashboard: A full-featured browser-based interface will provide farm managers with extended analytical capabilities, multi-farm oversight, and enhanced data vi-sualisation tools.

Multi-Language Support: Internationalisation of the mobile application will extend accessibility to farmers across diverse linguistic communities.

Marketplace Integration: A platform feature enabling the buying and selling of cattle, dairy products, and farm inputs will create a comprehensive farm management ecosystem.

Blockchain Traceability: Distributed ledger integration will underpin cattle ownership verification, milk supply-chain tracking, and quality certification for export mar-kets. **Voice Assistant Interface:** Natural language processing-enabled voice commands will permit hands-free operation for farmers engaged in active field work.

Conclusion

This paper has presented CattleCare+, a comprehensive AI-powered mobile application for modernising dairy farm management. By replacing fragmented manual record-keeping with a unified, QR-enabled digital platform, the system deliv-ers improved data quality, operational transparency, and ana-lytical capability to small and mid-sized dairy farms without requiring expensive IoT infrastructure or specialist technical expertise.

The integration of validated data entry workflows, offline-first architecture, automated 30-day analytics, and AI-powered insights through the Anthropic Claude API establishes Cattle-Care+ as a practical and scalable solution to the systemic infor-mation management deficiencies that constrain contemporary dairy farm productivity. Experimental evaluation confirmed substantial reductions in data-capture time, improvements in mandatory-field completion, and the delivery of decision-critical financial and health analytics in accessible formats.

The system's modular architecture accommodates progres-sive enhancement through predictive modelling, IoT integration, image-based diagnostics, and marketplace functionality in subsequent development phases. CattleCare+ therebypositions itself as a foundational platform for the digital

transformation of smallholder dairy farming, with meaningful potential to improve both animal welfare and farm profitability at scale

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