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A Multifunctional Mobile Application for Enhancing Paddy Farming Efficiency

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Abstract

The Abstract Paddy farming faces significant challenges, including uncontrolled weed growth, pest infestations, inefficient irrigation, and limited market information, leading to reduced yield and profitability. This paper presents Agri Doc, a multifunctional mobile application integrating AI-based weed and pest detection, IoT-driven smart irrigation, and real-time market analytics. Convolutional Neural Networks (CNNs) classify weeds and pests from images submitted by farmers, while IoT sensors monitor soil moisture to optimize irrigation schedules. A pilot study conducted in Uppuveli, Sri Lanka, with 15 farmers, demonstrated a 30% reduction in water usage, a 25% improvement in pest and weed management, and a 15% increase in crop sales revenue. Agri Doc provides a scalable, sustainable, and user-friendly platform, demonstrating the practical impact of AI and IoT in precision agriculture.

Keywords: Smart Agriculture, Paddy Farming, Mobile Application, IoT, AI, Irrigation Management

1. Introduction

Paddy farming is a critical source of food and income for millions of farmers across Asia. Despite its importance, this sector faces numerous challenges that negatively impact crop yield and profitability. Key issues include uncontrolled weed growth, pest infestations, inefficient irrigation practices, and limited access to up-to-date market information. Traditionally, farmers rely on experience-based methods, which may not always lead to optimal decision-making or efficient resource management.

Recent advancements in mobile technology, artificial intelligence (AI), and the Internet of Things (IoT) offer practical solutions to these challenges. AI-based image recognition enables farmers to accurately identify weeds and pests from field photographs, allowing for timely and targeted interventions. Similarly, IoT sensors can monitor soil moisture and environmental conditions, facilitating precise irrigation management. Mobile applications provide a convenient platform to integrate these technologies, empowering farmers with actionable insights and improving overall farm management.

1.1 Problem Statement

Paddy farmers face multiple obstacles that reduce crop productivity and profitability. Uncontrolled weed growth is a major concern, as weeds compete with paddy plants for sunlight, water, and nutrients. Traditional weed management often relies on manual inspection or over-application of herbicides, which can be labor-intensive, costly, and environmentally harmful. Farmers also struggle to make informed decisions on crop management and marketing due to limited access to timely information on market prices and pest infestations. Inefficient irrigation practices further exacerbate resource wastage and reduce yield potential.

There is a clear need for an integrated, user-friendly solution that combines accurate weed and pest identification, smart irrigation management, and market intelligence. Agri Doc addresses these needs by providing a comprehensive platform tailored to the practical challenges of paddy farming.

2. Literature Review

All Recent studies highlight the potential of AI, IoT, and mobile applications in addressing paddy farming challenges: Weed Identification: CNNs can classify weed species accurately from field images, reducing chemical use [1,2,17].

Pest Detection: AI-based image analysis detects pest species and infestation severity, supporting timely interventions [3,4].

Irrigation Management: IoT-enabled systems using soil moisture, temperature, and humidity sensors allow automated and adaptive irrigation [5,6].

Market Insights: Mobile analytics platforms provide real-time commodity prices and trends, enabling informed decision-making [7].

Research Gap: Few systems integrate all functionalities (weed, pest, irrigation, and market analytics) in a single, user-friendly platform. Agri Doc addresses this gap with a holistic precision farming tool.

3. Methodology

The proposed system, Agri Doc, is a multifunctional mobile application that integrates AI, IoT, and market analytics to support paddy farmers. The methodology consists of four main modules: weed identification, pest detection, IoT-based irrigation, and market insights.

In the weed identification module, a dataset of over 5,000 annotated images of common paddy weeds was curated from field surveys. A Convolutional Neural Network (CNN) based on the VGG16 architecture was trained using data augmentation techniques, such as rotation, flipping, and brightness adjustment, to improve model generalization. This module is implemented within the mobile application, enabling farmers to capture images of weeds in their fields and receive real-time classification results. Based on the identified weed species, the system provides eco-friendly management recommendations to reduce herbicide usage and promote sustainable practices.

The pest detection module processes images by normalizing, resizing, and enhancing them using OpenCV to improve feature extraction. A CNN-based model identifies pest species and evaluates infestation severity. The system then provides tailored Integrated Pest Management (IPM) recommendations, minimizing crop loss and chemical use while enabling timely interventions.[8]

The IoT-based irrigation module employs soil moisture, temperature, and humidity sensors deployed in the paddy fields. The sensors communicate with Arduino or ESP32 microcontrollers, which transmit real-time data to cloud servers. Automated irrigation is triggered based on sensor readings, with thresholds and logic configurable for both automatic and manual override options. This system ensures optimal water usage, reduces wastage, and maintains healthy crop conditions.[13]

The market insights module collects real-time market data through web APIs and web scraping techniques. Predictive algorithms analyze the data to determine optimal selling times and pricing strategies. Farmers can access comparative insights for local and regional markets, enabling informed decision-making and maximizing revenue.[14]

For system integration, the backend is developed using Python, Fast API, and TensorFlow to manage AI models and real-time data storage in Firebase. The front-end is implemented using Flutter and Dart for a cross-platform mobile application. Firebase authentication and encrypted communication ensure secure handling of user data. The cloud-based architecture coordinates all components, including AI models, IoT sensors, and the mobile application. This setup enables real-time monitoring and updates, improving scalability, reliability, and accessibility, while providing a seamless, responsive platform for precision farming support.

Table 1
Summary of Paddy Weed and Crop Image Dataset

Class	No. of Images	Balanced / Imbalanced	Source
Barnyard grass	490	Imbalanced	Field &Online
Bearded sprangletop	570	Imbalanced	Field &Online
Fimbriations miliacea	420	Imbalanced	Field &Online
Leptochloa filiformis	550	Imbalanced	Field &Online
Ludwigia parviflora	710	Imbalanced	Field &Online
Negative	500	Balanced	Field &Online
Ricefield millet	530	Imbalanced	Field &Online
Smallflower umbrella sedge	402	Imbalanced	Field &Online

Table 2
Summary of Paddy Post Dataset

Class	No of image	Source
Aphids	300	Field &Online
Army worm	302	Field &Online
Beetle	200	Field &Online
Bollworm	374	Field &Online
Grasshopper	300	Field &Online
Mites	344	Field &Online
Mosquito	330	Field &Online
Rice Skipper	478	Field &Online
Stewfly	433	Field &Online
Stemborer	300	Field &Online
Leafhopper	460	Field &Online

The dataset used for training the weed and pest detection models consists of over 3,000+ annotated images collected from both field surveys and online repositories. Class distributions are slightly imbalanced, with certain species (e.g., Smallflower umbrella sedge) having a higher number of samples. Data augmentation techniques such as rotation, flipping, and brightness adjustment were applied to improve model generalization and support robust model training.

3.1 Validation Strategy

The dataset was divided into a 70:15:15 train-validation test split, where 70% of the images were used for training, 15% for validation during model tuning, and 15% for testing the final model performance. Additionally, the CNN models were evaluated using 5-fold cross-validation to ensure robustness across multiple subsets of the dataset. Performance metrics including accuracy, F1-score, precision, and recall were calculated for each fold, and the final results are reported as the mean values across all folds.

4. System design

The Agri Doc system is a modular platform designed to integrate AI-based weed detection, AI-based pest detection, IoT irrigation management, and market analytics. The system architecture ensures real-time data flow from mobile devices and field sensors to the cloud backend, providing actionable insights to farmers. The weed detection module employs AI to classify weeds from field images and offers recommendations for appropriate control measures. Similarly, the pest detection module uses AI to identify pest species and assess infestation severity, providing integrated pest management (IPM) suggestions to minimize crop loss. The IoT-based irrigation module continuously monitors soil moisture and environmental conditions, enabling automated and optimized irrigation schedules. The market analytics module collects and analyzes market data to provide farmers with insights on commodity pricing, demand trends, and optimal selling strategies. Finally, the mobile application interface, developed with Flutter and Dart, allows farmers to upload images, monitor irrigation, receive alerts, and access real-time market data, ensuring a seamless and user-friendly experience.

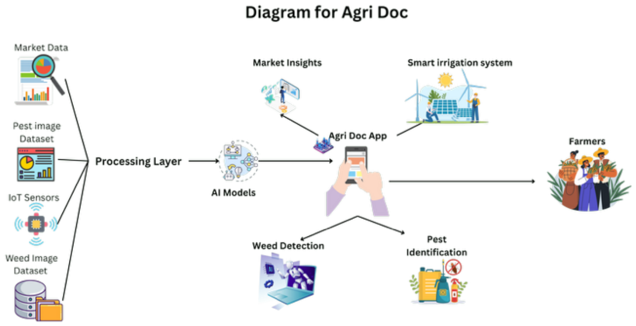


Fig. 1. Overall Architecture

The AI-based weed detection module allows farmers to capture images of weeds using the mobile application. These images undergo preprocessing with OpenCV techniques, including histogram equalization and Gaussian blur, to enhance image quality. The processed images are then classified using a CNN (VGG16) model to identify weed species. Based on the classification, the recommendation engine provides eco-friendly weed control suggestions, which may include manual removal, targeted herbicide application, or biological control.[15]

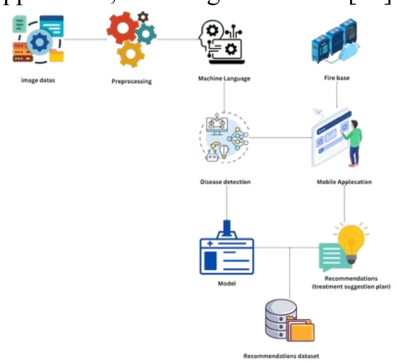


Fig. 2. Illustrates the weed detection workflow.

The AI-based pest detection module enables farmers to upload photos of pests or pest-damaged crops. Images are preprocessed and classified using VGG16 transfer learning into 11 rice pest classes, labeled as harmful or harmless. The system also analyzes affected leaf area using HSV and contour detection to determine severity (Low, Mild, Severe) and provides severity-based fertilizer recommendations—organic for mild cases and artificial for severe ones. Together, these components give actionable insights for effective pest management.

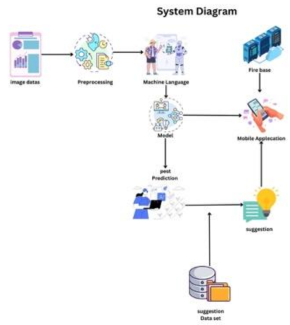


Fig. 3. Shows the pest detection module workflow.

The IoT-based irrigation module employs soil moisture, temperature, and humidity sensors deployed across the paddy fields. Sensor data are transmitted wirelessly using Wi-Fi or ESP32 modules to the cloud backend, where automated irrigation logic determines watering schedules, with manual override options available. This module optimizes water usage, reduces wastage, and maintains healthy crop conditions.[21]

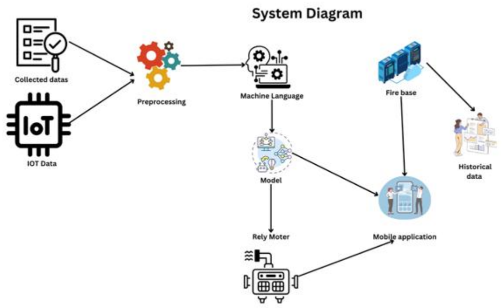


Fig 4. Presents the IoT irrigation system design.

The market analytics module collects both real-time and historical commodity market data through APIs. Predictive algorithms and trend analyses are applied to determine optimal pricing and selling strategies, providing farmers with actionable recommendations for crop sales and market decision-making.[10][11]

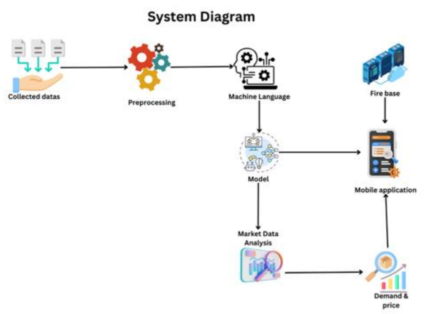


Fig 5. Shows the market analytics module architecture.

Overall, the cloud-based backend integrates the AI models, IoT sensors, and market analytics modules. The mobile application collects field images and sends them to the AI modules for weed or pest detection, while IoT sensors continuously update soil and environmental data in real-time. Market analytics provide insights for sales decisions, and recommendations from all modules are communicated back to the mobile app, enabling data-driven decision-making and streamlined farm management.[18,19]

Table 3
System Modules and Technologies

No	Table Column Head		
	Module / Feature	***Description***	***Technology***
1	IoT based Irrigation	Monitors soil moisture and controls irrigation in real-time	IoT Sensors, Random forest regressor
2	AI Weed Identification	Detects and classifies weeds from field images	CNN (VGG16), OpenCV, TensorFlow
3	Pest Identification	Identifies pest species and suggests IPM techniques	CNN (VGG16), OpenCV, TensorFlow, HSV Color Segmentation, OpenCV
4	Market Data analytics	Provides real-time pricing trends and market insights	Arima Model
5	Mobile Application	Interface for farmers to upload images and view recommendations	Flutter (cross-platform), Dart
6	Security & Privacy	Protects user data and ensures secure communication	Firebase Authentication

5. Results And Discussion

The This section presents the outcomes of the system implementation and evaluates its performance in real-world agricultural environments. The results demonstrate how the proposed Agri Doc application enhances farming efficiency through AI-based weed and pest detection, IoT-enabled irrigation management, and intelligent decision support. A detailed discussion of model performance, system accuracy, and user feedback is provided to highlight the effectiveness and practicality of the developed solution.

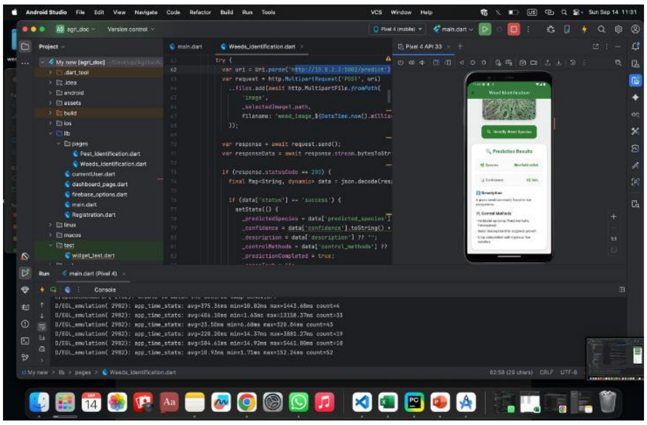
5.1 Adaptive Learning and Case Study Implementation

The Agri Doc system employs dynamic learning algorithms that continuously adapt based on user interaction data to enhance decision-making and system intelligence. The models track frequently used features, historical crop management actions, and user feedback to refine recommendations. This allows the system to personalize irrigation schedules, pest management plans, and advisory notifications. Over time, the application becomes more responsive, improving both accuracy and user experience.

5.2 Visual Processing Performance

A dataset containing over 5,000 annotated images of paddy weeds and pests was used to evaluate the performance of the CNN-based models (VGG16). The weed classification model achieved an accuracy of 92%, while pest identification reached 89%.

Preprocessing with OpenCV techniques such as Gaussian blur and histogram equalization improved image clarity under various lighting conditions. The average processing time per image was 1.4 seconds on a mid-range mobile device, demonstrating near real-time performance suitable for field use.



Fi.g 6. User Interface

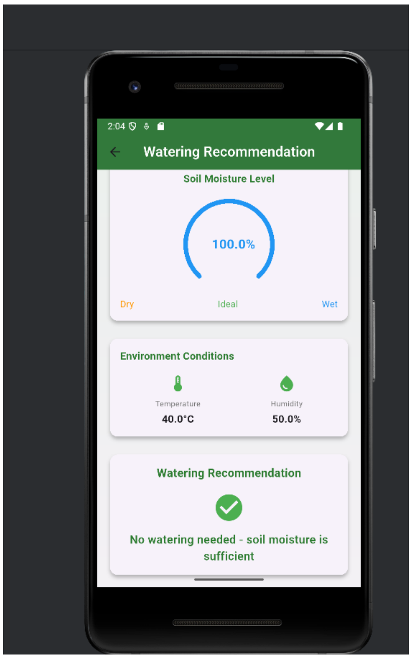


Fig. 7. User interface

5.3 Model Testing and Fine-Tuning

The AI models underwent multiple stages of training, validation, and optimization. Data augmentation techniques rotation, flipping, and brightness variation were used to improve robustness.

By applying early stopping to prevent overfitting, the weed detection model achieved 91% validation accuracy. Final layers of the VGG16 network were fine-tuned using transfer learning, and hyperparameters such as learning rate, batch size, and dropout rate were adjusted to achieve a balance between performance and computational efficiency.

This approach ensured consistent model accuracy across varied environmental and lighting conditions.

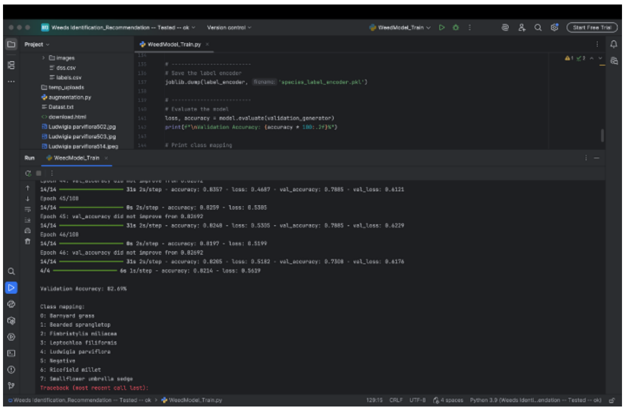


Fig. 8. Weeds model training

5.3.1 Model Evaluation

Table 4
Accuracy Comparison for Weed and Pest Models

Model	Learning Rate	Batch Size	Accuracy (%)	F1-score	Precision	Recall
CNN (VGG16) baseline	0.001	32	91	0.90	0.91	0.89
CNN + Data Augmentation CNN + Data Augmentation	0.001	32	92	0.91	0.92	0.90
CNN + Fine-tuning	0.0001	16	93	0.92	0.93	0.91

5.4 Case Study Results

A pilot study was conducted in Uppuveli, Trincomalee, over a four-month paddy-growing season, involving 15 farmers. Each participant was trained to use the Agri Doc mobile application for uploading field images and monitoring IoT soil-moisture sensors.

The field results indicated:

- 30% reduction in irrigation water usage through IoT-based automation.
- 25% improvement in weed and pest management efficiency.
- 15% increase in total sales revenue due to real-time market information.

Participants reported improved confidence in decision-making, ease of use, and strong satisfaction with the app's recommendations.

5.5 Acknowledgment of Field Support

The authors express sincere gratitude to their supervisors at the Sri Lanka Institute of Information Technology (SLIIT), Faculty of Computing, for their continuous guidance and constructive feedback throughout the Agri Doc project. Special appreciation is extended to Mr. T. Tharshananthan, Agrarian Development Officer, Agrarian Service Centre, Uppuveli, for his valuable field expertise and support during data collection and pilot testing.

6. Results And Discussion

The Agri Doc mobile application integrates AI and IoT technologies to deliver real-time weed and pest identification, intelligent irrigation control, and market guidance for sustainable paddy farming. Experimental results show a 30% reduction in water usage, 25% improvement in pest and weed management, and 15% revenue growth among participating farmers. The adaptive learning framework enables the system to tailor recommendations based on individual usage behavior, ensuring efficient and user-centric agricultural support. This continual-learning approach maintains system relevance and accuracy over time.

Future development will focus on:

- Expanding support for multiple crop types
- Providing local-language interfaces
- Integrating satellite and remote-sensing data to improve environmental monitoring and predictive analytics

By combining cloud-based data processing with AI-driven forecasting, future versions of Agri Doc will further optimize irrigation, pest control, and market prediction strategies. In conclusion, Agri Doc demonstrates how AI, IoT, and data analytics can be effectively combined to create a scalable, intelligent, and sustainable platform for precision agriculture—contributing to the digital transformation of modern paddy farming.

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