# A Low-Cost, Offline, Edge-AI Fertilizer Recommendation System for Crop-Stage-Aware Precision Agriculture


Presented by

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# INTRODUCTION

Precision agriculture combines IoT sensors, data analytics, and machine learning to improve yields, reduce costs, and enable sustainable farming. These tools allow farmers to monitor soil and crop conditions in real time for better decisions about fertilizer and resource use. However, most existing systems depend on cloud infrastructure, reliable internet, and expensive hardware, making them inaccessible to smallholder farmers in developing regions.

This research proposes a low-cost, offline-capable fertilizer recommendation system tailored for resource-limited environments. It uses ESP32 microcontrollers and Raspberry Pi edge computing to collect and process soil, environmental, and crop data directly in the field. By integrating image-based crop stage detection and adaptive machine learning, the system can deliver site-specific fertilizer guidance without requiring internet connectivity. This approach aims to make precision agriculture practical and affordable for small-scale farmers.

# RESEARCH GAP

Prior research and commercial systems have explored soil nutrient sensing and fertilizer recommendations. However, most solutions have the following limitations:

1. Cloud Dependency – Requiring continuous internet access for data processing and model inference.
2. Lack of Crop Stage Awareness – Failing to integrate crop phenology into fertilizer scheduling.
3. High Cost and Complexity – Using proprietary sensors and centralized platforms unsuitable for small farms.
4. Limited Local Adaptation – Models that do not continuously improve based on farmer feedback or local outcomes.

No existing system integrates edge-based machine learning, crop stage detection with low-cost cameras, and fully offline fertilizer optimization into a unified, farmer-friendly platform deployable in resource-limited settings.

# PROBLEM OVERVIEW

Small and marginal farmers often lack access to tailored, timely recommendations on the type, quantity, and timing of fertilizer applications specific to their soil conditions and crop growth stages. Existing precision agriculture platforms typically:

- Depend on stable internet connectivity for cloud-based computation.
- Require costly sensor networks and proprietary hardware.
- Offer recommendations without considering real-time crop phenological stages.

This results in inefficient fertilizer usage, increased production costs, degraded soil health, and suboptimal yields. There is a clear need for an accessible, cost-effective solution that can:

- Operate fully offline in low-connectivity regions.
- Adapt recommendations dynamically as crops progress through growth stages.
- Leverage low-cost, locally available hardware to minimize barriers to adoption.

# OBJECTIVES

This work aims to design, develop, and evaluate a novel fertilizer recommendation system with the following objectives:

**Develop a modular IoT architecture combining ESP32 microcontrollers and Raspberry Pi to collect and process multi-modal field data (soil, environmental, and crop images).**

**Machine learning to:**
- **Classify crop growth stages in real-time from camera images.**
- **Predict optimal fertilizer type and dosage per stage and soil condition.**

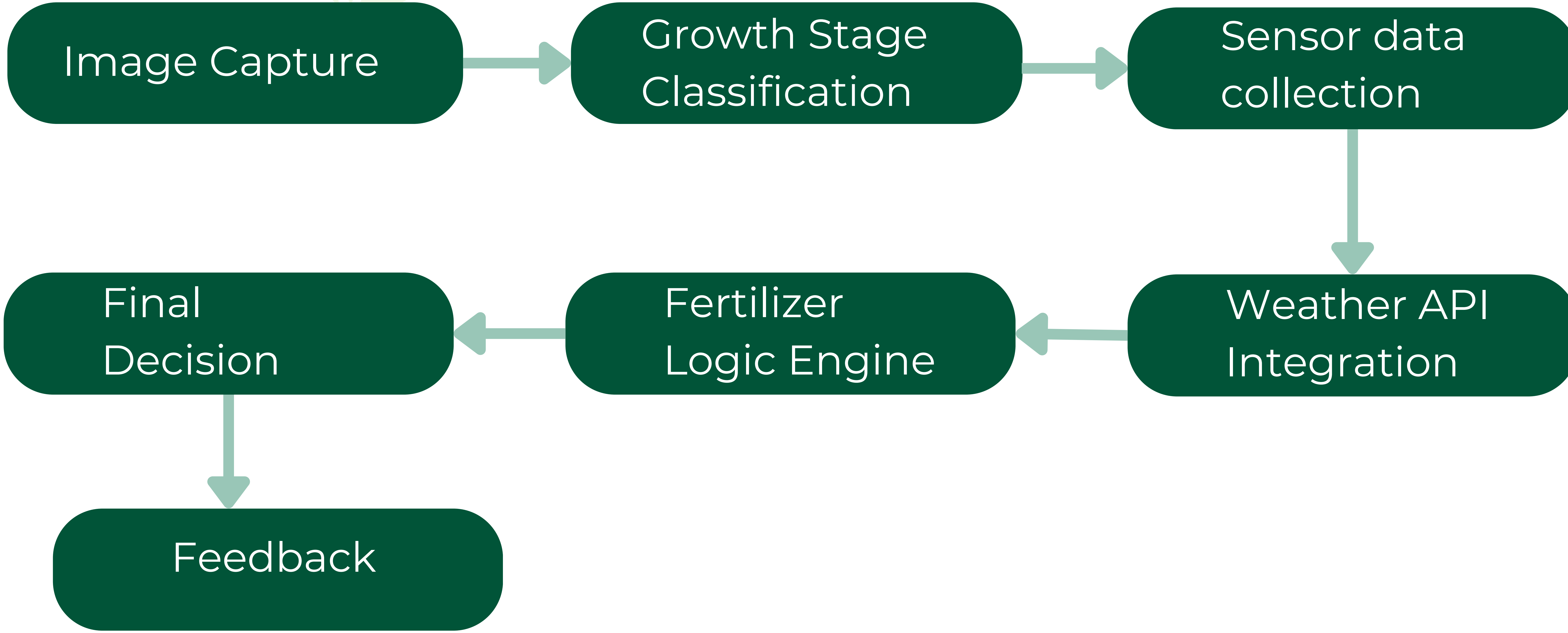
**Enable fully offline operation with periodic synchronization capability, ensuring resilience in low-connectivity environments.**

**Evaluate the system in pilot field trials, assessing recommendation accuracy, usability, and impact on fertilizer usage and crop yield.**

## Future Enhancements

Integrate multilingual, low-literacy interfaces, including voice-based advisories and simplified visuals, to maximize farmer usability.

# Methodology



# Thank You