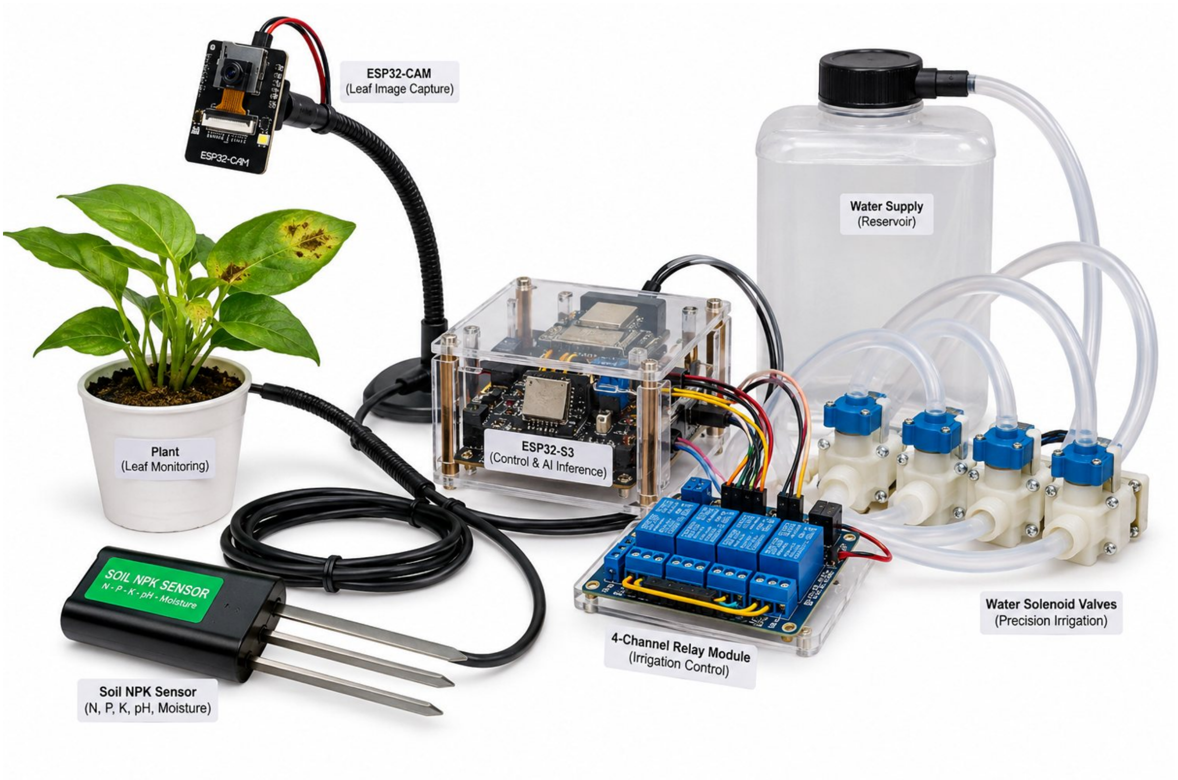
PROJECTECH

Academic Project Solutions

PROJECT ABSTRACT

Edge-AI Crop Disease Classifier & Precision Irrigation Hub

ESP32-CAM Vision, TinyML Classification, Soil Sensing and Automated Multi-Zone Irrigation



College-level prototype concept: camera-based leaf inspection, soil NPK sensing, relay-controlled irrigation zones and optional IoT monitoring.

Project Domain	Smart Agriculture / Embedded Systems / IoT / Artificial Intelligence
Project Type	Software + Hardware / Edge-AI Prototype
Core Controller	ESP32-S3 with ESP32-CAM
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1. Abstract

The Edge-AI Crop Disease Classifier & Precision Irrigation Hub is a college-level smart agriculture prototype that combines computer vision, embedded AI, soil-condition sensing and automated irrigation. The system is designed to demonstrate how crop-health assessment and water management can be integrated into one intelligent platform for educational and research use.

An ESP32-CAM captures images of crop leaves and provides them to a lightweight image-classification workflow. A trained model identifies whether an image matches one of the supported healthy or disease classes. At the same time, a compatible soil NPK or soil-condition sensor measures parameters such as nutrient levels and other supported soil values. The ESP32-S3 processes these inputs and applies configured decision rules for irrigation control.

When irrigation is required, the controller activates one of the relay channels and opens the corresponding solenoid valve. This makes it possible to demonstrate multi-zone irrigation, where separate plant areas can be watered independently. Wi-Fi connectivity can optionally be used for dashboard monitoring, historical data logging and remote alerts.

The project is intended as an academic prototype rather than a certified agricultural diagnostic or farm-control product. Disease classification is limited to the classes included in the training dataset, while irrigation decisions depend on sensor calibration and configured thresholds.

2. Problem Statement

Manual crop inspection can delay the identification of visible plant disease symptoms, while fixed irrigation schedules may provide too much or too little water. Student projects often demonstrate either AI-based disease detection or automatic irrigation separately; this project integrates both functions into one platform so that crop appearance and soil conditions can be evaluated together.

3. Main Objectives

1) Capture crop-leaf images using an ESP32-CAM module.
2) Classify supported healthy and disease categories using a lightweight AI model.
3) Monitor selected soil parameters using a compatible NPK / soil-condition sensor.
4) Compare sensor readings with configurable irrigation thresholds.
5) Control multiple irrigation zones through relays and solenoid valves.
6) Provide an expandable base for Wi-Fi dashboards, data logging and alerts.

4. System Architecture

The prototype is divided into sensing, intelligent processing, control and optional connectivity layers. This modular architecture keeps the project easy to explain, test and extend.

INPUT		AI		CONTROL		OUTPUT
Leaf image from ESP32-CAM	->	TinyML / lightweight disease classification	->	ESP32-S3 decision logic	->	Relay + solenoid irrigation zone

SOIL		THRESHOLD		ACTION		OPTIONAL
NPK / supported soil readings	->	Compare readings with configured limits	->	Open required valve / keep irrigation off	->	Wi-Fi dashboard, logging or alerts

5. Major Functional Modules

Leaf Image Capture	The ESP32-CAM is positioned toward a plant leaf. It captures images that can be resized and pre-processed before classification.
Edge-AI Classification	A lightweight trained model compares the captured image with the disease classes included in its dataset and returns the most likely supported class.
Soil Monitoring	The soil sensor provides NPK or other supported soil-condition data. Exact parameters depend on the selected sensor module and calibration.
Irrigation Controller	The ESP32-S3 compares configured values and activates the appropriate relay channel when watering is required.
Multi-Zone Water Control	Each relay output can drive a separate solenoid valve, allowing independent demonstration of multiple irrigation zones.
Optional IoT Layer	Wi-Fi can be used to send readings and events to a dashboard or logging service when remote monitoring is required.

6. Working Principle

1) The ESP32-CAM captures an image of the crop leaf and sends it to the configured Edge-AI classification process.
2) A trained lightweight image-classification model analyzes the leaf and identifies whether it matches one of the supported healthy or disease classes.
3) The soil probe measures available parameters such as soil nutrient levels and other supported soil conditions, depending on the selected sensor module.
4) The ESP32-S3 processes sensor readings and compares them with predefined irrigation thresholds.
5) When irrigation is required, the controller activates the corresponding relay channel and opens the required solenoid valve.
6) Different irrigation zones can be controlled independently based on the configured prototype logic.
7) Wi-Fi can optionally be used for dashboard monitoring, historical logging or remote alerts.

7. AI Disease Classification Flow

1. Capture	Camera acquires a clear image of the target leaf.
2. Pre-process	Image is resized / normalized to the model input format.
3. Infer	The trained lightweight classifier evaluates the image.
4. Classify	The system returns a supported healthy or disease class.
5. Display / Log	The result can be shown locally or sent to an optional dashboard.

8. Precision Irrigation Logic

The irrigation section is threshold-driven. Soil measurements are compared with configured values for the demonstration setup. When the logic determines that watering is needed, the selected relay channel energizes the corresponding solenoid valve. The valve remains active for the configured duration or until the relevant condition changes. This approach allows the same controller to manage several demonstration zones independently.

> Important: Irrigation thresholds must be chosen for the actual sensor, soil type, crop and prototype conditions. The default demonstration values should not be treated as universal agronomic recommendations.

9. Technologies / Components Used

1) ESP32-S3 development board	5) Water solenoid valves
2) ESP32-CAM module	6) TinyML / Edge-AI image classification
3) Compatible soil NPK / soil-condition sensor	7) Embedded C / Arduino framework
4) 4-channel relay module	8) Wi-Fi / IoT connectivity

10. Key Features

1) AI-based crop leaf disease classification from camera images.
2) ESP32-CAM-based leaf image capture for plant monitoring.
3) Soil nutrient and condition monitoring using an NPK sensor.
4) Automatic irrigation control based on configured soil thresholds.
5) Multi-zone irrigation using relay-controlled solenoid valves.
6) ESP32-S3-based sensor processing and Edge-AI integration.
7) Configurable irrigation and crop-monitoring parameters.
8) Expandable Wi-Fi connectivity for remote monitoring and data logging.

11. Applications

1) Final-year smart agriculture and IoT projects.
2) AI / ML crop-monitoring demonstrations.
3) Precision-irrigation laboratory prototypes.
4) Embedded systems and sensor-integration learning.
5) Multi-zone automated watering demonstrations.
6) Academic research on edge-based agricultural monitoring.

12. Prerequisites

1) The disease-classification model must be trained or configured for the selected crop and supported disease classes.
2) Soil sensors and irrigation thresholds require proper installation, calibration and testing.

13. Limitations

1) This is an academic smart-agriculture prototype and not a certified agricultural diagnostic system.
2) Disease-classification accuracy depends on the training dataset, leaf visibility, camera angle, lighting and image quality.
3) The AI model can identify only the crop diseases/classes included in its trained dataset.
4) Soil NPK and related sensor readings depend on sensor quality, calibration and soil conditions.
5) Automated irrigation decisions are based on configured thresholds and prototype sensor readings.
6) Wi-Fi/internet is required only for optional remote monitoring or cloud features.
7) Hardware components may vary depending on availability.
8) Custom dashboards, cloud hosting, mobile apps and additional sensors require separate customisation.

14. Future Scope

The prototype can be extended with moisture, pH, EC, temperature and humidity sensing; weather-data integration; a mobile application; cloud dashboards; additional crop-specific AI models; larger irrigation-zone support; alert notifications; historical analytics; automated pump control and solar-powered field nodes.

15. Project Deliverables

1) Source code
2) Circuit diagram
3) Component list
4) Project report
5) Abstract PDF
6) PPT / presentation
7) Installation guide
8) Setup support
9) Demonstration video
10) AI model integration and sensor calibration guidance

16. Conclusion

The Edge-AI Crop Disease Classifier & Precision Irrigation Hub demonstrates how camera-based AI, soil sensing and automated water control can be combined within a practical college-level smart farming prototype. It provides a strong platform for explaining embedded AI, sensor calibration, decision logic, relay control and IoT expansion while keeping the system modular enough for future customisation.