VineHealth

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https://course.ece.cmu.edu/~ece500/projects/s26-teame0/

Product Pitch

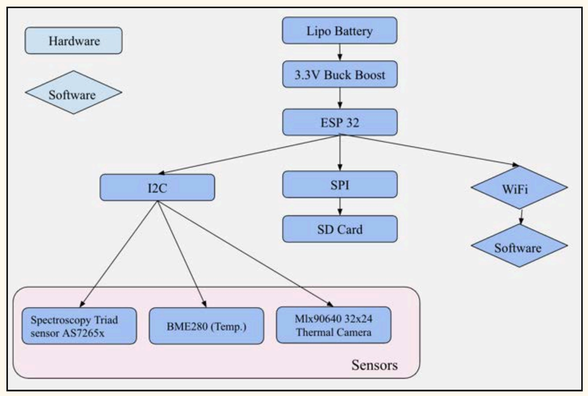
VineHealth is a low-cost, stationary plant health monitoring system designed for vineyard farmers to detect crop stress before visible symptoms appear. Unlike traditional methods such as field scouting and aerial imaging, which are labor-intensive and reactive, our system provides continuous, real-time monitoring for small-scale farms needing accessible tools for proactive plant care.

The system integrates multispectral sensing, thermal imaging, and environmental sensors to compute vegetation indices (NDVI, GNDVI, SAVI) and stress metrics such as CWSI, while measuring temperature, humidity, and leaf-air differences. Data is transmitted wirelessly to a mobile interface that displays health trends, alerts, and actionable insights. Each device provides ~5 ft coverage and operates at 3 readings/day to maintain ≥95% uptime.

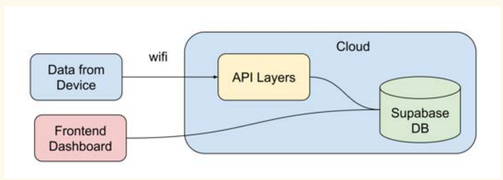
In testing, VineHealth detected stress up to 5 days before visible symptoms and achieved ±1.5°C temperature and ±5% humidity accuracy.

System Architecture

The system integrates hardware sensing and edge data processing with a supporting software layer.



Hardware Block Diagram



Software Block Diagram

Hardware: A **LiPo battery** regulated to 3.3V powers the **ESP32** and sensors. The ESP32 interfaces over I2C with a **BME280** (temperature, humidity, pressure), an **AS7265x spectroscopy sensor** (multi-wavelength reflectance), and an **MLX90640 thermal camera** (leaf temperature and transpiration estimation). An **SD card** connected via SPI provides local data buffering. The ESP32 performs onboard computation of **vegetation and stress indices** (NDVI, GNDVI, SAVI, CWSI) and transmits processed readings via WiFi to a backend for storage and visualization.

Software:
Sensor data from the ESP32 is sent via **WiFi** to a backend through a **REST API**, where it is stored with vegetation indices and environmental data. The system also supports user and device management and uses a relational database to power **alerts** and **dashboard visualization**.

Conclusions & Additional Information

VineHealth demonstrates a functional, low-cost system for continuous vineyard plant health monitoring using multispectral, thermal, and environmental sensing. While our initial goal emphasized highly accurate early detection of diseases, our final system prioritizes reliable data collection and actionable insights for farmers. Through this project, we learned to balance ideal performance with real-world constraints such as sensor limitations, environmental variability, and power management. Future work could potentially include improving classification accuracy with machine learning, expanding capabilities with added sensors, increasing the physical range of the device per sensor, and enhancing the user interface. Overall, VineHealth provides a strong foundation for an accessible and scalable precision agriculture solution.

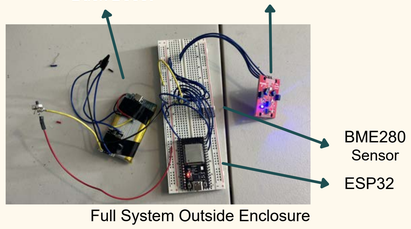
System Description

ESP32 based system combining multi-sensor hardware, onboard processing, and backend software for real-time vineyard health assessment.

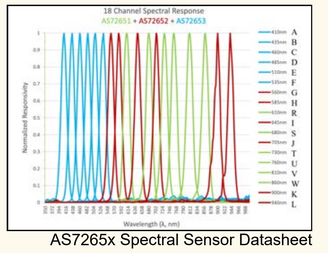
Case/ Device Stand: **Recycled wood frame** with a **3D-printed clamp bracket** enabling rigid, adjustable mounting via through-bolt compression. **Custom 3D-printed enclosures** protect electronics from environmental exposure.

Sensors/ Hardware: The **BME280** provides **ambient conditions (temperature, humidity, pressure)** for environmental context. The **AS7265x spectroscopy sensor** measures **multi-wavelength reflectance**, including **near-infrared**, **visible red**, and **green bands**. These wavelengths indicate chlorophyll content and light absorption, enabling computation of vegetation indices such as **NDVI, GNDVI, and SAVI**. The **MLX90640 thermal camera** captures **leaf temperature**, which reflects **transpiration** and **water stress**. Healthy plants typically maintain leaf temperatures around **25–35 °C**, allowing estimation of stress through **CWSI**. Additionally, an onboard SD card provides **local data storage**.

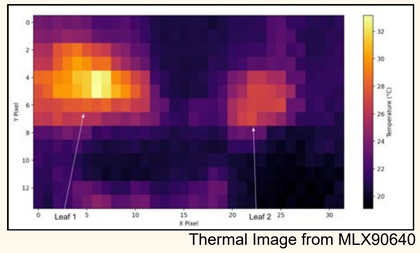
Case with Clamp Bracket



Full System Outside Enclosure



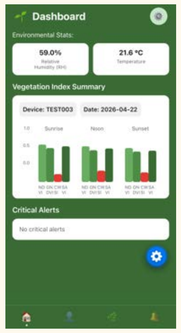
AS7265x Spectral Sensor Datasheet



Thermal Image from MLX90640

App Frontend: The mobile app provides a dashboard for monitoring vineyard conditions, displaying environmental data (temperature, humidity) and vegetation indices (NDVI, GNDVI, SAVI, CWSI) across different times of day. Users can **track trends**, view **device-specific data**, and **receive alerts** when plant health falls below critical thresholds.

Backend/Database: The backend is built on **Supabase**, which handles data storage, authentication, and real-time synchronization. Sensor data is received via REST APIs and stored in structured tables (Users, Devices, Data, Alerts). The system evaluates vegetation indices against predefined thresholds to generate alerts and support dynamic updates in the mobile app.



System Evaluation

Use-Case Requirements:

Metric	Testing Results
Battery Life	≥7 days operation under 3 samples/day; stable voltage throughout testing
Enclosure Testing	No water ingress during simulated rain; system fully functional
Plant Stress Detection	Detected stress ~5 days before visible symptoms via NDVI/GNDVI changes
Environmental Data	Temperature ±1.3°C; humidity ±4%; leaf-air temperature ±0.4°C accuracy vs reference
UI Testing	High usability (4–5/5); clear data visualization and alerts

Our design required trade-offs between accuracy, power, and cost. We reduced sampling frequency to 3 times/day to extend battery life and selected lower-cost sensors that still capture meaningful plant health trends at a significantly lower cost. The enclosure was designed to complement the sensors while minimizing signal interference. These decisions prioritize reliability and affordability over maximum precision.