# Project 4_2 Early Detection and Differentiation of Crop Diseases Using Hyperspectral Imaging and Spectral–Spatial Deep Learning

| PC Hub Theme (see list here) |
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| Theme 4 - Digital Agriculture and Machine Learning |
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| TBC |

## 1. Background and Motivation

Crop diseases cause substantial yield and economic losses worldwide. Conventional scouting and RGB imaging can only detect diseases at late stages, after visual symptoms appear. Hyperspectral imaging (HSI), by capturing reflectance across hundreds of contiguous narrow spectral bands, enables the identification of subtle biochemical and structural changes in plants before visible symptoms occur.

Existing studies mostly focus on single-disease classification under controlled conditions. However, real-field situations often involve multiple coexisting diseases whose symptoms overlap in both space and spectrum. Furthermore, traditional machine learning approaches relying on handcrafted indices (e.g., NDVI, PRI) fail to exploit the complex spectral–spatial correlations inherent in hyperspectral cubes.

This project aims to bridge these gaps by developing an end-to-end hyperspectral deep learning framework that performs early, accurate, and interpretable disease recognition under multi-disease conditions using pre-acquired hyperspectral datasets.

## 2. Research Aim and Objectives

*Overall Aim*

To develop and validate a spectral–spatial deep learning framework for early detection and differentiation of crop diseases using existing hyperspectral datasets.

*Specific Objectives*

- Spectral Characterization: Quantify the spectral and biochemical signatures associated with early-stage infection across multiple crop diseases.
- Model Development: Design a deep neural architecture that jointly captures spectral and spatial information from hyperspectral cubes to identify and differentiate diseases.
- Explainability and Generalization: Integrate model interpretability and domain adaptation techniques to ensure robustness across cultivars, environments, and sensors.
- Validation and Benchmarking: Evaluate performance against existing multispectral and RGB-based methods and establish benchmarks for early-stage disease detection.

## 3. Research Methodology

3.1 Data Sources

Pre-acquired hyperspectral datasets of disease-infected crops will be utilized. Each cube contains hundreds of bands (400–2500 nm) collected under controlled and semi-field conditions, along with corresponding disease severity scores and physiological measurements (e.g., chlorophyll, moisture content).

3.2 Data Preprocessing

- Radiometric and geometric correction (white reference normalization, band alignment)
- Noise filtering (Savitzky–Golay smoothing, PCA-based denoising)
- Band selection and dimensionality reduction using information gain and spectral attention mechanisms
- Patch-level cube segmentation for training

### 3.3 Model Design

A Spectral–Spatial Transformer Network (SSTNet) will be developed:

- Spectral Encoder: 1D spectral attention to learn biochemical feature correlations.
- Spatial Encoder: 2D convolutional or transformer layers to capture spatial context.
- Fusion Module: Cross-attention mechanism combining spectral and spatial embeddings.
- Output Head: Multi-class disease prediction and early-stage probability estimation.

Additional innovations include:

- Multi-instance learning (MIL) for patch-based weakly labeled data.
- Self-supervised pretraining to learn invariant spectral representations.
- Domain adaptation layers to transfer knowledge across datasets and environments.

### 3.4 Model Interpretability

Apply gradient-based saliency maps and spectral contribution analysis to identify key wavelengths and regions responsible for predictions, facilitating biological interpretability and trustworthiness.

### 3.5 Evaluation Metrics

- Classification accuracy, precision, recall, and F1 score.
- Early detection sensitivity at pre-symptomatic stages ($\Delta t$ before visible onset).
- Generalization across disease types, cultivars, and acquisition conditions.
- Model interpretability and computational efficiency.

## 4. Expected Outcomes

- A generalized deep learning framework capable of accurately differentiating multiple crop diseases at early stages using hyperspectral data.
- Spectral signature libraries linking key wavelengths to specific physiological indicators of disease stress.
- Benchmark dataset and evaluation protocol for early disease detection research.
- Publications in top-tier journals (e.g., *Computers and Electronics in Agriculture*, *Remote Sensing of Environment*, *Plant Methods*).

- Potential integration into real-time crop monitoring or decision-support systems in collaboration with agricultural technology partners.

## How to apply

The PC Hub offers a limited number of competitive scholarships.
To apply, please email the following documents to pchub@latrobe.edu.au by **15 February 2026:**

- Application form completed
- Up-to-date CV
- University transcripts

*Only shortlisted applicants will be contacted.*