Hyperspectral Detection of Heavy Metals in Spinach

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Introduction

Cadmium (Cd) is a toxic metal that can accumulate in spinach grown in contaminated soils, posing risks to public health. Traditional lab tests like ICP-MS are accurate but slow and expensive. This project explores hyperspectral imaging (HSI) as a faster, non-destructive alternative. Using a VS620 sensor (400-2500 nm), we analyze spectral data to identify patterns linked to Cd uptake, aiming to build a model that can quickly detect contamination in leafy greens and support safer agricultural practices.

Research Objectives

- Preprocess hyperspectral image data to correct noise and variability.
- Extract relevant spectral features linked to Cd-induced stress.
- Develop machine learning models to predict Cd levels in spinach tissue.
- Validate model accuracy using statistical metrics.

Motivation

- Spinach, a common leafy green, can absorb cadmium from soil.
- Excessive Cd intake is toxic and poses a risk to public health.
- Traditional ICP-MS lab methods are time-consuming and expensive.
- HSI offers a rapid, non-invasive method to detect plant stress and contamination.

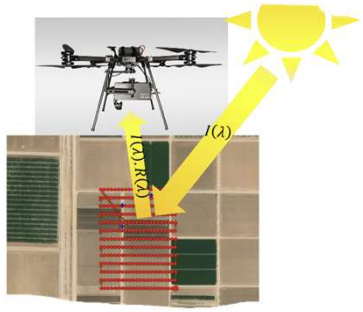


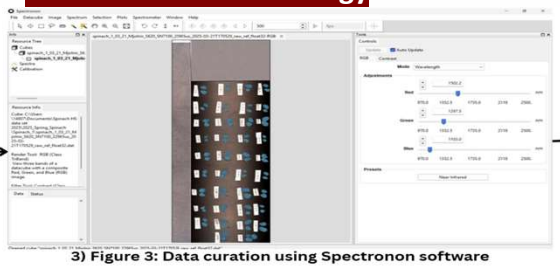
Figure A: Data collection in the field using a Hercules X8 drone

Sunlight has more information than what our eyes can see. Hyperspectral imaging lets you capture this "unseen" information.

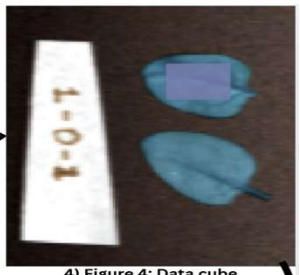
Process and Methodology

1)
Figure 1: HYSPEX VS620
Spectral Range: 400 – 2500 nm
Spectral channels and sampling:
1) 400-1000nm, 200 bands @ 3.0 nm
2) 970-2500nm, 300 bands @ 5.1 nm
Power consumption: 50 W
Dimensions (l–w–h): 374–202–178 mm
Weight: ~ 6 kg

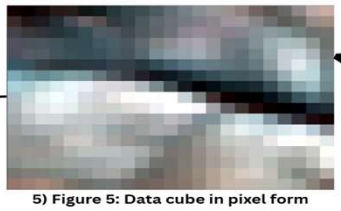
2) Figure 2: Sample in the lab for hyperspectral imaging



3) Figure 3: Data curation using Spectronon software



4) Figure 4: Data cube slection



5) Figure 5: Data cube in pixel form

6) Extract Features
Pick out important wavelengths and calculate plant stress indices (like NDVI or PRI).

7) Train the Model
Use machine learning (like Random Forest or PLSR) to connect spectral features with Cd levels.

8) Test Accuracy
Check how well the model's predictions match lab results (from ICP-MS).

9) Detect Contamination
Use the model to identify spinach with high cadmium

Results

- Hyperspectral images of spinach leaves have been collected using the VS620 camera.
- Reflectance data was preprocessed in Spectronon to correct for noise and lighting differences.
- Early spectral analysis shows visible differences between control and Cd-treated plants, especially in the 700-900 nm range.
- Spectral indices like NDVI and PRI are being calculated for use in model training.

Discussion

These early results suggest that cadmium stress may cause detectable changes in spinach leaf reflectance. Once ICP-MS lab results are available, machine learning models will be trained to predict Cd levels using spectral features. If successful, this non-destructive method could help identify contaminated produce quickly and support safer food production practices.

References

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