Calculating Potassium Concentration in Soil using Laser-Induced Breakdown Spectroscopy and Python Data Analysis

Kaylin Crocker, Shubho Mohajan, Amina Hussein
Department of Electrical and Computer Engineering

UNIVERSITY OF ALBERTA
WISEST

Introduction

- The **potassium** content in soil significantly affects **disease resistance, strength, and fruit quality** in plants by moving and creating starches, soils, and oils better.[5]
- **Laser-Induced Breakdown Spectroscopy (LIBS)** is a portable, time-effective, and cost-effective way to determine element concentrations using lasers.[4]
- **Lasers** work by trapping light particles (photons) between two curved mirrors until they are released through a small hole, continuously or in pulses.[6]

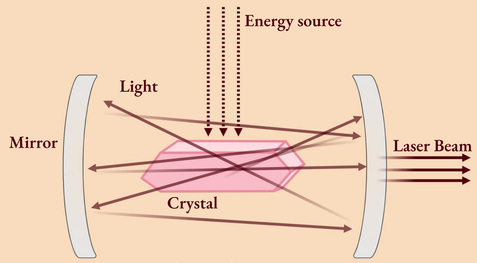

Fig 1. Diagram of the inside of a laser as energy is released.

- Powerful lasers can be directed at the soil to create **plasma**, an extremely hot group of ions and electrons.[3]
- LIBS operates by forming plasma with a laser; spectrometers then read the **spikes of energy** released at different wavelengths as the plasma cools.[1]

Methods

Python Logo. (n.d.). Retrieved July 17, 2024.

Jupyter Logo. (n.d.). Retrieved July 17, 2024.

- The laser used had a **Focal spot** of 44 um , 30 ± 2 um, an **Intensity** of 6.0 ± 0.4 × 10^{11} W/cm^2, and a **repetition rate** of 1.3 Hz.
- **38 soil samples** were taken from 3 separate locations in Alberta, 2 near CNRL oil extraction mines and 1 on farmland.
- Data was taken by a **spectrometer** that reads the emissions from the soil-made plasma. **300 shots** were taken per sample, totaling to **11400 raw spectra.**
- The **raw spectra** taken from the spectrometers are hard to read due to background noise, lens and experiment distortions, etc.
- We used **Python** to adjust the data to make it accurate, running the code in Jupyter Notebook.
- After averaging the spectra, there were **6 spectra per sample.**
- Predicting data within the set range was completed using a **Partial Least Squares Regression (PLSR)**, a method used to **reduce** the number of variables by combining them based on their correlation to each other[7], based **Machine Learning Model (ML)**.
- The ML model was trained using **Data Augmentation** and **Bootstrapping**, a method to infer results for an entire data set using a small portion of it[2], to provide the ML model with more data.

Processing

★ Raw data

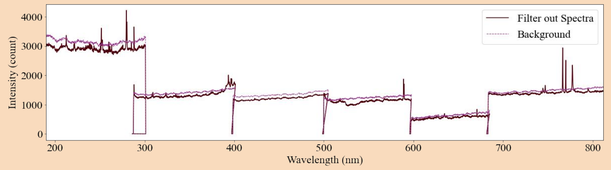

Fig 2. Raw Spectra data compiled together with comparisons to background emissions

★ Fixed data

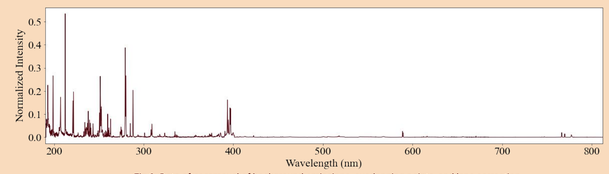

Fig 3. Data after removal of background emissions, overlapping points, and lens correction

★ Finding element peaks

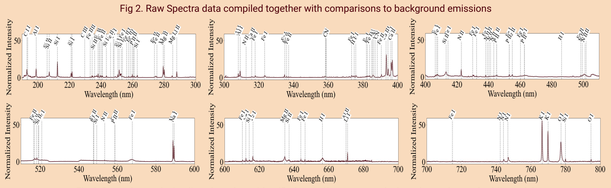

Fig 4. Data after emission lines have been identified to verify correct peaks have been chosen for ML model.

★ Taking relevant peaks

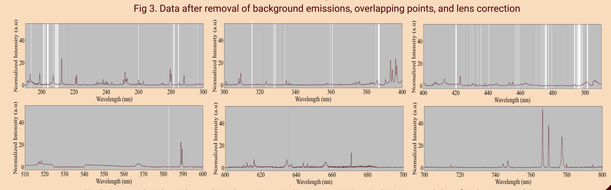

Fig 5. Data with selected wavelengths corresponding to potassium indicating used data for the ML model.

Results

- ML model's assessment of data was then **compared against new data points** from the set that the model hadn't seen, then calculating the **Root Mean Squared Error (RMSE) and Relative Error (RE)**.
- Soil sample 1:
  - RMSE: 75.8 mg/kg
  - RE: 7.91
- Soil sample 2:
  - RMSE: 6.55 mg/kg
  - RE: 9.95

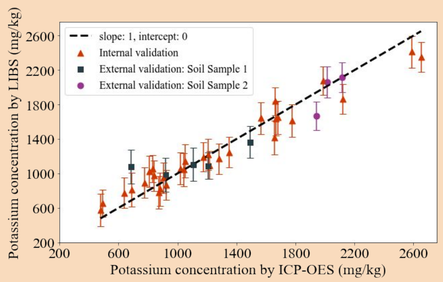

Fig 6. ML model calibrations compared to new soil types

Conclusion

- The trend line accuracy provides proof that LIBS can be utilized as an **on-site method with reliable and immediate results** to determine potassium concentration comparable to other predominant methods.
- This is **preliminary research** for potassium concentration with LIBS, with **more ML training** and available soil data, the error margin calculated will decrease.
- Once all important element concentrations, including potassium, can be reliably calculated, a **portable laser** with the data processing code will be sent to agriculture sites to determine the **needed fertilizers** for the soil.

Acknowledgements

- My place in WISEST would not have been an amazing experience if it weren't for the support of the WISEST staff and my fellow cohort members, thank you.
- Thank you to Canada Summer Jobs, NSERC, the Motorola Solutions Foundation, and the Hussein lab for providing the funding and support needed for my participation in the internship.

Canada
NSERC CRSNG
MOTOROLA SOLUTIONS FOUNDATION

Literature Cited

[1] Applied Spectra. (2023, October 8). *What is libs?*. Applied Spectra.

[2] Egbert, J., Plonsky, L. (2020). Bootstrapping Techniques. In: Paquot, M., Gries, S.T. (eds) A Practical Handbook of Corpus Linguistics. Springer, Cham.

[3] Mohajan, S. (2022, March 17). *Online REO Program: Laser-Induced Breakdown Spectroscopy*.

[4] Mohajan, S., Huang, Y., Beier, N. F., Dyck, M., Hegmann, F., Bais, A., & Hussein, A. E. (2023). Effect of laser wavelength on soil carbon measurements using laser-induced breakdown spectroscopy. *Optics Express*, *31*(20), 32335.

[5] *Plant nutrients in the soil*. NSW Department of Primary Industries. (2021, October).

[6] Reich, H. (2011, December 4). *How lasers work (in theory)*. YouTube.

[7] Tilevik, A. (2022, February 20). *Partial least squares regression (PLSR) - explained*. YouTube.