Estimation of soil nutrient content of Hyperspectral image using Machine learning algorithm

Domain: Machine Learning, Digital Image Processing

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Outline

Problem Statement

- To explore the capabilities of hyperspectral remote sensing technology in enhancing the evaluation of soil nutrient levels. This advancement has the potential to contribute to sustainable land use planning and effective crop management, particularly in tropical regions.
- In this study, we want to establish a systematic approach for utilizing hyperspectral data in order to accurately estimate essential soil nutrient parameters, specifically carbon, nitrogen, phosphorus, and potassium. Our primary emphasis will be on achieving high levels of precision and dependability in the estimation process.
- This study aims to enhance the comprehension of remote sensing techniques' application in treating soil nutrient deficiencies and variability in tropical soils. The findings of this research can have substantial consequences for improving agricultural production and promoting sustainable land use practices in Tamil Nadu, India.

Outline

Literature Review

Title	Methodology	Key Findings
Spectroscopic measurements and imaging of soil colour for field scale estimation of soil organic carbon	This study used digital camera and Sentinel-2 data to estimate SOC through soil color analysis. Random forest was used for modeling, and models were validated with repeated 5-fold cross-validation.	The advantages of using a digital camera for estimating soil organic carbon (SOC) include cost-effectiveness, efficiency, accurate predictions, and convenience compared to traditional spectroscopic methods.

Citation: Gholizadeh, A., Saberioon, M., Rossel, R. A. V., Boruvka, L., Klement, A. (2020). Spectroscopic measurements and imaging of soil colour for field scale estimation of soil organic carbon. Geoderma, 357, 113972.

Literature Review

Title	Methodology	Key Findings
Hyperspectral imaging for high-resolution mapping of soil carbon fractions in intact paddy soil profiles with multivariate techniques and variable selection	This study used hyperspectral imaging (HSI) to analyze soil C fractions in 16 paddy soil profiles. Linear and nonlinear multivariate techniques were compared, and CARS was used for spectral variable selection. Nonlinear multivariate techniques, combined with CARS, were more effective in mapping soil C fractions.	Improved Practical Applicability, Data Volume Reduction, This reduction in data volume enhances processing speed and efficiency. Faster Processing and consistent findings.

Citation: Xu, S., Wang, M., Shi, X. (2020). Hyperspectral imaging for high-resolution mapping of soil carbon fractions in intact paddy soil profiles with multivariate techniques and variable selection. Geoderma, 370, 114358.

Literature Review

Title	Methodology	Key Findings
Regional soil organic carbon prediction model based on a discrete wavelet analysis of hyperspectral satellite data	This study proposes a noise removal method for hyperspectral satellite soil data using DWT. It also implements a spectral input selection method and builds regional-scale SOC prediction models. The results showed that the proposed method effectively removes noise and improves the accuracy of SOC prediction.	the SOC prediction accuracy using hyperspectral satellite data is greatly improved. It is highly robust and accurate method for predicting and mapping regional SOC contents.

Citation: Meng, X., Bao, Y., Liu, J., Liu, H., Zhang, X., Zhang, Y., ... Kong, F. (2020). Regional soil organic carbon prediction model based on a discrete wavelet analysis of hyperspectral satellite data. International Journal of Applied Earth Observation and Geoinformation, 89, 102111.

Literature Review

Title	Methodology	Key Findings
Detection of soil organic matter using hyperspectral imaging sensor combined with multivariate regression modeling procedures citation:	PLSR - partial least squares regression - used to correlate spectral data from the sensor with SOM contents obtained from conventional methods.	The paper estimates soil organic matter concentrations at different depths, but doesn't analyze specific organic compounds.

Citation: Detection of soil organic matter using hyperspectral imaging sensor combined with multivariate regression modeling procedures, Remote Sensing Applications: Society and Environment, Volume 22, 2021, 100492, ISSN 2352-9385,

Literature Review

Estimation of Soil Nutrient Content Using Hyperspectral Data	Various techniques such as PLSR is used as a regression technique to find the optimal screening algorithm from the following three: PCC, LASSO, GBDT	The LASSO and GBDT performances were discovered to be optimal in determining the contents of TN and TP for the former and TK for the latter.

Citation:Peng, Y.; Wang, L.; Zhao, L.; Liu, Z.; Lin, C.; Hu, Y.; Liu, L. Estimation of Soil Nutrient Content Using Hyperspectral Data. Agriculture 2021, 11, 1129.

Literature Review

Title	Methodology	Key Findings
Usage of Airborne Hyperspectral Imaging Data for Identifying Spatial Variability of Soil Nitrogen Content	Hyperspectral imaging is performed to get the spatial and spectral imaging information for detecting physical, chemical and biological attributes in the Czech Republic, using laboratory and handheld spectrometers.	The paper only analyzes soil nitrogen content, not other organic matters like potassium, phosphorus, or carbon.

Citation:Pechanec, V.; Mráz, A.; Rozkošný, L.; Vyvlečka, P. Usage of Airborne Hyperspectral Imaging Data for Identifying Spatial Variability of Soil Nitrogen Content. ISPRS Int. J. Geo-Inf. 2021, 10, 355.

Literature Review

Title	Methodology	Key Findings
Soil Moisture, Organic Carbon, and Nitrogen Content Prediction with Hyperspectral Data Using Regression Models	Essentially, the study is comparing different machine learning methods for predicting soil properties using HSI data, with the goal of finding the most accurate and efficient approach. Principal Component Analysis is used to enhance model performance. Traditional methods like thermogravimetric, mass loss on ignition, Kjeldahl digestion are used for reference measurements of soil properties.	It reduces time and effort compared to conventional sampling techniques. This is advantageous for long-term monitoring and sustainable soil management.

Citation:Datta, D., Paul, M., Murshed, M., Teng, S. W., Schmidtke, L. (2022). Soil moisture, organic carbon, and nitrogen content prediction with hyperspectral data using regression models. Sensors, 22(20), 7998.

Literature Review

Title	Methodology	Key Findings
Using soil library hyperspectral reflectance and machine learning to predict SOC: Assessing potential of airborne and spaceborne optical soil sensing	PLSR, RF, Ridge, KNN, NN, CNN and LSTM are selected to identify the best combination. Vector Normalization, Continuum removal and First order derivative are performed for spectral pre-processing.	High accuracy can facilitate large scale SOC quantification. Imbalanced sample sizes may impact model error.

Citation: Wang, S., Guan, K., Zhang, C., Lee, D., Margenot, A. J., Ge, Y., ... Huang, Y. (2022). Using soil library hyperspectral reflectance and machine learning to predict soil organic carbon: Assessing potential of airborne and spaceborne optical soil sensing. Remote Sensing of Environment, 271, 112914.

Literature Review

Regional SOC prediction models based on a multivariate analysis of the Mid-infrared hyperspectral data in the middle Indo-Gangetic plains of India	SOC determined using Wet Oxidation method. To develop predictive models, PLSR,RF,SVR,MARS are used. For pre-processing, FD, SD, SNV, Multiplicative scatter correction methods are used.	MIR spectroscopy allows for a quick analysis and it is very accurate. But instrumentation cost of MIR spectroscopy is very high.

Citation:Ghosh, A. K., Hati, K. M., Sinha, N. K., Mridha, N., Sahu, B. (2022). Regional soil organic carbon prediction models based on a multivariate analysis of the Mid-infrared hyperspectral data in the middle Indo-Gangetic plains of India. Infrared Physics Technology, 127, 104372.

Literature Review

Title	Methodology	Key Findings
Monitoring Soil Properties using Enmap Spaceborne imaging spectroscopy mission	Data processing involves removing atmospheric effects and smoothing reflectance spectra. Soil properties such as soil organic carbon (SOC), clay, and carbonate content are mapped using local Partial Least Squares Regression (PLSR) and multitemporal composites. Validation is performed with ground truth datasets and spectral libraries to refine models.	Provides precise mapping of soil properties. Needs extensive, resource-intensive ground data.

Citation:Chabrillat, S., Milewski, R., Ward, K., Foerster, S., Guillaso, S., Loy, C., ... Demattê, J. A. (2023, July). Monitoring Soil Properties Using EnMAP Spaceborne Imaging Spectroscopy Mission. In IGARSS 2023-2023 IEEE International Geoscience and Remote Sensing Symposium (pp. 1130-1133). IEEE.

Literature Review

Title	Methodology	Key Findings
High-Resolution Mapping of Soil Organic Matter at the Field Scale Using UAV Hyperspectral Images with a Small Calibration Dataset	This study used UAV hyperspectral imaging to map soil organic matter (SOM) in a low-relief black soil area in Northeast China. The UAV images were processed .then Machine learning models(RF model)were applied to predict SOM from the preprocessed spectra.	UAV hyperspectral imaging provides fine spatial resolution, enabling detailed mapping of SOM. UAVs have restricted flight times and coverage areas, making them less suitable for large-scale mapping.

Citation: Yan, Y., Yang, J., Li, B., Qin, C., Ji, W., Xu, Y., Huang, Y. (2023). High-Resolution Mapping of Soil Organic Matter at the Field Scale Using UAV Hyperspectral Images with a Small Calibration Dataset. Remote Sensing, 15(5), 1433.

Outline

Objectives

- To design an efficient algorithm that can identify the relevant bands using optimization techniques.
- To design an prediction algorithm that estimates the soil nutrient content in hyperspetral spectroscopy data.
- To apply the developed algorithm for the real-world soil data and achieve the best regression model to predict soil nutrients. (in Project Phase 2)

Outline

Methodology

- The ground truth data has been obtained from Radhapuram, Tirunelveli.
- The spectral reflectance of the soil samples are recorded into a dataset which is to be processed with the help of ML models
- Various optimization techniques are used to reduce the number of redundant bands from the dataset.
- Regression trees are used to select significant bands.
- The resultant algorithm obtained is used to predict the soil organic content from any soil sample.

Outline

Block Diagram

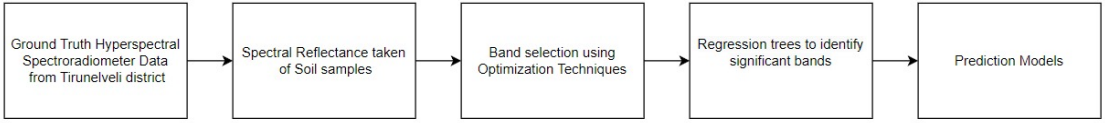

Figure: Proposed Methodology

Outline

Soil content mapping

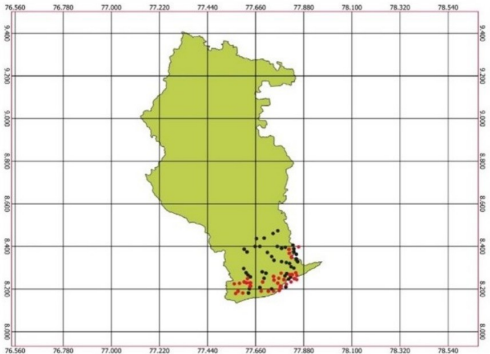

Figure: Flowchart of soil content mapping with hybrid optimizations

Outline

Results and Discussions

Table: Soil nutrient levels for spectroradiometer data

Soil Nutrients Levels	Low	Medium	High
Organic Carbon	<0.5 %	0.5 - 7.5%	>0.75%
Nitrogen	<240Kg/ha	240- 480kg/ha	>480Kg/ha
Phosphrous	<11.0 Kg/ha	11 – 22 Kg/ha	>22 Kg/ha
Pottasium	<110Kg/ha	110-280Kg/ha	>280Kg/ha

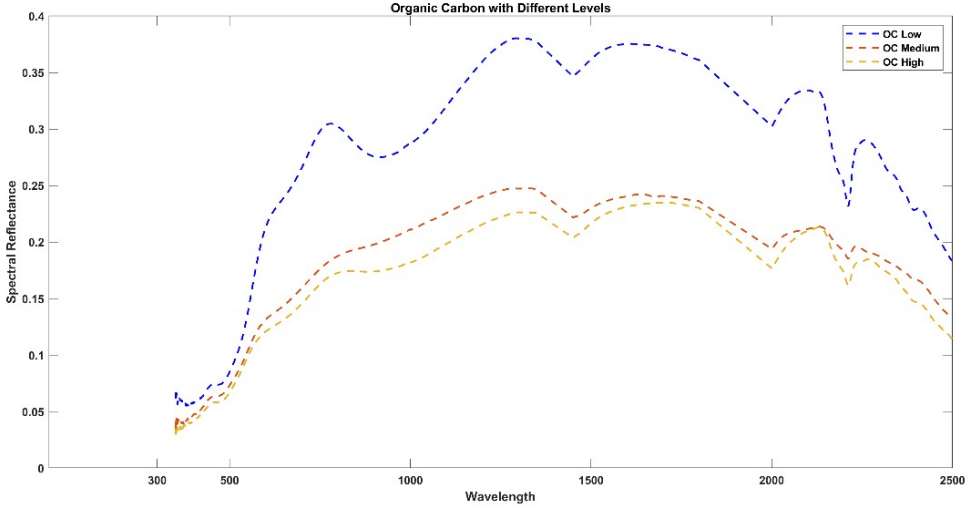

Figure: Organic Carbon with different levels

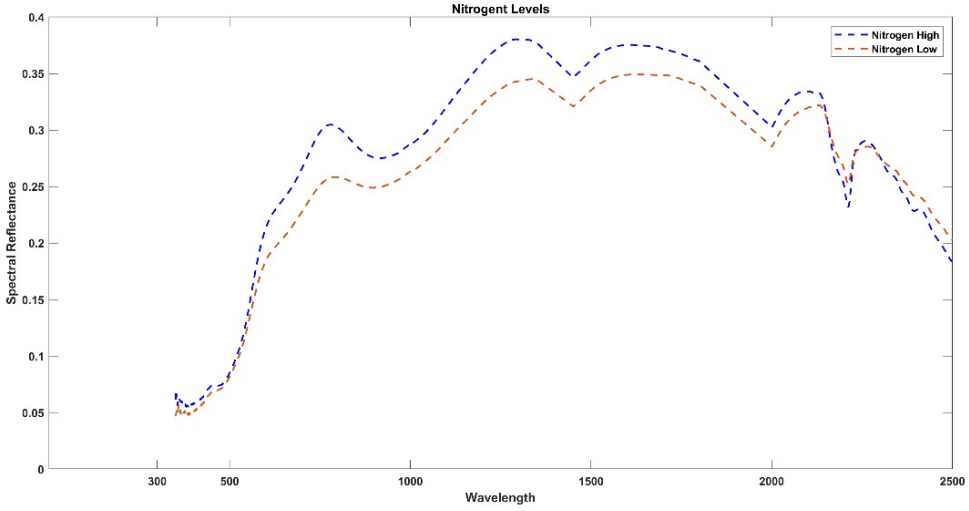

Figure: Nitrogen levels

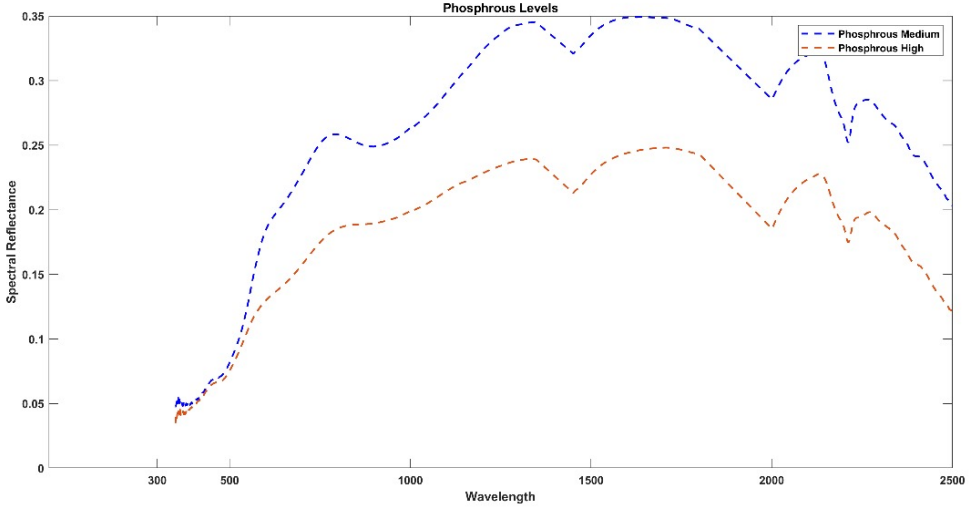

Figure: Phosphorous levels

Outline

Time Frame

S.No	Task Name	Project Phase 1					Project Phase 2			
		July	August	September	October	November	December	January	February	March
1.	Literature Review & Domain Identification									
2.	Data Preprocessing & Band Selection									
3.	Feature Extraction & Regression									
4.	Comparison of results									
5.	Project Report Writing									
6.	Preprocessing of Hyperspectral Satellite images									
7.	Deploy Band Selection Techniques to preprocessed images									
8.	Prediction of Soil Nutrient Content									

Outline

References

- **Datta, D., Paul, M., Murshed, M., Teng, S. W., Schmidtke, L. (2022). Soil moisture, organic carbon, and nitrogen content prediction with hyperspectral data using regression models. Sensors, 22(20), 7998.**
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