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Application Summary

Competition Details

Competition Title:	2025 South Dakota Nutrient Research and Education Council Invited Proposals
Category:	SDAES
Cycle:	2025
Submission Deadline:	10/15/2024 5:00 PM

Application Information

Application Title:	Estimation of Nitrogen Status in Corn Leaves Using Convolutional Neural Network, Machine Learning and Hyperspectral Imaging
Application ID:	3456
Submission Date:	10/14/2024 5:56 PM

Personal Details

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Co-Applicant(s)

Name	Email	Affiliation
No Co-Investigator(s)		

Application Details

Proposal Title

Estimation of Nitrogen Status in Corn Leaves Using Convolutional Neural Network, Machine Learning and Hyperspectral Imaging

Proposal Abstract

This project aims to develop a method for estimating nitrogen status in corn leaves using hyperspectral imaging and convolutional neural networks. By analyzing hyperspectral data collected from corn at key growth stages, the research will develop machine learning models that help farmers optimize nitrogen application. The project will lead to cost savings by ensuring that the correct amount of nitrogen is applied, improving crop yields, and protecting the environment from nitrogen runoff. Results will be shared with stakeholders through publications, workshops, and an online platform.

2025 Total Budget Request

64,479

Acknowledgment

Acknowledgement of Terms and Conditions

[Acknowledged] I have read and agree to abide by the South Dakota Nutrient Research and Education Council Terms and Conditions attached to this RFP.

Title: Estimation of Nitrogen Status in Corn Leaves Using Convolutional Neural Network, Machine Learning and Hyperspectral Imaging

PI and Collaborators: Dr. Pappu Kumar Yadav, Department of Agricultural & Biosystems Engineering, South Dakota State University, Brookings, SD, 57007 (PI), Dr. David Clay Department of Agronomy, Horticulture and Plant Science, South Dakota State University, Brookings, SD, 57007 (Collaborator), Dr. David Karki, SDSU Extension Agronomy Field Specialist, South Dakota State University, Watertown, SD 57201 (Collaborator), Dr. Graig Reicks, Department of Agronomy, Horticulture and Plant Science, South Dakota State University, Brookings, SD, 57007 (Collaborator), Thomas F. Burks, Department of Agricultural & Biological Engineering, University of Florida, Gainesville, FL. (Collaborator), Dr. Jianwei Qin, Beltsville Agricultural Research Center, USDA/ARS Environmental Microbial and Food Safety Laboratory, Beltsville, Maryland, USA

Summary

In-season nitrogen estimation is crucial for optimizing nitrogen fertilization in corn (*Zea mays* L.), ensuring that plants receive the right amount of nutrients at the right time. Excessive nitrogen application can lead to environmental issues such as groundwater contamination and greenhouse gas emissions, while insufficient application can hinder crop growth and yield. Traditional methods of nitrogen estimation are often time-consuming and labor-intensive. However, recent advancements in hyperspectral imaging (HSI) and machine learning (ML) offer a promising alternative for rapid and accurate nitrogen diagnostics.

Goals and Objectives

The primary goal of this project is to develop a robust and accurate method for estimating nitrogen (N) status in corn leaves using a combination of Convolutional Neural Networks (CNN), machine learning techniques, and hyperspectral imaging (HSI). The specific objectives are:

i. To develop a novel image processing pipeline utilizing a Hyperspectral Imaging (HSI) system to capture detailed spectral signatures of corn leaves from V6 to V12 growth stage. This pipeline will utilize the rich spectral information provided by the HSI to detect variations in nitrogen content.
ii. To design and implement custom Convolutional Neural Networks (CNNs) for spatial feature extraction from hyperspectral images. These CNNs will be designed to effectively handle the high-dimensional data and extract features relevant to nitrogen status determination.
iii. To integrate machine learning (ML) classifiers with the CNN models to enhance the accuracy and reliability of nitrogen status predictions. The ML classifiers will complement the CNNs by refining the classification of nitrogen status into three distinct categories.
iv. To identify the five most discriminating spectral bands out of the 348 bands captured by the HSI system using techniques such as Principal Component Analysis (PCA) and other feature selection methods. This will streamline the image processing pipeline by focusing on the most informative spectral data.
v. To validate the developed models and image processing pipeline with field data collected from corn crops in South Dakota. This involves rigorous testing and refinement to ensure that the models accurately estimate nitrogen content and can be reliably used in real-world agricultural settings.

Justification

This research is essential because nitrogen (N) is crucial for corn growth and yield, but current methods to estimate its levels are inefficient and inaccurate. By developing a cutting-edge system that uses hyperspectral imaging (HSI) and machine learning (ML), combined with convolutional neural networks

(CNNs), we aim to create a fast and precise way to detect nitrogen deficiencies in corn leaves from V6 to V12 growth stages. This project will identify key spectral bands that are most informative, making the technology more practical for farmers. Economically, this means farmers can save money by using the right amount of fertilizer, leading to better yields and reduced costs. Environmentally, it will help prevent excess nitrogen from contaminating groundwater and reduce greenhouse gas emissions, promoting more sustainable farming. In short, this research will provide farmers with a powerful tool to improve crop management, boost profits, and protect the environment.

Work Plan

The project will begin with finalizing the project team and roles, as well as procuring the necessary equipment in the first two months. A detailed project plan will be developed, outlining specific tasks, timelines, and deliverables. Initial training sessions will be conducted to familiarize team members with the equipment, hyperspectral imaging techniques, and machine learning tools to ensure everyone is prepared for the data collection and analysis phases. By months three and four, hyperspectral images will be captured from corn leaves at different growth stages (V6-V12), with particular attention given to ensuring comprehensive sampling across stages (Fig. 1) . Preprocessing of the raw hyperspectral images will also commence during this period to ensure that the data is ready for analysis. This is in line with our preliminary study that we have done so far (Fig. 2).

Fig. 1 Corn leaf sample data collection at different growth stages for scanning with portable HyperSpectral Imaging system to estimate foliar Nitrogen content.

In months five and six, the preprocessing of the images will be completed, followed by Principal Component Analysis (PCA) to reduce the dimensionality of the hyperspectral data, and identify the most informative spectral bands. Concurrently, the project team will design custom Convolutional Neural Networks (CNNs) to extract features from these images, focusing on nitrogen content estimation (Fig. 2). By months seven and eight, the CNNs will be integrated with machine learning classifiers to enhance accuracy, and the models will be trained using the collected and processed data. The final model validation will take place in months nine and ten, where field data will be used to test the model's performance, followed by necessary refinements. During this phase, the team will also prepare and submit manuscripts to academic journals.

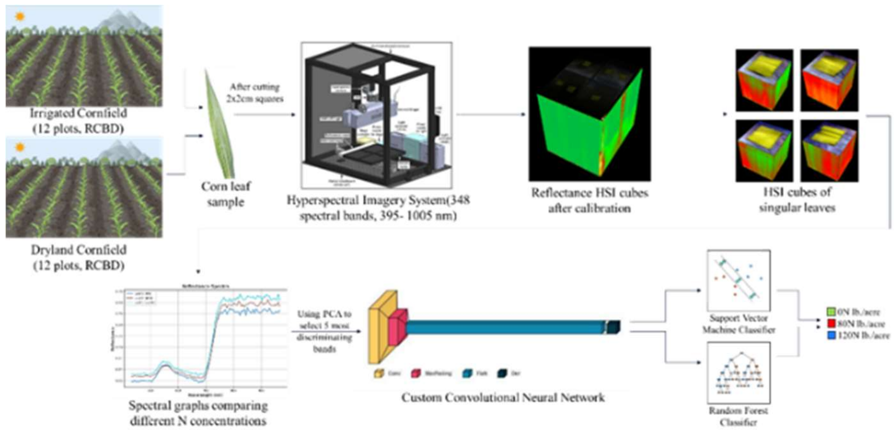


Fig. 2 Image processing pipeline from the preliminary study demonstrating pre and post processing of raw HyperSpectral Images of corn leaves at different growth stages that will be used in the proposed project.

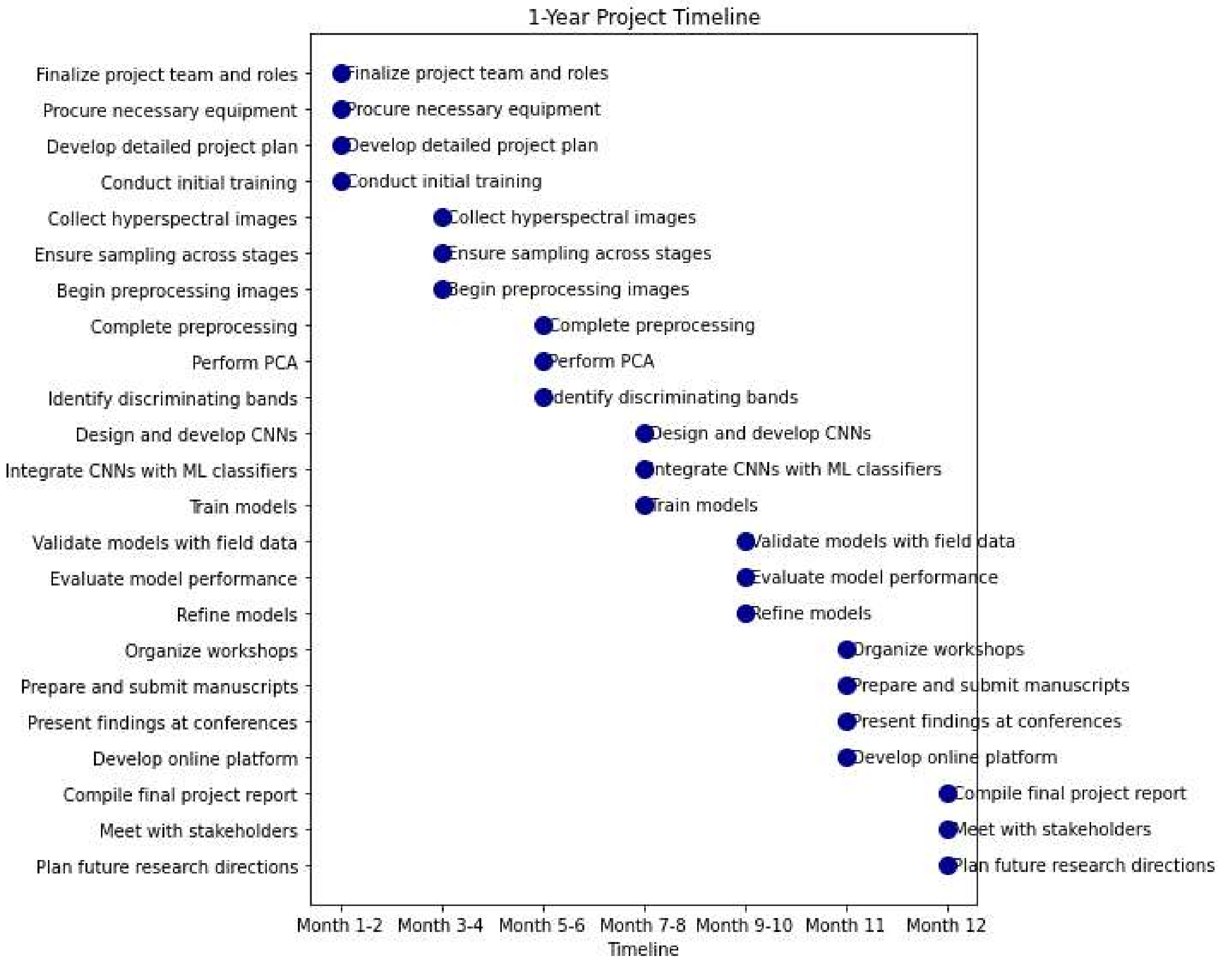
In the final two months, workshops will be organized to disseminate the findings to stakeholders, including farmers and researchers, ensuring the developed models are practical and easily adoptable. Results will be presented at conferences, and the final project report will be prepared. The team will meet with stakeholders to gather feedback and discuss future directions for research, ensuring a well-rounded conclusion to the project with plans for subsequent developments.

Potential Impacts

The potential impacts of this project are significant both economically and environmentally. From an economic perspective, the use of hyperspectral imaging and machine learning models for nitrogen estimation will allow farmers to optimize their nitrogen application, leading to more efficient use of fertilizers. By accurately determining the nitrogen status of corn leaves, farmers can apply the right amount of fertilizer at the right time, reducing over-application and minimizing input costs. This precise nitrogen management can lead to better crop yields, directly improving farm profitability. Additionally, the reduction in fertilizer use will lower operational costs, making farming more sustainable and cost-effective in the long run, particularly for large-scale corn producers in South Dakota and surrounding regions.

Environmentally, this project addresses a critical need for sustainable agriculture practices. Excess nitrogen runoff from agricultural fields is a leading contributor to groundwater contamination and the eutrophication of water bodies, which can lead to harmful algal blooms and loss of aquatic biodiversity. By providing a tool that helps farmers optimize nitrogen use, this project will directly reduce nitrogen leaching into groundwater and mitigate the release of greenhouse gases like nitrous oxide, a potent contributor to climate change. Moreover, the project aligns with the broader goals of promoting environmentally responsible farming practices by reducing the overall environmental footprint of agriculture. This research has the potential to improve water quality, reduce the environmental impact of farming, and contribute to long-term sustainability in agricultural ecosystems.

Timeline



The Gantt chart outlines a detailed 12-month timeline for the project, showing a structured approach to achieving its goals. The project begins with team formation, equipment procurement, and the development of a detailed plan during the first two months. This initial phase ensures that all resources and personnel are prepared for data collection and analysis. From months three to four, the collection of hyperspectral images from corn leaves will be the primary focus, with careful attention to sampling at various growth stages. Data preprocessing, including the use of Principal Component Analysis (PCA), will also occur during this time to ensure the data is ready for analysis.

In months five through eight, the core model development will take place. Custom Convolutional Neural Networks (CNNs) will be designed and developed to extract spatial features from the hyperspectral data. These CNNs will be integrated with machine learning classifiers for nitrogen status prediction. The models will be trained and refined during this period, followed by rigorous validation using field data in months nine and ten. In the final two months, the team will focus on disseminating the project results through workshops, conferences, and publications. The project concludes with a final report and planning for future research directions, ensuring that the work has lasting impacts beyond the initial 12-month period.

Project Budget

South Dakota State University				
PI	**Pappu Kumar Yadav**			
		Yr. 1	**Total**	**Budget Narrative**
A. Salaries and Wages				
Pappu	Yadav	9,681	9,681	PI's effort to conduct research and manage project.
David	Clay	3,683	3,683	Mentorship
Graig	Reicks	688	688	Assist of field work
David	Karki	937	937	Assist with farm allocation
Other Personnel		15,143	15,143	
Total Salaries		**30,132**	30,132	
B. Fringe Benefits		4,142	4,142	
C. Permanent Equipment		0	0	
D. Participant Support		0	0	
E. Project Travel		5,000	5,000	Travel for conferences and field data collection
F. Materials and Supplies		12,000	12,000	Supplies for experimental setup in fields as well as data collection
G. Publication Costs		4,000	4,000	Costs for journal article publications
H. Contractual		0	0	
I Computer Services		0	0	
J. Other		0	0	
Total direct costs		55,274	55,274	
I. Tuition Remission		9,205	9,205	
Indirect		0	0	
TOTAL		**64,479**	**64,479**	

Short Budget Justification

The proposed budget for this project is carefully structured to cover all essential components needed for its successful execution. Personnel salaries total $30,132, which includes the efforts of the PI and collaborators who will contribute to the research, manage the project, provide mentorship, assist with fieldwork, and coordinate farm-related tasks. These contributions are critical for keeping the project on track and ensuring high-quality research outcomes. Fringe benefits of $4,142 are included to cover the necessary benefits for all personnel involved. A travel budget of $5,000 is allocated for field data collection and attending conferences, which is important for both gathering data and sharing the project's findings with the broader research community. Additionally, $12,000 is designated for materials and supplies, including the setup of experiments in the field and any other equipment or resources required for data collection. We have set aside $4,000 to cover publication costs, ensuring that the research results are published in peer-reviewed journals. Finally, $9,205 is allocated for tuition remission, supporting the graduate student's involvement in the project. Overall, the total budget is $64,479, with each item thoughtfully included to ensure the project's success from start to finish.