Application_for_NRPU_Grant_from_HEC_20Oct2025.docx

by Muhammad Waqar Aslam

Submission date: 20-Oct-2025 12:06PM (UTC+0500)
Submission ID: 2786746237
File name: Application_for_NRPU_Grant_from_HEC_20Oct2025.docx (20.03K)
Word count: 2230
Character count: 12929

Application for NRPU Grant from HEC

Dr. Shahid Masud, Dr. Adeel Pasha

EE Dept, LUMS

Title

SAIFeR –Soil Analytics and Intelligent Fertilizer Recommendation using Custom Instrumentation and Artificial Intelligence

Problem Statement

In Pakistan, Agriculture sector contributes 23% to the Gross Domestic Product (GDP), 38% in employment generation, ensures food security, and leads to rural development [1]. But the potential for growth and productivity of this sector is hindered as it is confronted with numerous problems. There is a pressing need to take multiple research initiatives to address the challenges faced by farmers.

The productivity and efficiency of crop cultivation are directly linked to the application of fertilizers but due to inadequate fertilizer management practices, we are unable to compete with the rest of the growers in the region. Farmers are still using traditional and inefficient approaches for the application of fertilizers. Inadequate and overdose of fertilizers affects the crops adversely. It is also reported that soil health has declined with the over usage of fertilizers leading to nutrient imbalances along with negative impacts on the environment. It is a matter of huge concern for the farmers in developing countries like Pakistan as it results in an increase in the overall production cost of the crop and causes economic losses for the farmers due to less production.

To address the challenges stated above, this project proposes the idea to develop an innovative and intelligent fertilizer recommendation system that helps farmers to know how much fertilizer is required based on soil health. It will be a user-friendly wireless device that will measure the essential soil parameters in real-time required for the optimum growth of crops. This research project combines the disciplines of data analytics, precision agriculture, embedded systems, and sensing technologies. This will eventually promote sustainable agricultural practices and lead to the optimization of crop yield.

The macronutrients required by any crop to grow are Nitrogen, Phosphorus, and Potassium. The higher the concentration of these elements already available in the soil, the lower the dosage of fertilizers will be required to get maximum yield. Sensors installed in the portable device will detect the concentration of NPK in the soil along with a few other parameters including pH, Electrical conductivity, Humidity, Temperature, and Pressure. The data will be wirelessly transmitted to the other device that can be connected to the laptop for the detailed analysis of this data.

The data collected from the field will be subjected to different analytics algorithms. After a comprehensive analysis based on these parameters, the system will recommend accurate and tailored fertilizers recommendation for different crops. The data-driven application of fertilizers will empower farmers and ultimately lead to sustainable farming, higher crop yield, reduction in production cost, and minimizing hazardous environmental impacts due to excessive usage of fertilizers.

Objectives and Scope

Currently, traditional ways like blanket fertilizer application are being used for the application of fertilizers. The recommended fertilizer dosage by the government and other agricultural institutes is generalized for a specific region but in reality, the amount of required fertilizers may vary in each field depending upon the climate and terrain of that specific area. These approaches are now proven to be inefficient and cause environmental pollution and nutrient imbalances in the fields. In this research project, an integrated solution based on precision agriculture techniques, different sensors, and data analytics will be provided to increase fertilizer management practices.

Objective

The core objective of this research project is to develop an embedded intelligent fertilizer recommendation device based on soil analytics to optimize the production of crops. It will be a user-friendly and cost-effective portable device that will help local farmers and modern agricultural farms to take more informed decisions about the application of fertilizers. This research initiative will promote collaboration between academia and agricultural experts, including farmers which will eventually facilitate them in adopting modern tools and techniques in modern-day agriculture. In the long run, this research project will contribute to the sustainable development of agriculture in Pakistan and beyond, addressing the challenges of economic growth, food security, and environmental sustainability.

Milestones

The different stages that will be involved in our research project are discussed below in detail.

- Integration of sensors

In the first step, an embedded system based on the ESP32 LoRa development board will be developed. All the sensors measuring soil parameters and the GPS module will be integrated with it.

- Development of fertilizer recommendation model

In the second stage, a robust model based on Artificial Intelligence will be developed. This will take data from the portable embedded device (including sensors) and after complete processing using advanced analytical tools, it will provide customized accurate fertilizer recommendations.

- Field Trials and data collection

Once both the device and model are developed, extensive in-field trials will be conducted by collaborating with local farmers and agricultural experts. Based on the data collected, the recommendations given by the developed model with be then compared with the dosage suggested through traditional ways.

- Knowledge Dissemination

Sharing knowledge has always been our priority at LUMS. We aim that the knowledge and key insights of this research project will be disseminated through research papers and different workshops with be conducted in collaboration with industry where local farmers will be enlightened with these smart technologies.

Research Significance and Challenges Addressed

According to an estimate, around 38% of our labor is associated with agriculture but our yield has become the lowest in this region. Inefficient use of fertilizer along with soil degradation and nutrient imbalance is the primary reason for low crop yields. 90% of the farmers in South Asia don't have any access to soil testing [2]. Conventional techniques including blanket fertilizer method and fertilizer recommendation based on observations and crops appearance are suboptimal. A site-specific and data-driven precision-based approach needs to be developed to resolve issues of underutilization or over dosage of fertilizers [3].

In local context, the University of Agriculture Faisalabad (UAF) has conducted research on overall income gain from balanced use of fertilizer. The UAF fertilizer prediction model developed was deployed in three different villages. Data was collected from 60 wheat growers including 30 farmers who adopted their model and 30 farmers from each village who adopted conventional method of fertilizer application [4]. It was observed that higher yield of wheat crop was obtained with a benefit of Rs. 4194.6 per acre.

The agriculture sector has gone through multiple revolutions in the past two centuries. In ancient times, all the activities were performed manually using animals and indigenous tools. But around 1920, an industrial revolution took place which transformed agriculture 1.0 to a new era declared as agriculture 2.0. A major transformation was the mass production of tractors which proved cost-efficient for the farmers. Fertilizers and pesticides were also introduced, which enhanced the overall productivity of the crops. With the emergence of electronics in the second half of the 20th century, different electronic systems were developed for yield monitoring, irrigation, precision farming and improved storage and transportation. This was the beginning of agriculture 3.0 which later on incorporated multiple sensing equipment for data analysis and crop management. These agricultural revolutions

In late 2010s, agriculture sector has been revolutionized with the inclusion of artificial intelligence, Internet of Things and machine learning models aiming to transform agriculture and make farming autonomous with enhanced productivity and high resource efficiency. This is the modern era of agriculture 4.0 where cutting-edge technologies are being integrated in agriculture to address global challenges related to agricultural industry and food security. However, Pakistan lags in embracing agriculture 3.0 and 4.0. Agriculture sector in Pakistan still exists in Agriculture 2.0 and it is the need of the hour to bridge this gap. We must promote data-driven decision-making and precision agriculture and equip our farmers with modern tools to optimize resource usage.

Amid the current economic crisis in Pakistan accompanied by the shortage of foreign exchange reserves, it has become a dire need to move forward hand in hand with Agriculture 4.0 for increasing the quality as well as the quantity of agricultural goods to be exported. Despite exporting our agricultural goods, we have been importing basic food commodities including wheat and cereals for the last ten years. Our farmers won't be able to compete with the rest of the world if they continue using the same old techniques. Thus, adoption of modern and intelligent agricultural tools like our proposed SAIF recommendation system will improve crop yield and help Pakistan in becoming an export-led economy.

Research Methodology

The proposed research methodology aims to develop an integrated Soil analytics and intelligent fertilizer recommendation (SAIF) system involving different sensors and using Custom Instrumentation, advanced algorithms, computational techniques, and Artificial Intelligence.

Contrary to the existing soil testing techniques, SAIF will consist of two parts. One of which is meant for data sensing and transmission while the other part is to be connected with the laptop to receive soil data. The idea is to sense the nutrients concentration in the soil using a portable device and the measured data is transmitted wirelessly to other devices where the soil parameters will be analyzed for precise tailored fertilizer recommendations.

The portable data sensing device will be equipped with multiple sensors for measuring NPK nutrients, pH, EC, pressure, humidity, temperature, and coordinates of that area. The existing models for determining soil nutrients content incorporate only a few parameters while in this technique all the necessary parameters will be measured to assess the soil health and fertility. For this purpose, JXCT 7-in-1 integrated soil sensor will be used. It provides the values of all the above parameters except pressure and coordinates [24].

For data acquisition and data processing ESPLoRa32 will be used as it has more computational power and memory. For a higher communication range between sensor and receiving station, LoRa technology is incorporated in our design [28]. We don't have to carry the whole station for soil sensing over hectares as we can communicate and send data even if it is a few kilometers apart. Instead of using a separate LoRa module, ESPLoRa32 comes with a built-in LoRa module [25]. The soil sensor provides RS-485 output signal. However, ESP32 operates at TTL which makes it incompatible with soil sensor. To convert RS-485 signal to TTL level, MAX485 TTL to RS-485 interface module will be used [26].

The existing soil testing techniques don't incorporate location tracking whereas NEO-6M GPS module will be used in SAIF system and help in mapping of soil testing locations [27]. Geospatial data of soil nutrients could be saved and will enable farmers to take more informed decisions based on the variations in the soil fertility of a particular area over a period. Atmospheric pressure is also a key factor in determining the growth of different crops, therefore we have incorporated this sensor in our design as well. Co-relation between air pressure and soil heath indicators could be formed for fertilizers recommendations.

All these modules will be integrated into a single portable device. The possible interconnections and overview of all the above modules are shown below graphically. This device will be inserted into the field at multiple locations and the data will be transferred to the other end wirelessly using LoRa technology. Inclusion of all the possible sensors critical

in soil characterization and fertilizer recommendations overcomes the limitations of the existing models. SAIF is a more accurate and comprehensive system for the assessment of different soil health indicators and holistic overview of soil fertility.

After developing the SAIFeR system, the performance of the proposed SAIF system will be evaluated. We will collaborate with the local farmers and this system will be deployed at multiple field location in different areas for data collection of diverse soil types with different cultivated crops. The data collection will continue for a complete season starting from seed sowing to harvesting. This will give a holistic overview of the variations in soil quality and the impact of fertilizers. The data collected will also be compared with the results obtained using laboratory testing and the designed system will be calibrated if required. A complete assessment will be made of the accuracy and effectiveness of the SAIFeR system.

Expected Outcomes

Soil Analytics and Intelligent Fertilizer SAIF Recommendation system will bring significant value addition to both LUMS and the agricultural industry in Pakistan. This project indicates LUMS dedication to cutting-edge technology and creative approaches in the agricultural sector. LUMS showcases its proficiency in embedded systems, data analytics, and sustainable agriculture practices by creating and executing an advanced fertilizer recommendation system. LUMS will be playing a leading role in agricultural innovation by opening doors for interdisciplinary academic collaborations, industry partnerships, and knowledge sharing.

Researchers at LUMS will get an opportunity to investigate cutting-edge approaches and algorithms for analyzing soil data, creating sophisticated models for fertilizer recommendation, and advancing our understanding of nutrient management in agriculture. The study's findings could be published in renowned academic journals, boosting LUMS's stature and influence in the agricultural research community on a global scale. This initiative will also attract leading scholars and authorities in the disciplines of embedded systems, data analytics, and agronomy, opening chances for interdisciplinary collaboration.

The Specific Deliverables of this research project will be:

- Prototype of a fully operational fertilizer suggestion system.
- Information on sensor calibration and verified measurements.

- Microcontroller and receiving device firmware and software codebase.
- Algorithms for data analytics that recommend fertilizer.
- User guides, technical specifications, and research paper.
- Materials for workshops or training sessions for farmers.

Application_for_NRPU_Grant_from_HEC_20Oct2025.docx

ORIGINALITY REPORT

0%	0%	0%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		