National Institute Of Technology Raipur

Department Of Information Technology

MINOR PROJECT

Topic: **Smart Fertilizer Recommendation System using UAV and Machine Learning**

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Presentation Outline

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INTRODUCTION

- **The Problem: Traditional fertilization is based on guesswork, which wastes money and harms the environment.**
- **Our Solution: We use a UAV (drone) to collect precise field data and an AI model to provide smart, data-driven fertilizer recommendations.**
- **The Goal: To make farming more efficient, profitable, and sustainable.**

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Here we have a visual breakdown of the data collection process, which is a core part of our proposed system.

- First, Data Acquisition: The process begins with the UAV, or drone, flying over the agricultural field. It’s not just taking pictures; it's equipped with specialized sensors to actively scan and collect specific agronomic data points like soil nutrient levels, moisture content, and crop health indicators.
- Second, Secure Transmission: As the data is collected, it is immediately transmitted wirelessly to the ground. A crucial aspect of our proposed architecture, and a key part of our future work, is ensuring this communication is secure. The padlock icon you see here represents an encrypted data link, which protects the farmer's valuable data from unauthorized access.
- Finally, Data Reception at the GCS: The secure signal is received by the Ground Control Station, or GCS, which is the field operator's laptop. As you can see on the screen, the GCS not only receives the raw data but also provides an initial visualization through charts and graphs. This is the final step before the data is fed into our machine learning model for the final fertilizer recommendation."

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IoT Proposed System Vs Traditional One

- First, let's look at Data Collection and Decision Making. The traditional approach relies on taking a few manual soil samples and making decisions based on experience or general advice. Our system, however, is completely data-driven. The UAV captures thousands of data points across the entire field, and our ML model makes decisions based on this comprehensive, real-time information, removing the guesswork.
- This directly impacts Precision. Traditional methods use a 'one-size-fits-all' approach, applying the same fertilizer mix everywhere. As you can see on the right, our system enables high-precision, targeted application, treating different parts of the field according to their specific needs.
- In terms of Efficiency and Resource Use, the old way is slow and often wastes a significant amount of expensive fertilizer. Our system is not only faster and more scalable, but it optimizes resource use, leading to significant cost savings for the farmer.
- Finally, and most importantly, is the outcome. The traditional method often results in inconsistent yields and has a negative environmental impact due to chemical runoff. Our system leads to healthier, more consistent crop yields and promotes sustainable agriculture by protecting the environment.

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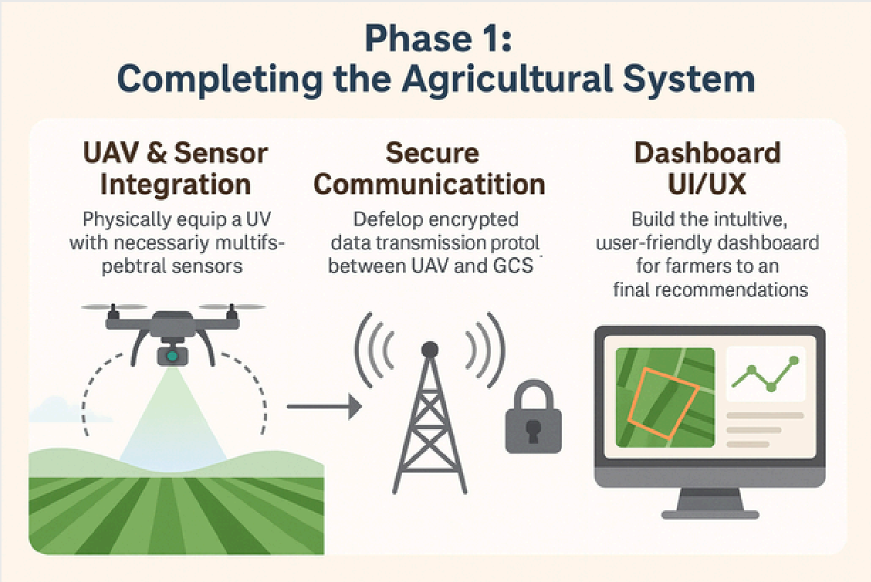
Our Proposed System Vs Traditional One



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Background - The Technological Evolution

Legacy Technologies & Their Limits

- Manual Soil Testing: Was the standard, but it's slow, costly, and only represents a few spots in a large field.
- Satellite Imagery: Provided a broader view but was often hindered by low resolution, high costs, and cloud cover. Both methods lack the detail needed for true precision.

The Modern Approach: UAVs and AI

- Unmanned Aerial Vehicles (UAVs): Drones are the game-changer, offering on-demand, high-resolution data at a low cost, capturing the specific details satellites miss.
- Machine Learning (ML): This is the intelligence layer. ML processes the complex data from the UAV to provide the accurate, data-driven recommendations that are central to our project.

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Identifying the Research Gaps

While previous work has demonstrated the potential of both UAVs and Machine Learning in agriculture, there are critical gaps between the existing research and a practical, deployable solution.

- The Integration Gap: Most studies focus on either data collection or data analysis in isolation. There is a significant lack of a seamless, end-to-end system that connects the UAV in the field to an intelligent prediction model and then to the farmer in real-time. The pieces exist, but they haven't been put together.
- The "So What?" Gap (Lack of Actionable Insights): A lot of research stops after the prediction is made. The crucial final step—translating complex model outputs into a simple, clear, and actionable recommendation on a farmer's dashboard—is often overlooked.
- The Accessibility Gap: Many existing solutions are either too complex or too expensive for the average farmer to adopt. There is a need for a system that is not only technologically advanced but also user-friendly and cost-effective.
- Our project directly targets these gaps by designing a blueprint for a fully integrated, user-centric system that bridges the divide between raw data and practical, on-the-ground decisions.

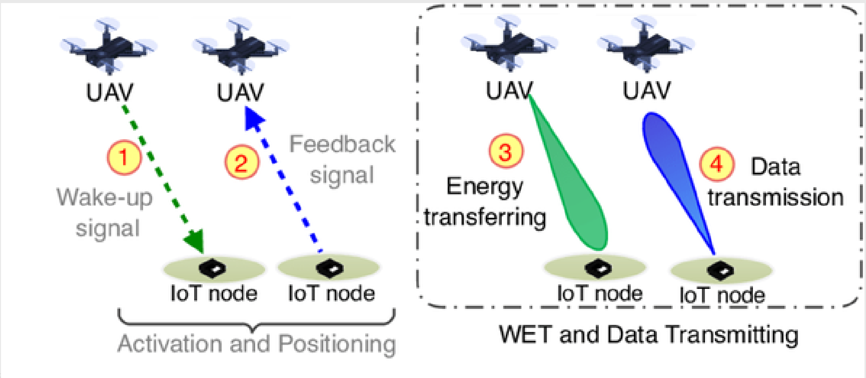
04

Proposed System Architecture (Methodology)

Our proposed system is designed as an end-to-end workflow, seamlessly moving from data collection in the field to a final, actionable recommendation for the farmer. The architecture is broken down into four key stages:

Stage 1:Data Acquisition (The Eyes of the System)

- An autonomous Unmanned Aerial Vehicle (UAV) is deployed over the farmland.
- It is equipped with multispectral sensors to capture critical agronomic data points, including Nitrogen (N), Phosphorus (P), Potassium (K) levels, soil pH, and moisture content across the entire field.



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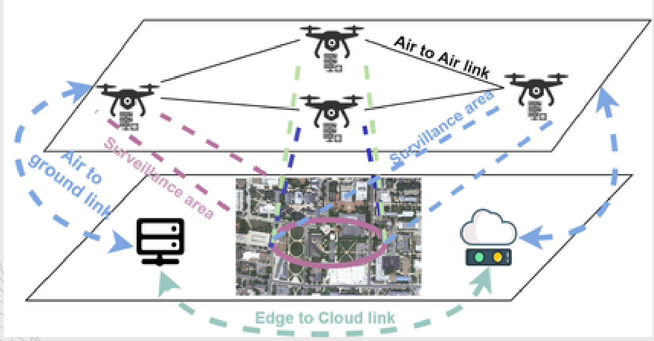
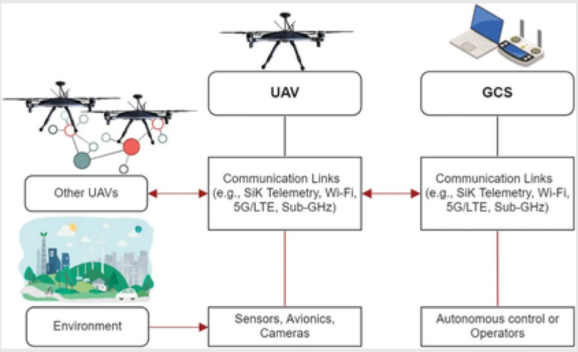
Stage 2: Secure Data Transmission (The Communication Link - Future Work)

- The data collected by the UAV is transmitted in real-time to a Ground Control Station (GCS).
- This transmission will be protected by a secure and encrypted wireless protocol to ensure data integrity and prevent unauthorized access.





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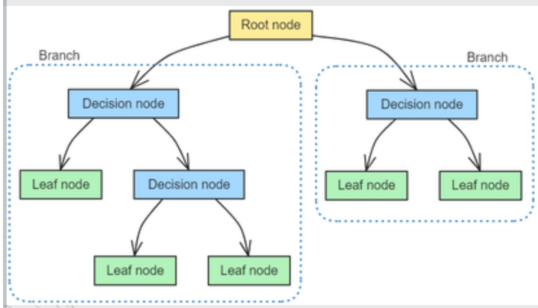
Stage 3: ML Model Analysis (The Brain of the System - Work Completed)

- This is the core of our completed work. The raw data from the GCS is fed directly into our pre-trained Machine Learning model.
- The model processes this complex dataset to identify patterns and predict the optimal fertilizer type and dosage required for specific zones within the field.



How a Decision Tree Works

- The algorithm recursively partitions the feature space by selecting the attribute at each node that results in the highest Information Gain or the lowest Gini Impurity.
- This creates a hierarchical tree structure where internal nodes represent feature tests, branches represent the outcomes of those tests, and terminal leaf nodes hold the final class labels.
- The process continues until a stopping criterion (like maximum depth) is met, but a single, fully-grown tree is highly susceptible to overfitting the training data.

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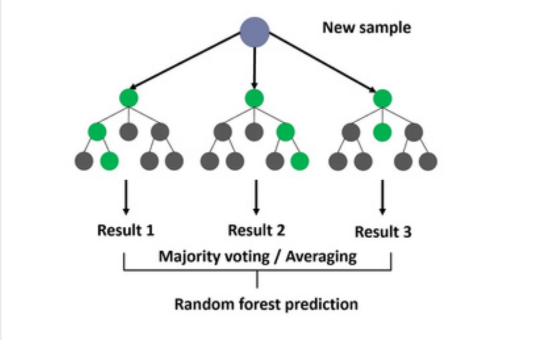
Random Forest

How a Random Forest Works

- It's an ensemble learning method utilizing Bootstrap Aggregating (Bagging) to build a multitude of unique decision trees from the training data.
- To decorrelate the trees and reduce variance, each tree is trained on a random bootstrapped sample of the data, and each split is made by considering only a random subset of the input features.
- The final output is determined by aggregating the results from all trees—by taking the mode of the predictions for classification or the mean for regression—which significantly improves accuracy and robustness over a single tree.



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	Accuracy
Logistic Regression	0.5177
Decision Tree	0.5822
Random Forest	0.5886
XGBoost	0.5891

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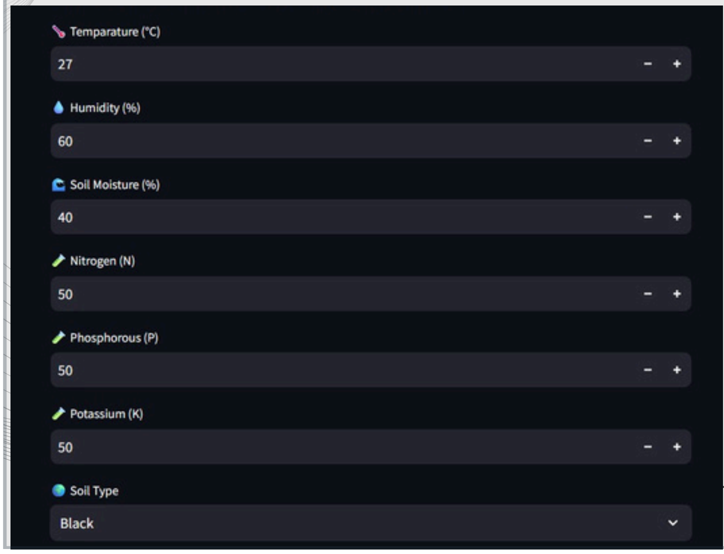
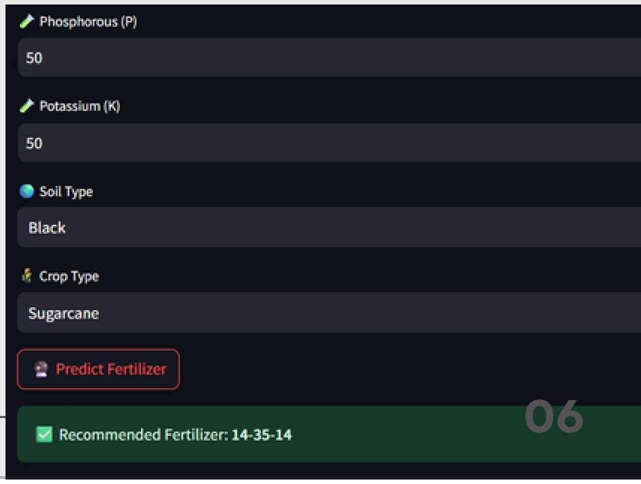
Stage 4: Actionable Recommendation (The User Interface)

The final output from the model is translated into a simple, easy-to-understand recommendation.

This recommendation will be displayed on an intuitive web-based dashboard, showing the farmer exactly what fertilizer to use, how much to apply, and where to apply it.





Results - ML Model Performance

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Saving DATASET-TRAIN.csv to DATASET-TRAIN.csv
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	Temparature	Humidity	Moisture	Soil Type	Crop Type	Nitrogen	Phosphorous	Potassium	Fertilizer Name
0	35	35	38	Black	Wheat	79	8	62	DAP
1	32	75	22	Clay	Cotton	57	82	87	20-20
2	21	55	56	Clay	Wheat	54	33	85	17-17-17
3	37	52	31	Loamy	Pulses	44	54	12	14-35-14
4	26	45	49	Black	Groundnut	50	68	45	14-35-14

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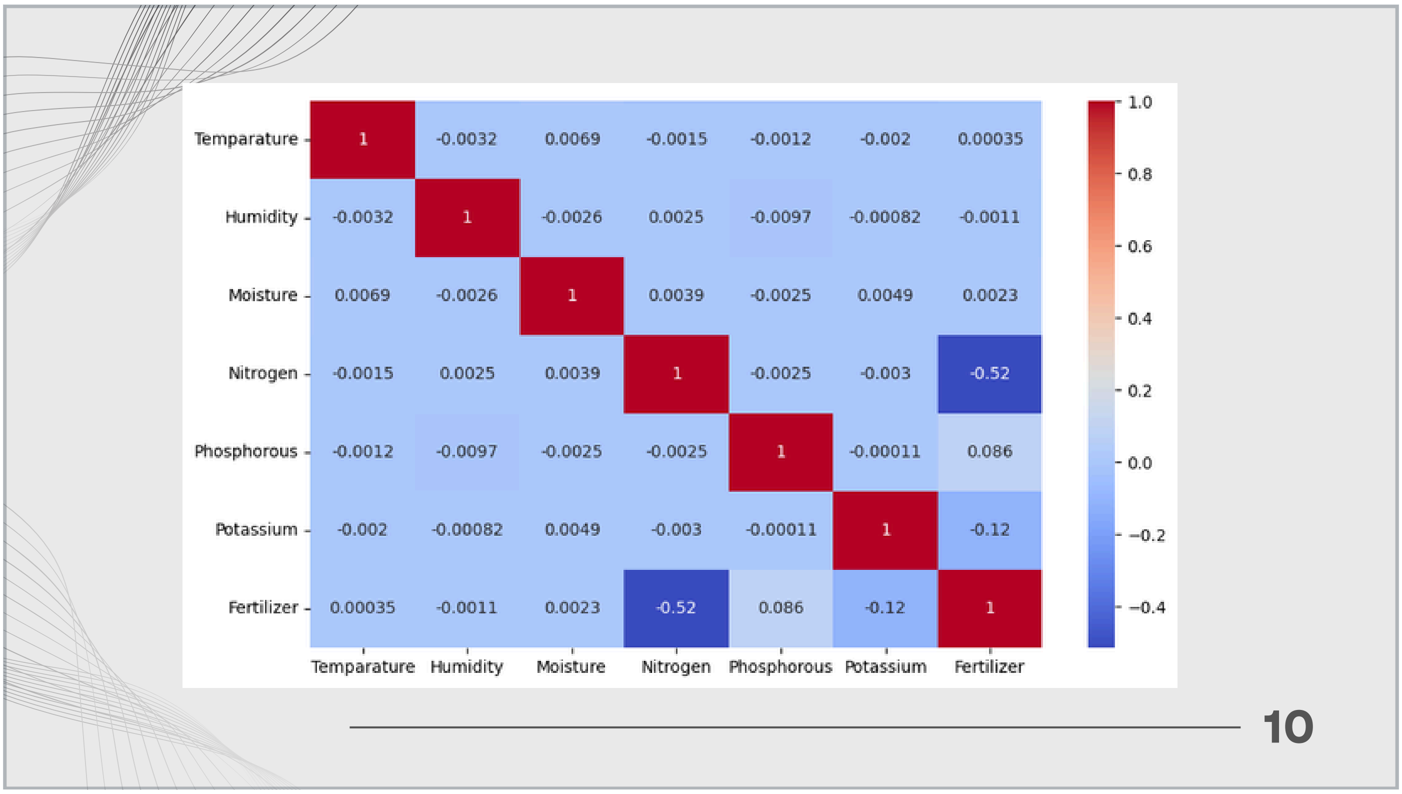
Temparature
Humidity
Moisture
Nitrogen
Phosphorous
Potassium
Fertilizer
1 -0.0032 0.0069 -0.0015 -0.0012 -0.002 0.00035
-0.0032 1 -0.0026 0.0025 -0.0097 -0.00082 -0.0011
0.0069 -0.0026 1 0.0039 -0.0025 0.0049 0.0023
-0.0015 0.0025 0.0039 1 -0.0025 -0.003 -0.52
-0.0012 -0.0097 -0.0025 -0.0025 1 -0.00011 0.086
-0.002 -0.00082 0.0049 -0.003 -0.00011 1 -0.12
0.00035 -0.0011 0.0023 -0.52 0.086 -0.12 1
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
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Conclusion

- We Have Successfully Built the "Brain" of the System: In conclusion, we have successfully developed and validated the core intelligent component of our proposed precision agriculture system—a high-accuracy machine learning model.
- The Approach is Validated: The strong performance of our model provides a clear validation of our data-driven approach. It confirms that it is entirely feasible to replace traditional guesswork with a scientific, precise, and optimized system for fertilization.
- Foundation for the Future is Laid: This model is not just a standalone achievement; it serves as the foundational engine for our entire end-to-end vision. We have proven the core concept, which makes the future integration of the UAV and the dashboard a purposeful and well-defined next step.
- Clear Path Forward: Ultimately, this project has laid the critical groundwork for a complete, functional system. We now have a clear and validated path forward to build the integrated platform that will bring the full potential of precision agriculture to life.

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Future Works & Applications

1. **Smart Irrigation Management**
How it works:
Instead of nutrient sensors, we would use thermal and multispectral cameras to detect crop water stress. The UAV would gather soil moisture and plant temperature data.
The ML Model's Job: The model would be retrained to predict the exact watering needs for different zones in the field.
Outcome: This prevents over-watering or under-watering, conserving massive amounts of water and ensuring optimal crop growth.

2. **Early Pest & Disease Detection**
How it works:
We would use high-resolution RGB and multispectral cameras. The UAV would capture detailed images of plant leaves.
The ML Model's Job: The model would become an image classification system, trained to identify the earliest visual signs of common pests and diseases (like blight or rust) before they are visible to the naked eye.
Outcome: Allows farmers to perform targeted spraying on affected areas only, drastically reducing pesticide use, saving money, and protecting the environment.

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3. **Automated Weed Detection & Management**

How it works:

Similar to pest detection, the UAV's camera would identify weeds growing between crop rows.

The ML Model's Job: The model would be trained to differentiate between crops and various types of weeds, generating a precise map of weed infestations.

Outcome: This data can be fed into smart sprayers that only apply herbicide to the weeds, protecting the main crop and minimizing chemical usage.

4. **Crop Yield Prediction**

How it works:

Throughout the growing season, the UAV would regularly monitor factors like plant height, density, and color.

The ML Model's Job: The model would be trained on this time-series data to accurately forecast the expected crop yield weeks before harvest.

Outcome: Gives farmers invaluable information for planning logistics,

References

1. N. M. Basavaraju, U. B. Mahadevaswamy and S. Mallikarjunaswamy, "Design and Implementation of Crop Yield Prediction and Fertilizer Utilization Using IoT and Machine Learning in Smart Agriculture Systems," 2024 Second International Conference on Networks, Multimedia and Information Technology (NMITCON), Bengaluru, India, 2024, pp. 1-6, doi: 10.1109/NMITCON62075.2024.10699184.
2. Apuroop et al., "Applying Machine Learning Approaches in Fertilizer Optimization and Yield Prediction for Smart Agriculture," 2025 International Conference on Automation and Computation (AUTOCOM), Dehradun, India, 2025, pp. 53-58, doi: 10.1109/AUTOCOM64127.2025.10956684.

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