Smart Crop Prediction and Fertilizer Recommendation using Machine Learning

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***Abstract*— In the era of modern agriculture, the convergence of the Internet of Things (IOT), Machine Learning (ML), and real-time data visualization technologies is revolutionizing farming practices. Our project demonstrates this transformation by employing Internet of Things (IOT) sensors such as temperature, humidity, and moisture sensors also N,P, and K values in agricultural fields. Data collected from these sensors is transmitted via NodeMCU, a low-cost open-source IOT platform, and displayed on Thing Speak-a cloud-based IOT platform. The data collected from the IOT sensors provides real-time insights into the environmental conditions of the field. This information is combined with historical data and processed through a Gaussian Naive Bayes (GNB) Machine Learning algorithm. GNB is an expert at handling multivariate data and is employed to predict crop growth patterns and yields with remarkable accuracy. Furthermore, our project integrates crop prediction and fertilizer recommendation system that takes into account soil conditions, and environmental factors. This recommendation system empowers farmers to make informed decisions about fertilizer application, reducing waste and environmental impact. The collaboration between IOT, GNB-based ML, and NodeMCU for data transmission and Thing Speak for real-time data display is at the forefront of precision agriculture. It equips farmers with the tools to monitor, analyze, and optimize farming practices in an efficient, cost-effective, and environmentally responsible manner. This project not only enhances crop productivity but also represents a pivotal step towards sustainable agriculture. Bridging the gap between traditional farming and advanced technology, it finds the way for a future where data-driven insights drive agriculture toward greater efficiency and sustainability. Precision agriculture, driven by IOT and ML, is the key to meeting the ever-growing global food demand while protecting our environment. In summary, our project serves as a prime example of how innovative technology can be implemented to create a more productive and responsible agricultural future, boosted by the integration of a kaggle dataset for crop prediction and fertilizer recommendations. The evaluation of our proposed solution further validates its effectiveness, with the GNB model exhibiting exceptional accuracy, achieving 99% accuracy in training and 96% accuracy in testing datasets.**

Keywords—NodeMCU, Thing Speak, Naïve Bayes, Soli PH Sensor , Humidity Sensor, Temperature Sensor .

I. Introduction

In traditional agriculture, the effective use of crop fertilizers stands as a big challenge. Traditional methods of fertilizer application often led to undesirable outcomes, with farmers frequently facing the problem of overuse or underuse. These results in reduced crop yields, increased production costs, and adverse environmental effects, collectively reducing the sector's sustainability and efficiency.This is due to the absence of precise, data-driven approaches for crop prediction and fertilizer management. An immediate challenge calls for an inventive remedy that effectively integrates two forefront technologies: Machine Learning (ML) methods and the Internet of Things (IOT). This innovative solution aims to predict and enhance crop selection and fertilizer usage with high precision. Within the realm of IOT, it encompasses a network comprising various objects integrated into devices, sensors, machinery, software, and human interaction via the internet, facilitating seamless communication, information exchange, and interaction, thereby bridging the gap between physical and virtual domains.

II. ReLATED WORK

A. A. Khan et al. [1] the authors have implemented a method for Providing fertilizer guidance utilizing the fusion of machine learning techniques and Internet of Things (IOT) technology.. In this paper, they used the NPK sensor as an IOT part to collect data from the field for recommendation purposes and then this data is transferred to a machine learning model for fertilizer prediction where we used a support vector machine (SVM) algorithm.

V. K. Quy et al. [2] This study offers an overview of IOT solutions and explores their integration potential within the realm of smart agriculture. To fulfill this aim, the authors delve into envisioning IOT-enabled smart agricultural ecosystems, scrutinizing their architectural components such as IOT devices, communication technologies, big data storage, and processing. Furthermore, the paper examines the applications and developmental trajectory of these ecosystems, while also shedding light on emerging trends and opportunities within IOT applications for smart agriculture. Additionally, it highlights unresolved issues and challenges associated with deploying IOT applications in this agricultural domain.

Devdatta A. Bondre, Mr. Santosh Mahagaonkar [3] The primary emphasis of the paper lies in crafting a predictive model designed to forecast crop yields for future use. It provides a concise examination of utilizing machine learning methodologies for predicting crop yield outcomes.

A.Rahman et al. [4] This paper reviews IoT technologies for advanced monitoring and control in agriculture, aiming to comprehensively evaluate smart agricultural practices. It explores IoT applications, benefits, challenges, and potential solutions within the agricultural domain. The focus is on optimizing crop yield and efficiency by leveraging existing techniques such as water and pesticide management, irrigation practices, crop monitoring, and fertilizer application.

J Madhuri and M Indiramma [5] propose an Artificial Neural Network (ANN) driven crop recommendation system that considers climatic conditions, soil type, and crop attributes. This recommendation system holds significant promise in crop planning, boasting an impressive 96% accuracy rate in predicting suitable crop types. In addition to facilitating smart irrigation and disease forecasting, the integration of IOT and machine learning is pivotal for accurately mapping soil attributes.

S.Pudumalar et al. [6] Precision agriculture employs contemporary farming methods that leverage research findings on soil characteristics, soil types, and crop yield data to recommend suitable crops based on specific site conditions. This approach minimizes the risk of selecting inappropriate crops and enhances overall productivity.

Ravesa Akhter et al.[7] The IoT-enabled system integrates wireless sensors to monitor crop conditions, analyzed via a web app using data mining. Mobile app notifies farmers about soil moisture, and recommends watering, based on optimal conditions like 29–30°C temperature and 72–81% humidity for high yields. This dynamic approach ensures crops receive tailored care, fostering increased productivity and quality in agriculture.

S.Sundaresan et al.[8] IoT and machine learning unite to curtail annual crop losses, notably in India surpassing $11 billion, through a comprehensive system integrating crop selection, autonomous watering, and fertilizer recommendations. The paper highlights successful simulations of crop recommendation, automatic irrigation, and fertilizer suggestion systems, underscoring their potential to mitigate losses caused by adverse atmospheric conditions.

Aman Kumar Dewangan et al.[9] IoT and cloud tech are vital for improving agriculture amidst growing demand. AI enhances data-driven decisions, utilizing public datasets for crop optimization. Precision farming, with soil and seed analysis, is empowered by blockchain for efficient distribution. Streamlined IoT solutions offer monitoring and analytical capabilities, aiding logistics and productivity.

III. PROPOSED SYSTEM

The proposed system consists of two interconnected components: an Internet of Things (IOT) sensor network for continuous data collection and a Machine Learning (ML) application for precise crop prediction and fertilizer recommendations in agriculture. Utilizing sensors installed across fields, the IOT segment monitors critical elements such as soil moisture, nutrient status, and meteorological parameters. This information is then relayed to a central hub, where it merges with weather predictions and soil analysis results, culminating in a comprehensive dataset. The ML application, designed for user accessibility, forms the core of the system. Farmers can input specific details such as N, P, K values, and IOT sensor data. Utilizing historical data and advanced ML algorithms, the application generates tailored crop and fertilizer recommendations. The ultimate aim of this proposed system is to revolutionize crop prediction and fertilizer management in agriculture. By bridging the gap between IOT technology and ML-driven decision support, it provides an integrated approach to optimize fertilizer usage and to help to plant the right crop in the farm. This innovation enhances crop yields, reduces costs, and fosters sustainable agricultural practices, addressing critical global challenges.

A. *Internet of Things for Crop Prediction and Fertilizer Recommendation*

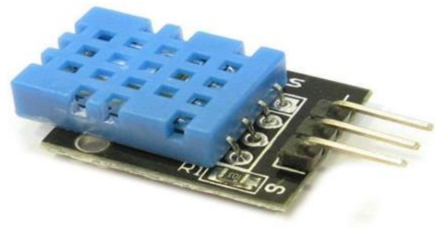

Fig 1. DHT11 (Temperature & Humidity Sensor)

The DHT11 sensor, known for its affordability, is widely employed to gauge temperature and humidity levels. Deployed in crop fields, the DHT11 aids in monitoring environmental conditions crucial for crop growth, particularly temperature and humidity. This gathered data plays a vital role in evaluating the microclimate suitability for various crops, thereby aiding in informed decision-making regarding crop cultivation.

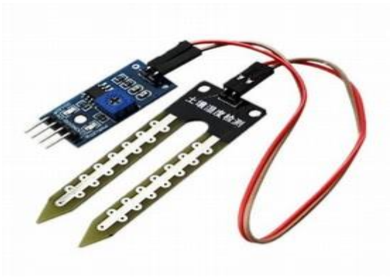

Fig 2. Soil moisture sensor

A moisture sensor is a tool utilized to gauge the moisture levels in a substance, commonly soil or air. It functions by detecting alterations in electrical conductivity or capacitance triggered by moisture fluctuations. Typically comprising two electrodes, the sensor measures the resistance or capacitance between them. As moisture content increases, resistance decreases or capacitance rises.

B. *Machine Learning Model for Crop Prediction and Fertilizer Recommendation*

1. Data Input

This block is responsible for acquiring the dataset from Kaggle. The dataset likely contains historical agricultural data, including information about Environmental conditions, Soil pH and Soil nutrients. Data from this block is sent to the next block for crop prediction processing.

2. Crop Prediction

In this block, the dataset is used to train a machine-learning model for crop prediction. This model is based on Gaussian Naive Bayes (GNB) algorithm. Crop prediction involves using historical data to predict the most likely crop that will thrive in specific environmental conditions. The predicted crop information is then passed to the next block for further processing.

3. Data Preprocessing

Before the data can be used for model training, it must be preprocessed. Preprocessing can involve tasks like data cleaning, handling missing values, and scaling features. Feature extraction may also occur in this block, where relevant features from the dataset are selected for training the model.

3. Model Training

In this block, the preprocessed data is used to train the machine learning model. The use of Gaussian Naive Bayes (GNB), which is particularly effective for multivariate data. During training, the model learns the relationships between environmental factors and crop outcomes.

GNB (Gaussian Naïve Bayes)

The Naïve Bayes algorithm, a supervised learning method, relies on the Bayes theorem to address classification tasks, particularly suited for high-dimensional datasets such as text classification. Renowned for its simplicity and effectiveness, the Naïve Bayes Classifier facilitates the rapid development of machine learning models capable of swift predictions. Operating as a probabilistic classifier, it derives predictions from object probabilities. Its primary advantage lies in its simplicity and potency, offering a straightforward implementation and quick real-time predictions. Consequently, it stands as a preferred choice for solving real-world problems, adept at responding promptly to user queries.

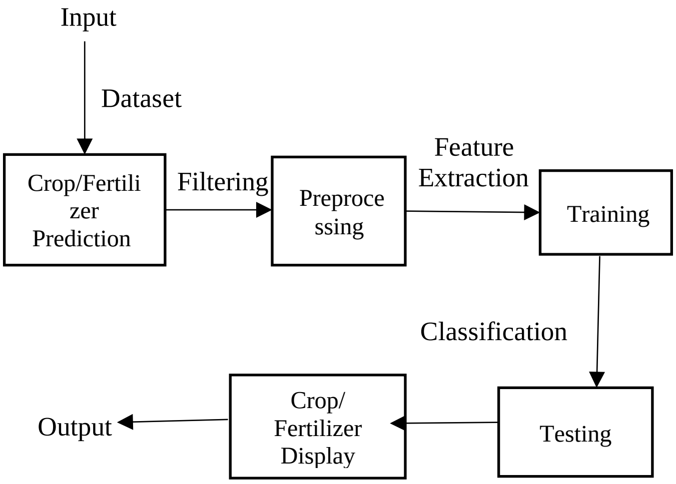

Fig 3. GNB Working Flow

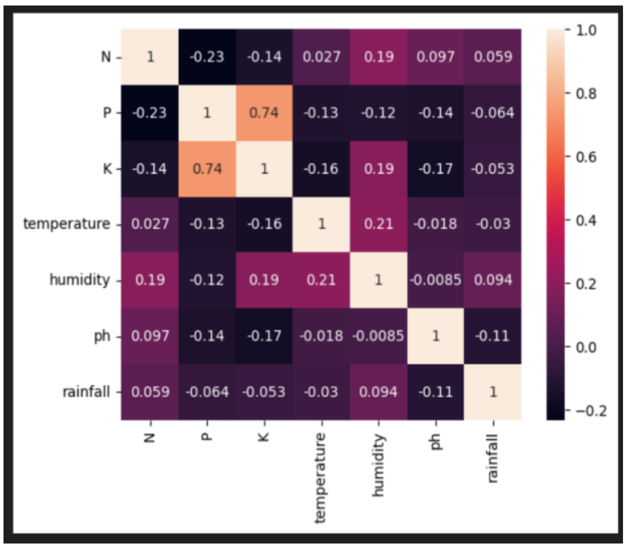

Fig 4. Confusion matrix of GNB Algorithm

In the context of crop classification and fertilizer recommendation, we have three classes of crops: Class K (e.g., crops that require high levels of potassium), Class N (e.g., crops that require high levels of nitrogen), and Class P (e.g., crops that require high levels of phosphorus). We'll also consider the following environmental variables: rainfall, pH level, humidity, and temperature.

IV. METHODOLOGY

1. Data Collection Using IOT Sensors.
2. NodeMCU Data Transmission.
3. Data Storage and Visualization with Thing Speak.
4. Data Preprocessing.
5. Integration with GNB Algorithm.
6. Crop Prediction.
7. Fertilizer Recommendation.
8. User Interface for Farmers.

Bayes theorem is a formula that offers a conditional probability of an event A taking happening given another event B has previously happened. Its mathematical formula is as follows

$$P(A|B) = \frac{P(B|A).P(A)}{P(B)}$$

Where,

- A and B are two events
- P(A|B) is the probability of event A provided event B has already happened.
- P(B|A) is the probability of event B provided event A has already happened.
- P(A) is the independent probability of A
- P(B) is the independent probability of B

Now, this Bayes theorem can be used to generate the following classification model –

$$P(y|X) = \frac{P(X|y).P(X)}{P(y)}$$

Where

- X = x1,x2,x3,.. xN are list of independent predictors
- y is the class label
- P(y|X) is the probability of label y given the predictors X

The above equation may be extended as follows:

$$P(y|x1, x2, x3..xN) = \frac{P(x1|y).P(x2|y).P(x3|y)\ldots P(xN|y).P(y)}{P(x1).P(x2).P(x3)\ldots P(xN)}$$

V. SYSTEM ARCHITECTURE

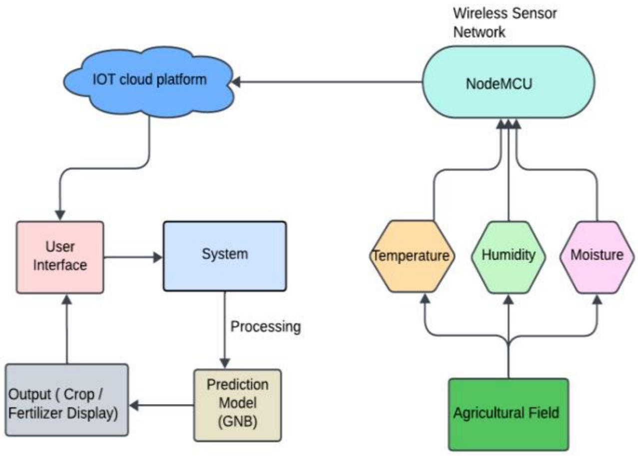

Fig 5. Architecture Diagram of Fertilizer Recommendation and Crop Prediction System

This fertilizer recommendation and crop prediction system combines sensor technology with machine learning to empower farmers. A network of wireless sensors collects data like temperature, humidity, and moisture from the field. This data is then transmitted to the cloud via an open-source IOT platform. By analyzing this data using a machine learning model, the system can predict optimal crop yields and recommend the most suitable fertilizer for specific conditions. This information is then presented to the user through a user interface, enabling farmers to make informed decisions for better agricultural outcomes.

VI . RESULTS

A crop prediction and fertilizer recommendation system based on IOT (Internet of Things) and ML (Machine Learning) provides real-time, data-driven guidance for applying the right type of crops and amount of fertilizer to crops. It optimizes fertilization by considering soil conditions, weather data, crop type, and environmental factors. The result increased crop yields, reduced fertilizer waste, and improved resource efficiency.

A. Datasets

Dig into our Kaggle dataset tailored for crop prediction and fertilizer recommendations using cutting-edge machine learning algorithms. Gain granular insights into optimal planting times, crop varieties, and nutrient requirements for your specific soil and climate conditions. Revolutionize your farming strategy with personalized recommendations, maximizing yields while minimizing environmental impact.

B. Outcomes

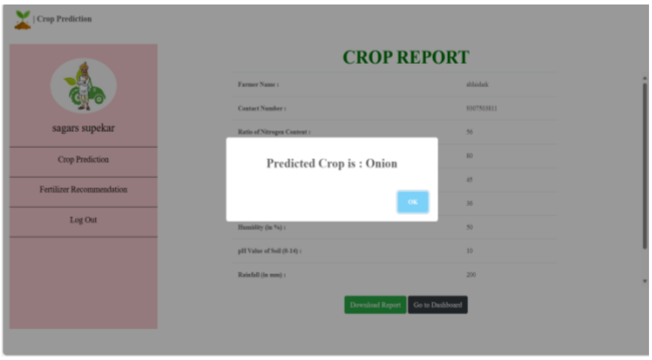

Fig 6. crop prediction based on different environmental factors

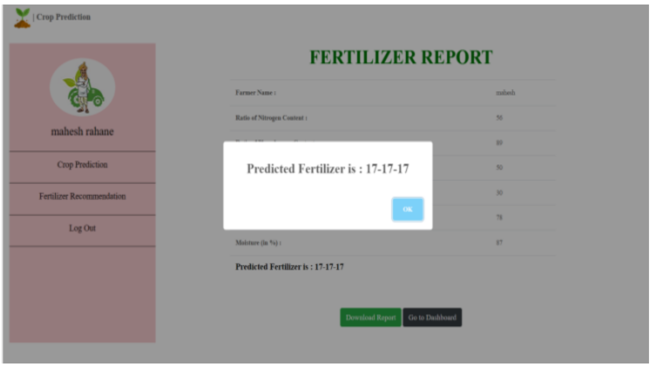

Fig 7. Fertilizer recommendation based on different environmental factors

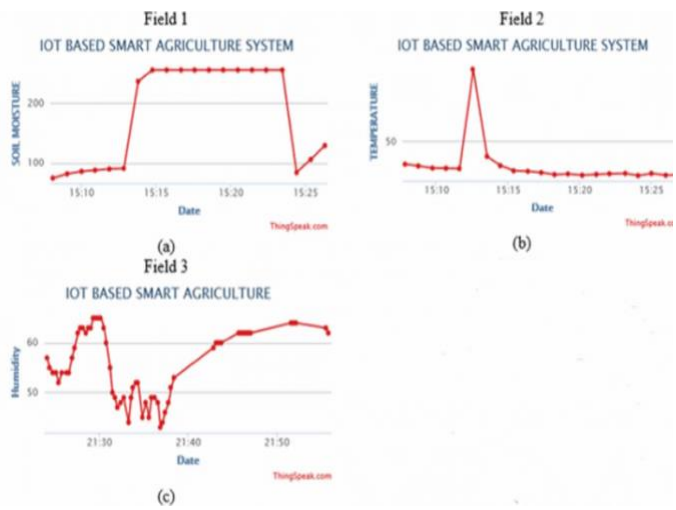

Fig 8. Thing Speak dashboard sensor readings

C. Performace Evaluation

No. of Sample Inputs	Applied Algorithm			
	Proposed Method	Existing Methods		
	GNB	RF	SVM	KNN
	Accuracy (Percentage)			
10 - 100	99%	95%	95%	90%
101 - 400	98%	91%	90%	87%
401 - 1100	96%	85%	87%	83%
1101 - 2200	93%	80%	85%	80%
Average Accuracy	97 %	88%	90%	85%

Table 1. Algorithm Performance Comparison

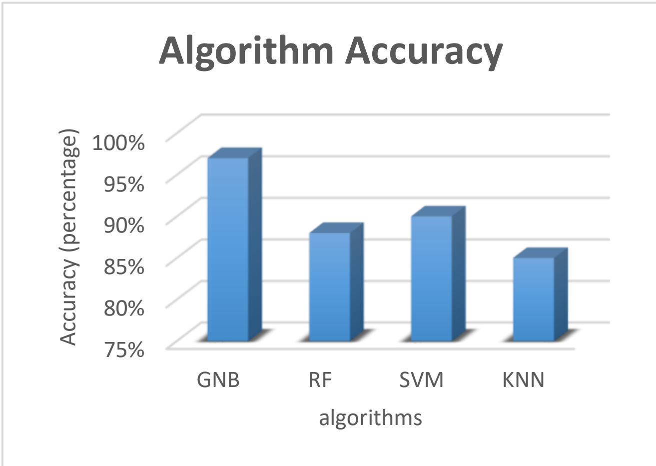

Fig 9. Algorithm Performance Comparison

VII . CONCLUSION

In conclusion, our project on "Smart prediction of crop and fertilizer recommendation using GNB Algorithm, IOT Sensors, NodeMCU, and Thing Speak" represents a significant leap forward in the jump of sustainable and efficient farming practices. By seamlessly integrating IOT sensors, the GNB machine learning algorithm, NodeMCU for data transmission, and Thing Speak for real-time data display, we have provided farmers with a powerful toolkit for informed decision-making. This toolkit not only enhances crop productivity but also significantly reduces resource wastage and minimizes the environmental impact associated with excessive fertilizer use. The project's fusion of data collection, analysis, and visualization technologies reflects a harmonious blend of tradition and innovation in agriculture. It points the way towards a future where data-driven insights empower farmers to optimize their practices, ultimately meeting the growing global food demand while safeguarding our environment. In essence, precision agriculture, as exemplified by our project, underscores the importance of responsible and efficient farming. It showcases how the collaboration of IOT and ML technologies can transform the agricultural landscape, making it more sustainable, productive, and environmentally conscious. As we move forward, this project provides a compelling vision of the role technology can play in shaping the future of agriculture.

VIII. FUTURE SCOPE

- Enhance the system to be scalable and adaptable to different agricultural settings and regions, considering variations in climate, soil types, and crop varieties.
- Implementation of automated irrigation systems and drone technology for precise and targeted application of fertilizers and pesticides, further optimizing resource usage.
- Expansion of machine learning algorithms to incorporate deep learning models for more intricate analysis and prediction of crop growth patterns.
- Embracing sustainable farming practices such as regenerative agriculture and agroforestry, leveraging IoT and ML technologies to promote biodiversity and ecosystem resilience while maximizing agricultural productivity.

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