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AI and NLP For Sustainable Food Security

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Abstract:

Agriculture is an important sector of sustaining food security, nevertheless, there are instances when farmers experience problem face issues in making decisions because they do not have access to technology and expert advice. The project will offer an intelligent agricultural advisory system on the basis of Artificial Intelligence (AI) and Natural Language Processing (NLP) methods that will assist the farmers in a straightforward and effective manner. The application will offer a platform on which users can chat using a multilingual chatbot, which will benefit users who have low technical expertise. This app gathers environmental information including soil type, temperature/rainfall and location and will apply a Random Forest algorithm to determine crop yield and health. With such information the application will be capable of providing recommendations based on the choice of the language used by the user. Offline functionality will also be made possible by the system since it will have the local data sets that can be accessed offline. This is necessary so as to allow the system to operate even in regions where the connectivity is poor or non-existent. It is estimated that, based on predictive analysis, communication, and personalization, the suggested system will enhance decision-making, productivity and sustainable agriculture and food security.

Keywords:

Agricultural data analysis, Crop Yield Prediction, Multilingual Chatbot, Precision Framing, Sustainable Agriculture, Smart farming.

Introduction:

Agriculture plays a critical role [5] in providing a foundation that is critical to the existence of the human population. This is because of the contribution of agriculture in food production and economic stability. The economic livelihoods of a country and the world in general depend on agriculture as a key factor in food production. In India, agriculture is a source of livelihood to a massive population. Other than food production, agriculture plays a very crucial role in the development and growth of industry and economy.

Although agriculture is significant, it is faced with numerous challenges. Among the challenges that farmers are facing [3], [4], there are alterations in the weather and rainfall pattern, the quality of the soil, pest, and climate changes. All these have rendered the life of farmers unpredictable. It has resulted in a risky condition of crop loss. Additionally, the farmers may not be in possession of the required technology, information, and guidance. Thus, the farmers might be left to make their own decisions based on traditional practices and their experiences on their crops, irrigation facilities, fertilizer, and pest control mechanisms, etc. Although the traditional methods may help

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the farmers in taking decisions regarding their crops and the above-mentioned areas, the methods may not prove to be helpful in dealing with the challenges faced by the farmers.

Lack of information [1] is one more large issue in agriculture. This information could be environmental conditions and crop related. This information is very vital for the farmers, as they will be in a position to make the right decisions. The difficulty however lies in accessing this information. This is a challenge that is mostly felt by the rural farmers as they are not digitally equipped. Secondly, this challenge is also attributed to the fact that the farmers do not use the English language, but instead prefer to use their own language. These problems can result in the reduction of the crop production, loss of the economy and uncertainty in agriculture. On the other hand, the increase in population results in a high demand for food products.

This is one more aspect of agricultural productivity. Therefore, there is need to come up with intelligent and easy to use systems that will help farmers make the right decisions regarding their farming business. Recently, new technologies have been produced to address this issue. Artificial Intelligence (AI) helps to make correct decisions [4], [9] according to analysed data on such parameters as soil, temperature, rainfall, and crop history. Precise predictions of crop yield and crop condition can be done by use of machine learning algorithms like the random forest [11]. Natural Language Processing (NLP) is another technology that makes it simple to communicate either through text or voice [6], [7]. It is possible to communicate in a non-monolingual way with the help of NLP. This will enable the farmer to express himself or herself using the language that allows them to make sense.

The technologies render the farming solution more efficient and convenient to the farmer. They aid in the reduction of the traditional practices since they give the correct information. The given solution is credible and efficient. But the majority of these systems rely on either prediction or communication [2] but not both. In order to address this issue, it is suggested that a unified platform be developed, which can incorporate AI and NLP to use in agriculture. It will allow farmers to interact with a chatbot, collect environmental data, and provide personal recommendations in a manner easily comprehensible.

This will be capable of working with and without the internet. This will render it appropriate to use in the rural areas too. It will also be user-friendly in the sense that even farmers who are not so techno savvy can use it without difficulties. The reason behind this is that it will not involve special knowledge or training. This will be of great assistance to most farmers as they will be able to make good decisions, become productive and encourage sustainable farming. This will enable farmers to undertake relevant measures in order to counter changes. This will be extremely useful in making the modern technology more accessible, practical and useful in the day to day.

2. Proposed System:

The suggested system has the benefits of a smart and built-in solution to the implementation of Artificial Intelligence (AI) and Natural Language Processing (NLP) [1], [6], which can be applied to promote sustainable farming and increase food security. The current agricultural systems do not have the incorporation of the analysis and communication with farmers. The proposed system comes in to close this gap by combining the two concepts.

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The proposed system does not only assist in processing of agricultural data and producing useful ideas, but it also has the merit of displaying the produced ideas in a simple and easy to comprehend format.

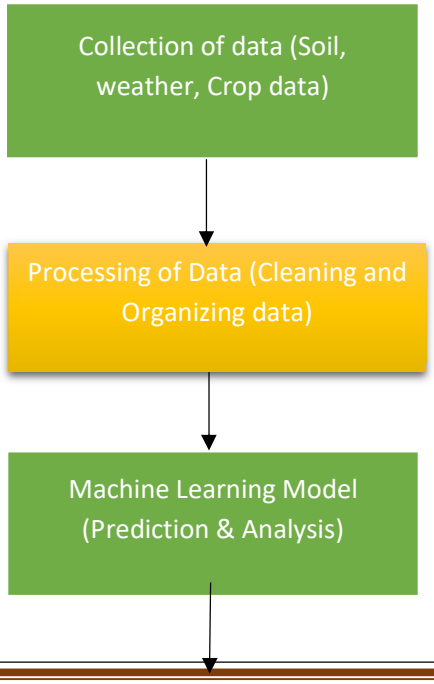
The system is farmer-centric, and one of its aims is to make it easy to use, accessible, and helpful in real-time. It collects vital information such as weather conditions and soil information. It then compares the information with machine learning, i.e., predicts the yield of the crops [3], [4], [17], the nature of the crops that could be grown or the risks involved. It then outlines the information in terms of straightforward recommendations which can easily be comprehensible by the farmers. The system includes the information in the form of a chatbot, which allows the farmers to communicate with the system through a conversation. The system allows the farmers to make optimum decisions using the information given without technical expertise. It does not only assist the farmers in their activities but also assists in decreasing confusion and encouraging the use of sustainable practices.

2.1 The Process of the Proposed System.

The suggested system contains a systematic step-by-step process to convert raw agricultural information into suggestions to the farmer. The system flow helps to establish the connection between every step of the process. This implies that the output of one step is the input of the other step.

Firstly, the system gathers raw information such as soil composition, weather and crop data. This raw data is then refined so as to eliminate any errors. After this processing, machine learning algorithms are used to predict based on the data and determine the kind of crops to be planted, yield of crops, and potential risks. After this prediction [4], [11], it is then changed into a recommendation. Lastly, the recommendations are forwarded to the farmer as a chatbot.

This flow makes the system run effectively between data collection and final output therefore making it user friendly and effective in decision making.



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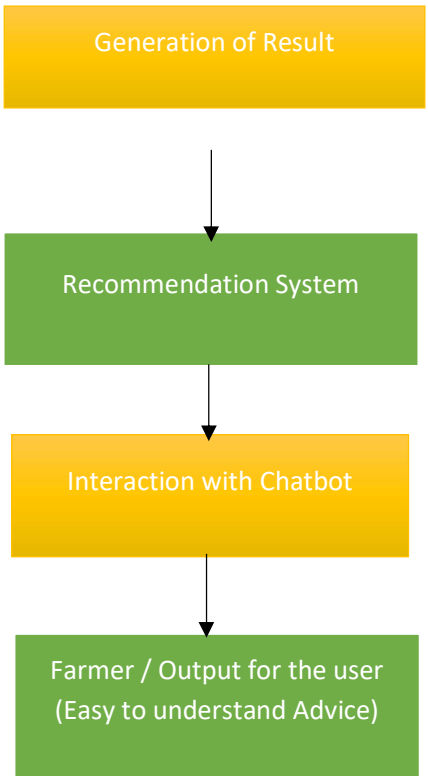

Fig 2.1. The Flow of the Proposed system

The flowchart in Fig. 2.1 clearly shows the whole process of the system operation, from data gathering to data analysis through machine learning techniques. The obtained output is then made understandable in the form of advice, which helps in better decision-making. Lastly, the interaction with the chatbot guarantees that the advice provided to farmers is easily comprehensible.

2.2 System Architecture

The offered system is supported by the layered architecture, according to which each of the components is supposed to perform a single task, but all the components are connected to one another so that they could deliver the correct predictions and appropriate recommendations. The proposed system is designed in a manner that it supports the efficient flow of information between input collection and output delivery. All the parts of the proposed system are discussed below**.**

2.2.1 External Data Sources

This is where the raw data is provided to enable the system to run. It is made up of different data sources which include weather, satellite data, government data on agriculture and IoT devices among others. This information comprises of real time data and historical data including temperature, rain, soil, and crops among others. This information is assumed to be the raw information to be processed further by the system.

2.2.2 Data Collection Layer

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The data collection layer gathers data of all external sources and provides it in a useful format. It ensures that the information that is obtained in different sources is well integrated. This stratum is of importance in ensuring the consistency and correctness of the input data.

2.2.3 Data Preprocessing Layer

Data preprocessing is performed on the received data. It is necessary to remember that data might contain errors, have insufficient size or can be biased in some way. For this reason, data preprocessing includes three stages - data cleaning, data normalization, and data selection.

2.2.4 AI-Based Prediction Module

This module is the core part of the system. The processed data is analyzed by means of machine learning algorithms like the Random Forest and regression models [11],[13]. According to the analysis, it forecasts yield of the crop, crops to be cultivated and possibility of drought or attack of pests to the crops.

2.2.5 Recommendation Engine

The recommendation engine processes the outcome of prediction and gives viable recommendations. It does not provide complicated numerical findings, but gives simple advice to the users. It also instructs them on what to plant, how much water to apply, how to apply the fertilizers.

2.2.6 NLP Chatbot Module

The chatbot module allows the users to communicate with the system. It is able to interpret user queries [6], [8], and give a response to them. This does away with the technical knowledge thus making the system easy to use.

2.2.7 Multilingual System

Multi lingual system [2] is a feature of a chatbot that enables the chatbot to communicate in different language. It is a system of translation that also provides the option of voice communication where the chatbot can be used by farmers of various regions and languages.

2.2.8 User Interface Layer

The user interface refers to the front-end of the system. This is the element of the system to which the farmer is in contact. Its user interface is made easy to use. It has functions like text input, voice input, display output and could be carried anywhere. This makes sure that even an illiterate farmer would be able to use the system.

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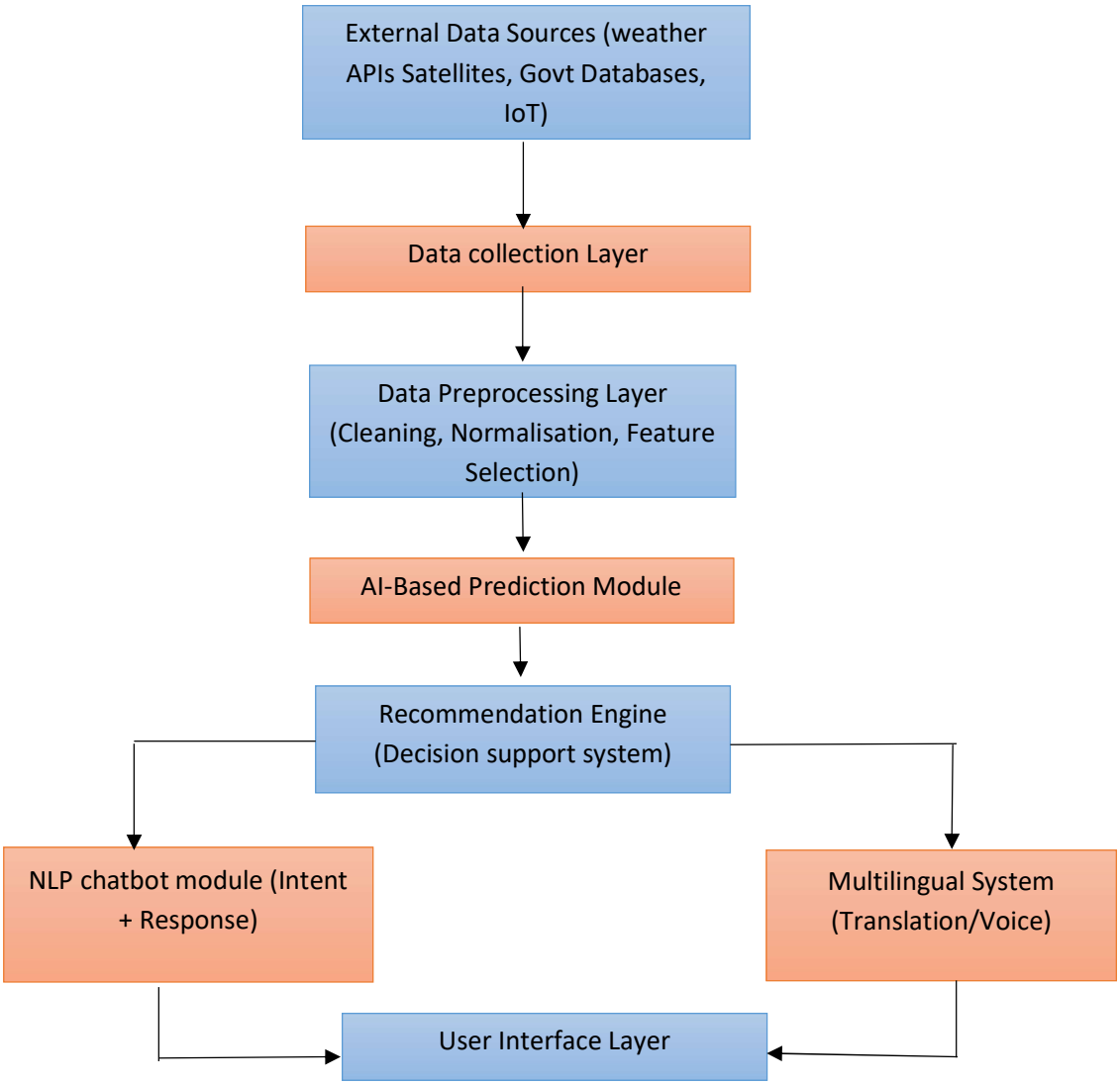

Fig 2.2. System Architecture

In Fig. 2.2, the architecture of the system demonstrates a sequential workflow process from data gathering to user engagement. Data gathered are analyzed by applying machine learning models to provide precise predictions and suggestions. This data is subsequently communicated via a natural language processing-based chatbot and multilingual interface to make the system convenient and user-friendly.

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2.3 Major Features of the Proposed System.

These are some of the key characteristics of the proposed system, and they render it applicable in the real-world farming. It combines Artificial Intelligence and Natural Language Processing into a single system, allowing prediction and communication to exist together and collaborate with each other. It makes use of real-time data that are actual like weather and soil so as to ensure that the system gives accurate results. It is easy to use and this is one of its strengths and users can interact with it without any technical knowledge being needed. The chatbot is a characteristic of natural communication and it is also offered in different languages to access farmers of different regions. It is a scalable system and one can add more to it in future.

2.4 The Proposed System has the following advantages.

• Data-driven and precise recommendations.

• Assists in making improved decisions.

• User friendly, even non-technical users.

• Has multiple languages to enhance accessibility.

• Eliminates the necessity to refer to agricultural specialists.

• Enhances crop production and productivity.

• Live support in the form of a chatbot.

3. Experimental Setup

The test system that was proposed was implanted and tested with a combination of software and data to validate that the system works. This was implemented with the help of Python programming Language that is said to be good in supporting machine learning and data processing. Data handling involved libraries like NumPy and Pandas and Scikit-learn [11], [12], [13] was used to create machine learning models in order to predict crops. The data sets utilized to support agriculture such as information on soil properties [5], weather conditions and crop yields were accessed both on the internet and on government websites.

The data was cleaned and preprocessed before training. The data was separated into training and testing data in order to test the prediction model performance. In the case of the chatbot module, Natural Language Processing methods were used through the deployment of basic NLP libraries [6], [8]. A chatbot has been created to comprehend the queries of the user, to determine intent and to give appropriate answers based on the results of the prediction.

The support in a multilingual version was provided with the help of translation tools. The system was also tested on an ordinary computer having medium level specifications i.e. at least 8 GB RAM, and on a stable internet connection to fetch the weather data immediately. The accuracy of the predictions and the quality of the chatbot

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replies were the basis of the performance of the system. From the results, it was clear that the system was able to provide accurate predictions and suggestions in user-friendly way.

4.Results

The system in this paper has been tested on the basis of prediction of agricultural performance and farmers support, and the aspects of the system that are being considered are intelligence and natural language conversational features. The paper evaluates the accuracy of machine learning predictive models and the applicability of the systems. Based on the collected data, it can be observed that AI and NLP systems integration leads to increased predictive accuracy and usability. Machine learning models are already widely applied in the agricultural industry to analyze different variables, including temperature, rainfall, soil, and many others that are of great significance to crop forecasting. This gives us the assurance of using the same in the current system.

4.1 Dataset Overview

The dataset used to analyze the performance of the proposed system is noteworthy before evaluating it. The data employed is associated with the agricultural parameters such as nutrients in the soil and the weather conditions. The sample of the dataset is presented in Table 1.

Table 4.1: Soil and Weather-Based Crop Prediction Dataset

N(Nitrogen)	P(Phosphorus)	K(Potassium)	Temperature (Celsius)	Rainfall (mm)	Crop
90	42	43	26	200	Rice
85	58	41	28	150	Wheat
60	55	44	30	100	Maize
74	35	40	25	220	Rice
78	50	45	27	180	Wheat
69	48	38	29	90	Maize

A sample representation of the data that was used in training the crop prediction model is indicated in the table 4.1. The parameters that are represented in the table are the required nutrients that should be incorporated into the soil, such as nitrogen (N), phosphorus (P), and potassium (K). Moreover, the table contains such environmental parameters as temperature and rainfall. The parameters are critical in predicting the optimum crop to be planted in a given environment. The dataset is useful to the prediction model because it incorporates both soil parameters and environmental parameters. The prediction model is useful with the changing values of the parameters in the table. The real data however are employed in the effective training of the prediction model.

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4.2 The performance of the prediction model is summarized as follows:

The agricultural data sets that have been used to train the prediction model include data on the soil nutrients, weather conditions and crops. The data set has been divided into training and testing data set in order to test the model adequately. The prediction model has equally succeeded in predicting the crop yields and the crops to be grown appropriately [3], [4], [18]. Complex identifications have succeeded in sophisticated algorithms such as the Random forest. Accuracy in relationships between features according to research, machine learning models can be accurate, to the extent of 97% or more [4].

Table 4.2: Performance Metrics

Metrics	Value
Accuracy	85% - 90%
MAE	Low
Prediction Stability	High

The table 4.2 presents a simple and easy way of presenting the overall performance of prediction model. Based on the table, it is possible to note that the system is rather accurate, which means that the predictions are credible and can be applied to the real world. Additionally, the small value of the error indicates that the model is generating less errors as it generates results. Further, the high stability level implies that the system works in a consistent manner even with the provision of different inputs.

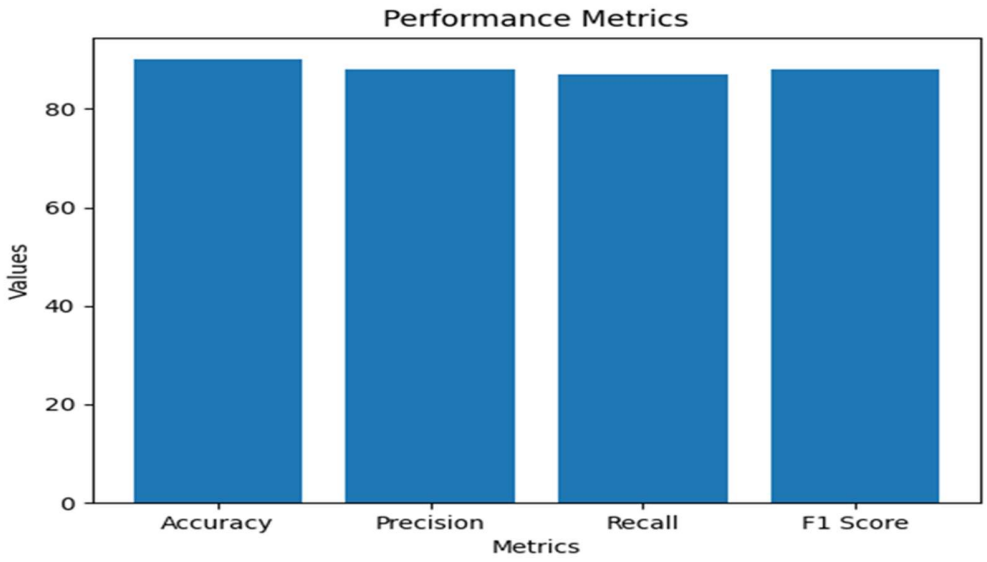

Fig 4.1. Performance metrics Graph

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The Fig 4.1 will provide a clear idea of the performance of the model in terms of all the evaluation parameters such as accuracy, precision, and error. This will assist in comparing the weakness and the strength of the model in a simpler way. Fewer errors and greater accuracy means that the model is giving reliable predictions. The consistency of the model will also be easier to understand with the help of this graph.

4.3 Model Accuracy in Graphical Representation.

Graphical method can be used in understanding the performance of the model better.

Explanation:

The graph indicates the accuracy increases with the training iterations. It denotes that patterns of learning are effective in the model and that they stabilize with time.

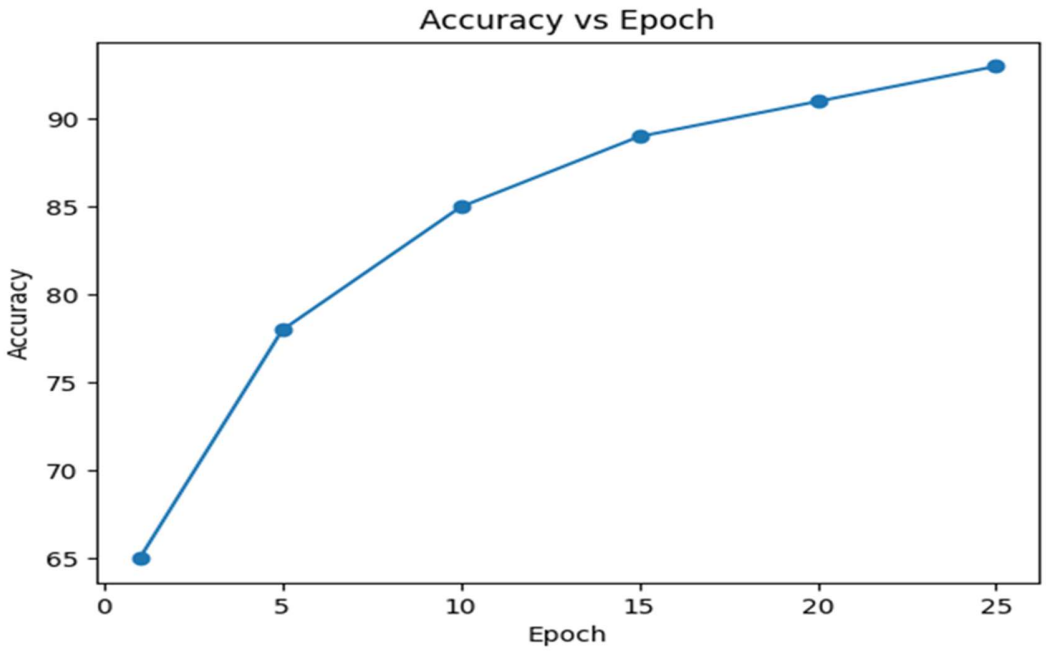

Fig 4.2. Accuracy Vs Epoch Graph

The Fig 4.2 demonstrates the improvement in the performance of the model. In the early stages, the accuracy increases at a fast rate as the model is starting to learn. But the more the epochs the lower the rate at which the accuracy increases. This means that the model is taking shape. A flowing curve shows that the model is learning well. The graph shows that the model is well trained.

4.4 Effect of Preprocessing of Data.

The processing of data enhanced the system. The raw data were originally missing and erroneous.

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Table 4.3: Preprocessing Impact

Parameter	Before	After
Accuracy	Moderate	High
Error Rate	High	Reduced
Data Quality	Poor	Improved

Based on the table 4.3, it is clear that the performance of the system as a whole is improved by the data preprocessing [9], [10]. The data was not processed and had flaws prior to the preprocessing, and this influenced the accuracy of the predictions. Nevertheless, once the data was cleaned and normalized, the data was well organized and correct and the model was precise and correct in its predictions.

4.5 Error Analysis

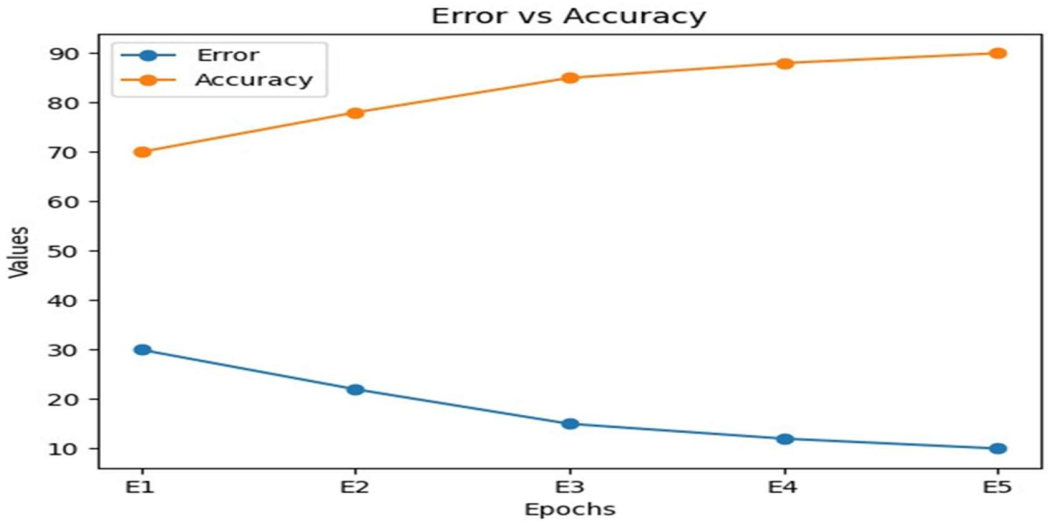

Fig 4.3. Error Vs Accuracy Graph

The fig 4.3 shows correlation between error and accuracy in course of training. The error rate reduces with time as the model learns more about the data. The accuracy increases with time. This implies that the model is getting better at making correct predictions. The smooth trend of the above graph also shows that the process of learning is uniform. Based on the results of the above, it has been established that the model can learn the data.

4.6 Chatbot Performance Evaluation

Tested under different user inputs. The chatbot interprets [6] a query and generates a reasonable response.

Table 4.4: Chatbot Evaluation

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Parameter	Result
Response Accuracy	High
Response Time	Fast
User Understanding	Easy

The effectiveness of the chatbot to respond to the interaction of the user is shown in the table 4.4. As seen in the table 4.4, the chatbot provides correct information within a brief period, thus the system is fast and effective. The user will have the ability of comprehending the information provided, and the system will be more user-friendly particularly to those users who lack technical knowledge.

4.7 Multilingual Feature Evaluation

The multilingual communication aspect will provide the farmers or the users in the different regions to use the system comfortably.

Table 4.5: Multilingual Results

Features	Results
Translation Accuracy	Good
Language Support	Multiple
Accessibility	High

The table 4.5 shows how the multilingual characteristic has enhanced the usability of the system. The characteristic makes the system to support various languages, and offer understandable translation, therefore, opening a possibility of a user in one part of the world to communicate with another one with ease. The system is more inclusive and the farmer can easily understand the presented information.

4.8 User Interaction Analysis

The usability of the system was also tested in order to gauge how easy it is to use.

Table 4.6: Usability Results

Parameter	Observation
Ease of Use	High
Navigation	Simple
Learning Curve	Low

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As seen in Table 4.6, it can be seen that a lot of attention has been paid to the aspect of usability in designing this system. The ease of use of the system suggests that the system will be easy for the users to operate without having to strain too much technically.

4.9 Comparative Analysis

Table 4.7: Comparison

Feature	Existing	Proposed
Prediction	Yes	Yes
Chatbot	Limited	Integrated
Multilingual	Rare	Available
Ease of Use	Medium	High

Table 4.7 provides a clearer picture about this contrast between the current system and the proposed system. The important thing that needs to be noted here is that there are certain prediction features common to both the systems. The distinctive characteristics of the proposed system can be described as chatbot capability and multilingual capabilities. From the above discussion, we may safely draw a conclusion.

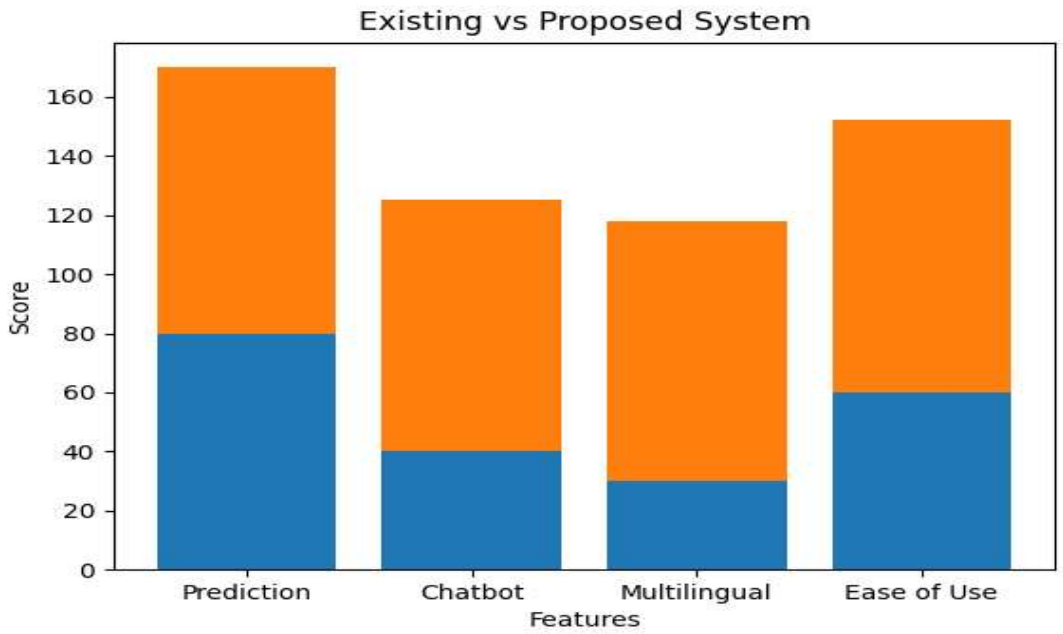

Fig 4.4. Existing Vs Proposed System Graph

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Based on Fig 4.4, it is quite evident that the performance of the proposed system is superior to the present system. This system not only boasts of high precision but also quick responses and a better user interface. The inclusion of additional features such as chatbot conversation and multi-language capability makes it even more convenient for the users.

4.10 System Efficiency

Table 4.8: Efficiency

Parameter	Result
Prediction Time	Fast
Response Time	Real-Time
Load Handling	Efficient

The table 4.8, demonstrates the efficiency of the system based on the parameters of efficiency. Based on the table, it is evident that the prediction process is expedited, and this enables the user to get the results in real time. In addition, the system response time is real time and as a result, the user can interact with the system in real time. Moreover, the system is also capable of effectively managing the workload of the system and this makes the system reliable regardless of the number of people interacting with the system at a particular time.

4.11 User Satisfaction Analysis

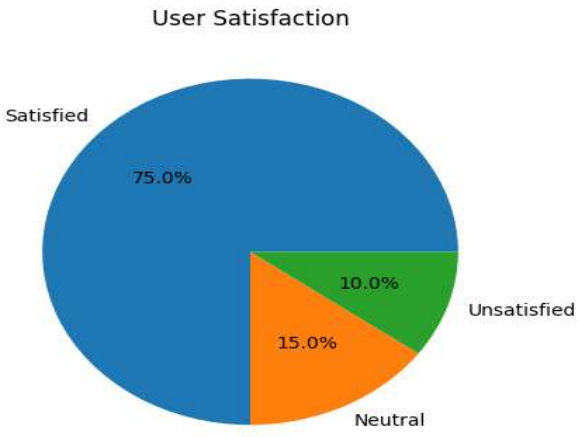

Fig 4.5. User Satisfaction Pie Chart

The Fig 4.5 provided below represents the satisfaction level of users using the system. From the pie graph provided above, it is clear that most users are satisfied with the system because of its efficiency. Nonetheless,

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based on the above pie chart, one will also observe that only a few numbers of users were neutral about the efficiency of the system. Likewise, only a few numbers of users were dissatisfied with the system.

4.12 Discussion of Results

The test proves that the system is good both for prediction and communication. The chatbot is easy in the manner of presentation of the results and the machine learning is effective. The integration of AI and NLP will enable us reduce dependence on specialists and improve our decision making. This will be based on the amount and quality of available data.

4.13 Overall Summary

The proposed system incorporates all the features of predicting and communication. The simple and positive recommendations are given to framers. This means that the system is functioning, and also user friendly. The system is applicable practically in the field of agriculture.

4.14 Screenshots

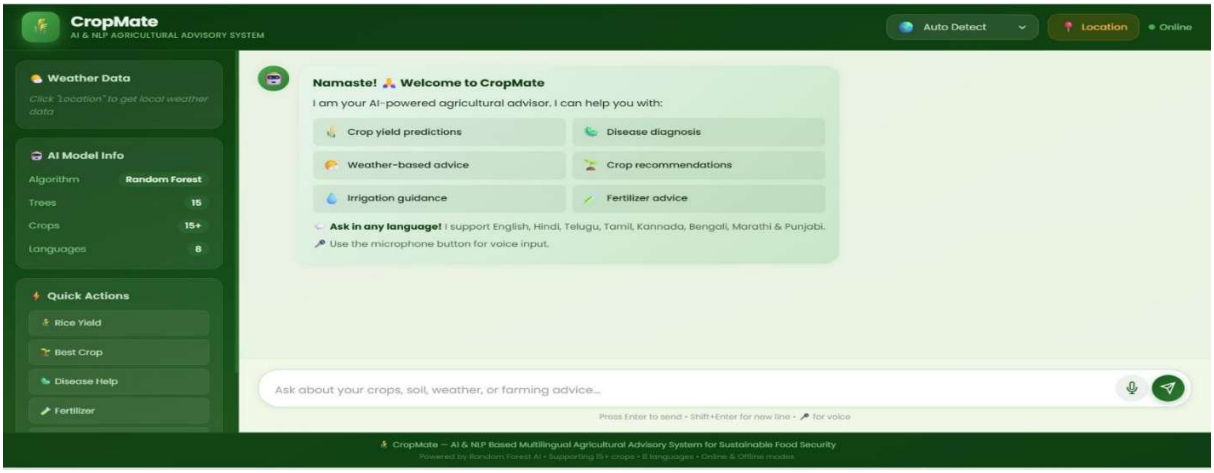

Fig 4.6. User Interface

Figure 4.6 presents the user interface of the web-based application, which is an AI-driven agricultural advisory system. This system offers functionalities such as crop prediction, disease identification, and weather advisory services. There is a multilingual chatbot that makes communication easy through text and voice inputs.

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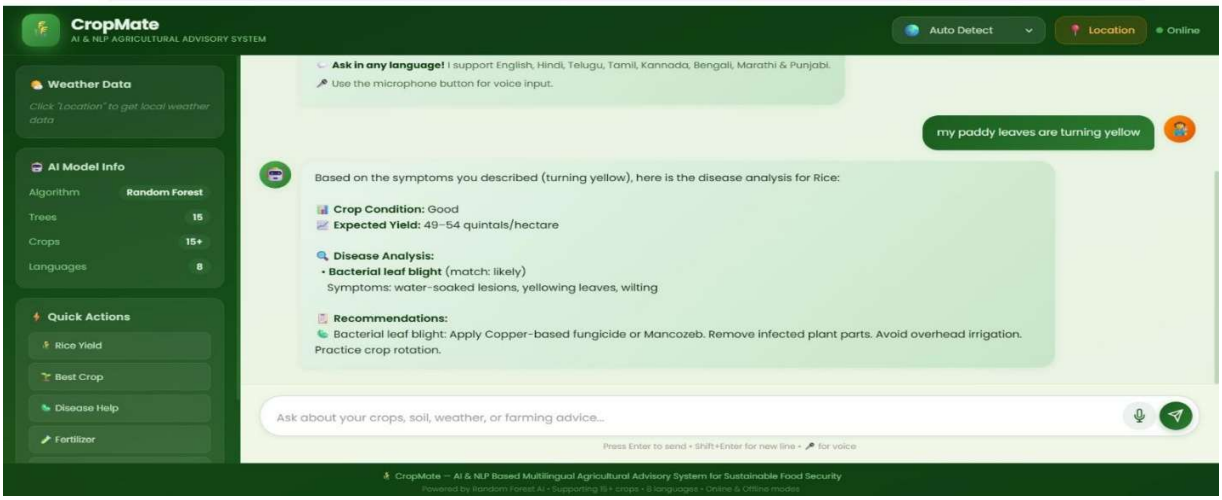

Fig 4.7. Disease Diagnosis and Recommendation Interface

Fig 4.7 is an illustration of the disease diagnosis capability of "CropMate" software where a farmer inputs the symptom of yellowing leaves of paddy plants. From this symptom analysis, the system diagnoses bacteria leaf blight along with information on the condition of the crop, likely yield, and recommendations.

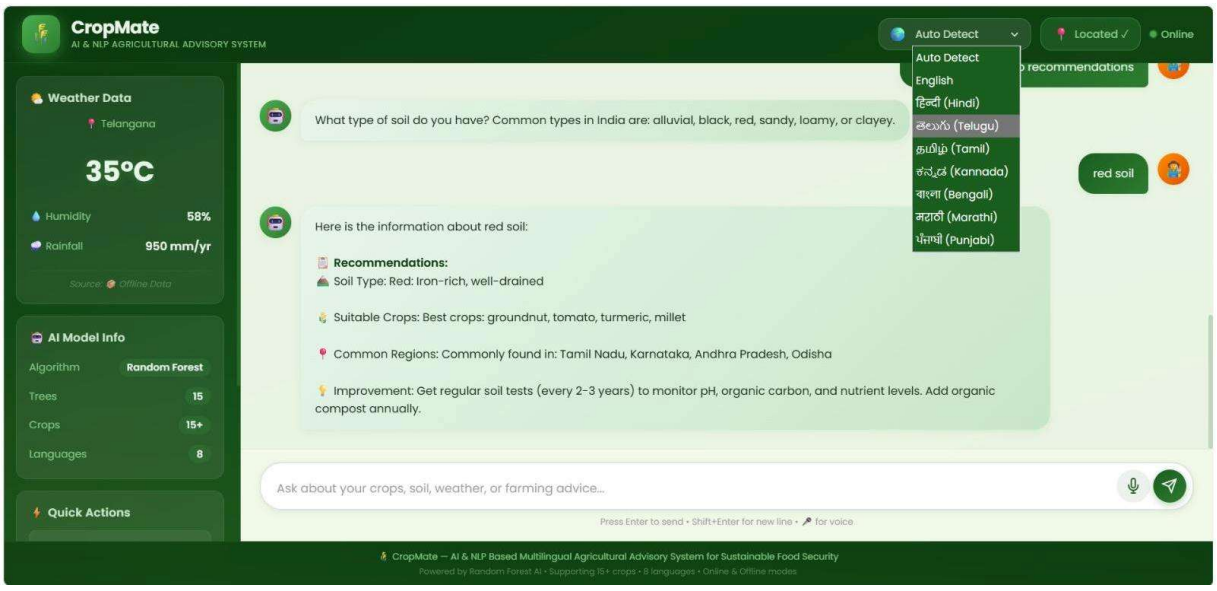

Fig 4.8. Soil Analysis and Multilingual support Interface

Fig 4.8 demonstrates the soil analysis component of the application as well as the language option within the system. The system provides relevant details and suggestions according to the chosen soil type, such as which crops will suit it and how it can be improved. It also offers various languages that one can opt for.

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Fig 4.9. Chatbot Interaction in local language

Fig 4.9, shows significant data, such as weather and AI models, which can help in decision making. The chatbot function provides relevant suggestions to users using the regional language. As such, the conclusion drawn is that the proposed interface is easy to understand and use.

5.1 Applications

The proposed system could have applications in different areas within agriculture, and assist the farmers to make sound decisions and improve their agricultural practices. Crop selection is the initial field where the proposed system can be used. The farmer will be in a position to choose the best crop based on the weather and the soil [17], [18]. This farmer will be in a position to choose the most appropriate crop basing on the soil and weather conditions. This will reduce the possibility of crop failure and will assist the farmer in making better decisions. The confidence of the farmer to select the appropriate crop will also increase because the proposed system will have a high possibility of growing well.

The second field of use of this proposed system is the prediction of yields. The yield of the crop is predicted by the proposed system and this will help the farmer to use resources like water and fertilizers [3], [4]. The proposed system predict will also assist the farmer in identifying possible risks such as drought and pest attacks at a early stage. This will assist the farmer in taking better control of their activities and avoid any possible loss. The proposed system will be a chatbot, and this will make it user-friendly. The suggested system will be user-friendly even to an individual who does not understand technology. This also increases the availability of the system particularly to people in other regions [6]. It is comfortable even to those who are not very familiar with the work of technical devices. The system can be regarded therefore as the digital helper in one's farming endeavors.

5.2 Discussion

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Based on the results, it is evident that the proposed system is effective regarding proposed system works well both in relation to prediction and interaction with users. The results of the machine learning model are trustworthy whereas the chatbot gives the results in a straightforward and comprehensible format to the farmers. This will allow the farmers to apply the information in actual circumstances that may arise. It also fills the gap between theory and practice [1], [6].

The ability to combine the prediction and communication functions is one of the strengths of the system. This simplifies the system and allows the user to get the information without necessarily having the technical knowledge. The fact that the system has a multilingual option also contributes to its strength by rendering it easier to use by more users. This makes the system more real life applicable.

The quality of the input data fed into the system however also determines the performance of the system. In case of poor or inadequate data, it can influence the output of the predictive abilities of the chatbot. The chatbot might also experience certain issues with handling more complicated queries in case the input data is not clear. However, the prospects of the improvement of the system are enormous.

5.3 Ablation Study

The ablation study was carried out to determine the importance of the components in the system. When the preprocessing step was removed the accuracy of the predictions was related because the data was dirty and inconsistent. This is a good sign that preprocessing steps is very important in improving the system performance. Thus, the system is not able to work effectively when the step is omitted.

Moreover, the system was not user friendly when the chatbot module was removed. The prediction s made were not explained well and therefore the users could not comprehend them. This illustrates very well that the chatbot module plays a very important role in ensuring that the system is user-friendly.

In addition, the system was not user-friendly when the multilingual support module was disabled to those users who did not understand the default language. The accuracy of the predictions that the system made also decreased due to the simpler machine learning models.

6. Conclusion

The proposed system also exemplifies the application of both the artificial Intelligence and Natural Language Processing simultaneously in a way that makes the entire process of decision-making in the sphere of agriculture easier. Based on the findings, one can observe that system can offer credible predictions in such fields as crop selection, yield, and risks within the sphere of agriculture using the agricultural data. Nevertheless, the chatbot interface is also capable of offering a straightforward and uncomplicated format of the information and the farmer can interact with the system without any technical complication [1], [4].

The point of significant contribution of this work is that the prediction, the recommendation, and the communication is incorporated in one platform. This is contrary to other system in that the results are well explained in the output and thus the farmers find it easy to use the results in their farming practices. The addition of multilingual support has made the system more accessible and usable by people of different regions [3], [11].

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This has assisted the farmers in decision making and has made the work more efficient and minimized the degree of confusion in the farming activities.

The system can be enhanced in the future by incorporating new features like crop disease detection by use of images, real-time monitoring through the use of IoT devices and price prediction. This would help to make the system more dependable and applicable in large scale use in the agriculture field.

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