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Artificial Intelligence Driven Weather Forecasting Framework for Sustainable Agriculture

B Jeevan[1], Jatoth Heeraman[2*], Ratod Vinod Kumar [3], S Padma Tejaswi [3]

1. Department of Mechanical Engineering, Holymary institute of technology and science, hyderabad Telangana, India
2. Department of Mechanical Engineering, Malla Reddy (MR) Deemed to be University, Hyderabad, Telangana, 500100, India
3. Department of Civil Engineering, Malla Reddy (MR) Deemed to be University, Hyderabad, Telangana, 500100, India

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Abstract

This research presents an intelligent weather prediction system designed to enhance decision-making in agriculture through accurate, location-specific forecasting. The proposed framework integrates Internet-connected weather stations, Earth-observation datasets, and artificial intelligence algorithms to generate reliable short- and medium-term predictions. By analyzing historical temperature records, soil conditions, humidity patterns, and climate variables, the system provides farmers with actionable insights tailored to crop growth requirements. In addition, an integrated alert mechanism notifies users of potential weather-related hazards, enabling timely preventive measures to protect crops, livestock, and farm infrastructure. The model delivers real-time agricultural information through an accessible interface, ensuring usability even for farmers with minimal technical proficiency. Overall, the system aims to improve agricultural sustainability and productivity by mitigating the risks associated with increasingly unpredictable climatic conditions.

1. Introduction

Agriculture is inherently vulnerable to the impacts of climatic variability and harsh weather due to its strong reliance on weather patterns. Around the world, farmers usually face serious issues as a result of weather unpredictability, which affects agricultural productivity, food security, and financial stability. Recent years have seen a rise in the number and intensity of extreme weather occurrences, like storms, floods, and droughts. Farmers have over the years, depended on their instincts, regionally bestowed knowledge and previous weather phenomenon in managing the farming practices. However, while currently there is a relentless increase of available meteorological data and use of technologies, there is an excellent chance to redefine the major trends in agricultural practices through the construction of new generations of weather forecast [1-3]. They also complement the gardeners' actions through offering them reliable and specific estimates depending on the crop requirement, and region [4].

As a result, the current paper proposes a new weather forecasting system for agricultural decision-makers, which meets their requirements [5]. Today's meteorological models, satellite information, and artificial neural networks included in this system allow providing accurate weather forecasts quickly, as well as some recommendations on how to improve the efficiency of agricultural activities. However, supplementing the historical climatic data and crop specific parameters to the system would make the prediction robust and benefit the farmers to a large extent by enabling them know when and how to protect the crops from the changes in the climate pattern [6-8].

Moreover, the proposed system will contain alarm signals to inform the farmers of the issues related to weather patterns as soon as possible. The people in this sector would be able to quickly introduce contingent strategies and

✉ Corresponding author: heeramanj@gmail.com (Jatoh Heeraman)

activities that are rather elastic. This system aims at improving the agricultural production and sustain ability against climate variability by providing farmers with simple and reliable weather information. Thus, the presented sections of the paper are going to detail the characteristics of the offered weather forecasting system, its versatility, as well as its overall layout. We propose to explain its immense importance when it comes to sustaining and building a more resistant and stable agricultural business and reduce weather-related dangers through research [9-12].

2. Objectives of the study

The main objective is to avail technical support with principles of informativeness to facilitate improvement of infrastructure in agriculture sector. This system leads to timely alerts and specifics of disasters, localized crop advisory based on existing weather conditions for the farmers to help its shows a flow chart of figure 1.

Also, it also provides a multilingual chatbot all the time farmers have any need they can ask in their native language. Together, these elements provide the system with an ability to deliver valuable resources, knowledge, and guidance to farmers, thus helping them mitigate risks, improve decision making, and increase yield in the agricultural sector its shows a flow chart of figure 5.

3. Features of weather prediction system for agriculture

3.1. Localized weather forecasts

It gives accurate and more specialized results depending on farmers' locality so that they could decide on how to go about the farming depending on the current weather is shown in figure 3.

3.2. Customized crop suggestions

Hence creating a model that analyses historical meteorological data, crop specific parameters and applying artificial intelligence techniques, the system provides information on which practice is best suited for cultivation, planting, irrigation among others and time most suited for harvesting.

3.3. Real-time data integration

For instance, you get data from satellites, weather stations, and sensors to provide real-time information for decision-making processes at that particular time.

3.4. Alert mechanisms

It also allows farmers to always know when there is a threat ranging from storms, very low rainfall, or even frosts and this would therefore help them to apply necessary measures towards avoiding a resultant damage.

3.5. Multilingual chatbot

Multinational agriculture consultative chatbot is language diverse as it covers the various languages used by farmers as well as increasing the information reach.

3.6. User-friendly design

This includes its usability where the interface is pretty blunt and straightforward; therefore, expects of the farmers do not have to possess highly technical skills in order to comfortably interact with the system.

3.7. Flexibility and scalability

It can also be used in all types of farming because the algorithms can be easily adapted to cover various sizes, types of crops and regions.

3.8. Data analytics and visualization

Thus, practical commercial information and agricultural data are transmitted and eased for the general public through data analysis and display, as well as complex weather data that has been simplified. This puts the farmers in a better position to review the data and to use the insight meaningfully.

3.9. Remote access

It is also designed to be accessed from remote locations such as from a laptop or a mobile device this makes it easier for the farmer to monitor ad make decisions even when they cannot be on the farm.

4. Literature review

R. S. De Oliveira, A. C. Fraga, and R. Morales [13], Update of a Risk Management Climate Agriculture System through Meteorologic Agricultural Indices. 2020. To sum up, the general purpose of this research is to develop a guideline for constructing and using agricultural weather index for climate risk assessment purposes. Weather data has to be used when developing key decisions during the fight against crop diseases through the battle models. The specifics regarding the changes in meteorological characteristics should be spelled out to the sensitives as the factors that may be instrumental

in altering the climate and hence have reverberations on farming. These indexes help the farming organisations to solve various problems that may incase includes but are not limited to provide resource management information on the calendar for crop planting, irrigation among others.

An Examination of Weather Information and Forecasting Models for Agriculture [14]: This paper has more concentration on the models and sources of data used in anticipating the weather condition necessary for agriculture. There has been a realization that the need for accurate and informed weather forecasts is imperative to enable the reduction of risks and decision making based on facts. In the study, there are many forms of prediction techniques examined, which includes statistical, machine learning and numerical weather plight. There is an emphasis put into the notion that there must be the accumulation of many data inputs such as satellite imagery for enhancing the premises for prediction and increased precision.

Agriculture's Use of Weather Index-Based Insurance: An Example of INSURANCE BASED ON WEATHER INDEX A Requirement for Additional INSURANCE BASED ON WEATHER INDEX. This is an article that explores the significance of insurance in reducing vulnerability in agriculture. This process is aimed at making farmers have a better way to manage some aspects of climate in as much as they reduce the risks of facing hazardous weather conditions. It does, nonetheless, also present challenges that need to be addressed to ensure that insurance policies reached the desired end goal of agricultural risk management someday in the areas of cost, data, and index.

Weather Based Disease Forecasting Model To Predict Diseases In Agricultural Crops was published by S. khan, A. H. Baloch, A. A. Khan in the International, Journal of Agriculture and Biology in 2020 [16]. The internal analysis explains that it is a new or an improved approach of utilizing weather dates in anticipation of crop diseases. When simultaneously using meteorological data and incidence information, the method can effectively help detect early forms of the disease and, therefore, apply the necessary preventive measures. This helps to reduce instances whereby crops are destroyed as well as apply the right kind of pesticides, an exemplary vagaries weather-based discipline to prevent diseases [17-21].

5. Proposed method

5.1. Data collection

Open Weather collects meteorological information from a number of sources, such as

Weather forecast : These devices track several aspects of the local weather, including humidity, temperature, wind speed, and precipitation.

Satellites: Over vast geographic regions, satellites give information on temperature distribution, atmospheric pressure, and cloud cover.

Radars: In real time, weather radars identify atmospheric events such as storms and precipitation.

The variable D_t should be used to represent the raw weather data, which contains variables like temperature (T), humidity (H), wind speed (W), atmospheric pressure (P), and precipitation (R).

5.2. Data processing

To ensure accuracy and dependability, preprocessing is carried out to clean and check the raw data (D_t) acquired.

Quality control techniques can be used to find and fix any mistakes or discrepancies in the data

Assign D'_t to the processed weather data at time t.

5.3. Weather prediction

To predict the weather in the future, sophisticated weather models and machine learning algorithms examine both historical and current data.

Among other mathematical equations are atmospheric physics and numerical weather prediction models whereby some equations like the Navier Stokes equations gives simulation of the behavior of the atmosphere at any particular time.

Based on the forecasted values the temperature at time t should be represented by T', the humidity by H', the wind speed by W', the atmospheric pressure by P', and the precipitation at time t by R'.

5.4. API interaction

By using Open Weather API, client can form queries to which they have to enter the place they want to get information about and in reply, they get some weather information is shown in figure 2.

As a result, the user informs the location, either by the city name or the coordinates and the

type of data that is wished to be obtained: current state of weather now, forecast, history, and so on; and make an HTTP request to the API.

In response to this, the API looks for the requisite information of the local weather conditions either in a database or in a forecast model.

Finally the developed output is supplied to the user in formats such as JSON or XMl, which would contain all the required weather information.

Let, \(API_{req} \) represents the user request to the API and \(API_{resp} \) represents the response of the API which contains the wanted weather information of the user.

5.5. Enhancing performance

To ensure optimal effectiveness and scalability, Open Weather employs several strategies:

Caching: As mentioned earlier, a high cache is used to improve response time of the application mainly for sets of data that is often demanded frequently.

Load balancing: Thus, linking to many servers for splitting the incoming requests evenly and to

Rate Limiting: Deliberate restrictions of the specific number of requests a single customer is allowed to make in a certain period of time are put in place to avoid overloading of the system.

Together with the help of the Open Weather API , the users can accurately and quickly observe the meteorological data, define the prognosis of meteorological conditions, carry out the climatic investigation , and make the decisions for industries [22-25].

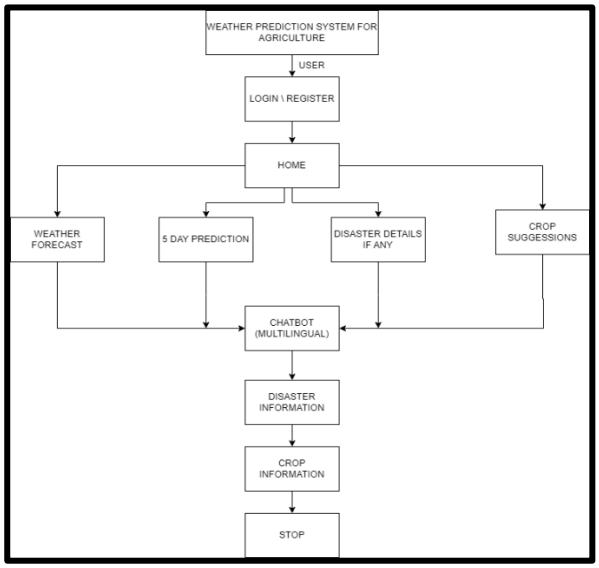

Figure 1: Flowchart of the proposed system

1. Accessing the System: Go to the web address where this application is hosted through your web browser. You will be redirected to the page, which will make you enter the account and password information.
2. Logging In: In the username field, type “username” in the field and in the password field type “password”. Users should click on the “Login” button to get the access into the system.
3. Main Dashboard: When you log into this app, you are required to enter the desired place. This input is the location from which you wish to pull weather and agricultural data.
4. Weather Updates: When the location of the place is entered, the system will show the weather condition of the entered place at that moment. There you can observe five-day weather forecast.
5. Chatbot Assistance: As a part of the chatbot, the users can directly ask questions or request help regarding weather and agriculture. The chatbot is a useful feature in that it actively responds and sends advice depending on the user’s searches.
6. Crop Recommendations: Get suggestions of crops that would be appropriate in the climatic conditions of your area. Choose different crops to cultivate and their conditions.
7. Farming Techniques: useful tips and strategies on the recommended crops to grow. Prescribe information on planting schedules, soil preparation, irrigation, fertilization, and pest management.
8. Disaster Information: Various natural disasters and ways to minimize their consequences can be discovered from this set of lessons. The routes to be followed in case of an emergency, ways and means to contact concerned authorities and ways to protect oneself and property can all be found here.
9. Crop Information: For those who are interested in specific data regarding various crops look through the list below. Discover the best conditions necessary for crop plant growth; techniques of ensuring proper crop care; and ways of crop harvesting.

Logging Out: In order to log out, there is the

"Logout" tab which you are supposed to find in the menu or the dashboard. This makes sure that your account and Your information are well protected.

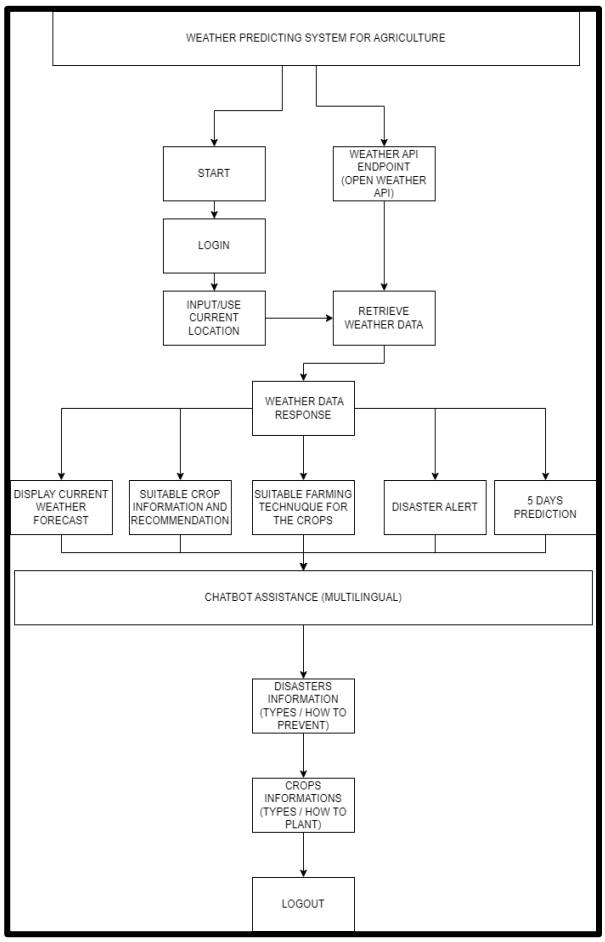

Figure 2. Sequential Description of the System

In the figure. 2, you can find a sequential description of the API process in order to obtain weather data. It starts with the user entering their desired place, which makes a request to the required Weather API Endpoint. After this, the system interacts with the API to source fuller weather details as well as the conditions of the atmosphere at the specific time as well as other forecasts. This retrieved information includes several climatic factors like; temperature, humidity, wind speed, rainfall, and pressure. After collecting weather data, the data is transformed in the system before presenting it to the users. The current presentation also contains a graphic design of the user interface through which the users can easily understand the displayed weather information. Also, as a part of the proposed system, there is a number of extra services designed to improve usability and add extra value to the application [26-29].

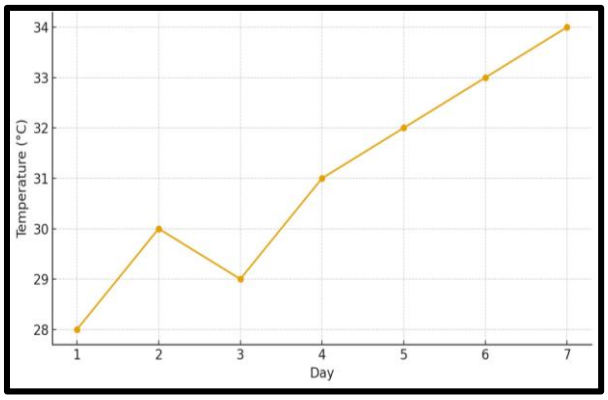

Figure. 3. 7 Days Temperature Forecast

One characteristic is the ability to predict the weather for the next five days, achieving a specific target of informing people about the expected climate for the forthcoming days. Also, the system contains a feature of chatbot assistance where they can communication to the system in case they wish to ask a certain question on the weather or if they need further information. Furthermore, using climate information, the system provides the clients with the best crop types to cultivate depending on the prevailing climate. These suggestions are unique to the particular conditions of the user's area and therefore distinctive and germane. In addition to crop recommendations the system offers methods of farming that can be used for the proposed crops. These techniques include matters such as plant planting frequency, ways used to prepare the soil, ways used to water plants, methods of fertilizing and ways used to control pest. Other features are the special pages of the disaster and an overview of the crops. A separate page dedicated to the disaster information gave brief information regarding the possible natural disasters and their precautionary measures so as to minimize their effects. On the other hand, the crop details page gives vital information in regards to various crops and how to plant, where to plant and how to maintain the crops [30-32].

Through the integration of these multifaceted aspects, the system seeks to equip its users with accurate weather reports and reliable agriculture advice to facilitate efficiency in farmers' work and productivity is shown in figure. 4.

1. User Input: A farmer queries the chatbot with an example of a question they would like answered: "What is the weather forecast for tomorrow in Mumbai?".
2. NLP, or natural language processing: NLP is used by the chatbot to handle user

inquiries. Each word or token in the query is separated out. Each token (noun, verb, etc.) is given a part-of-speech tag. Words are reduced to their basic or root form is present in figure 6.

3. Recognition of Entities and Intent: The chatbot recognizes the query's purpose (weather forecast, for example).Entity recognition algorithms are used to extract named entities (such as location and date) from the query.
4. Data Retrieval: Based on the identified intent, the chatbot calls pertinent data sources using APIs. To retrieve weather predictions (OpenWeatherMap API).To retrieve crop suggestions according to meteorological circumstances. To retrieve data on disasters.
5. Data Analysis and Processing: A logical response is produced by processing and analyzing the collected data. For instance, crop recommendations are customized depending on the predicted weather conditions and weather data is converted into a legible prediction.
6. Multilingual Assistance (where relevant): If multilingual support is enabled, the response is translated via a translation service into the user's preferred language.
7. Generation of Response: A natural language response is produced using the data that has been processed. Information like crop recommendations, specifics of the weather forecast, and any pertinent hazard alerts are all included in the answer.

Display response: The user sees the generated response on the chatbot interface is shown in fig .7.

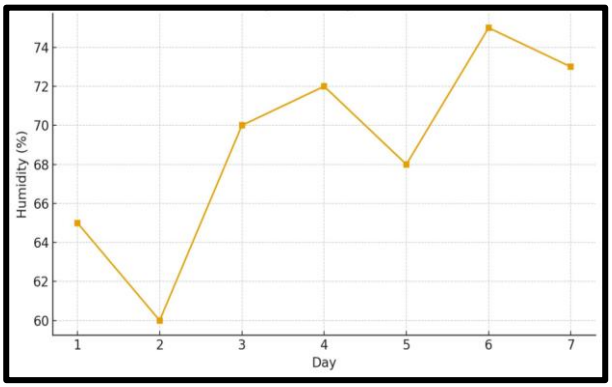

Figure. 4. Weekly Humidity Variation

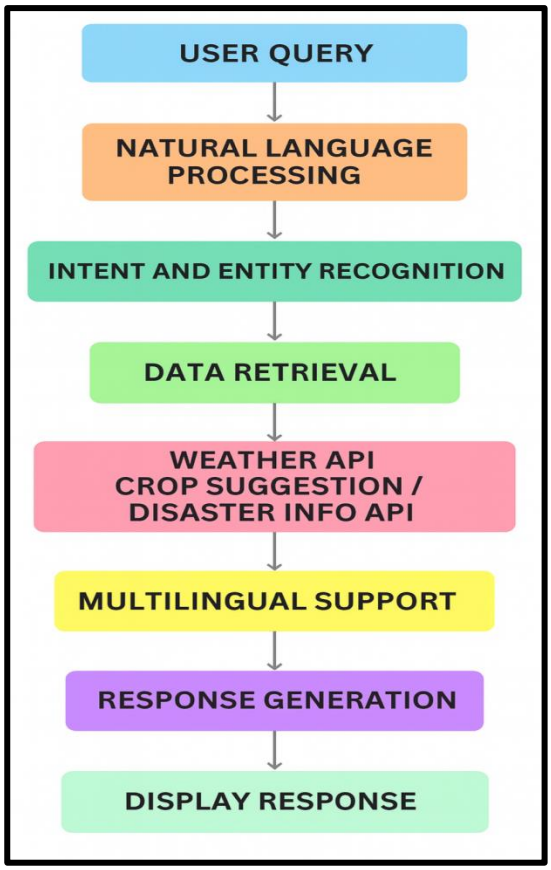

Figure. 5. Working Of Chatbot

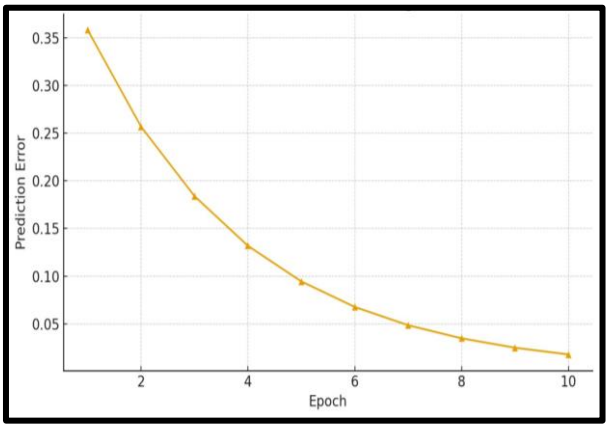

Figure. 6. AI Weather Model Training Error

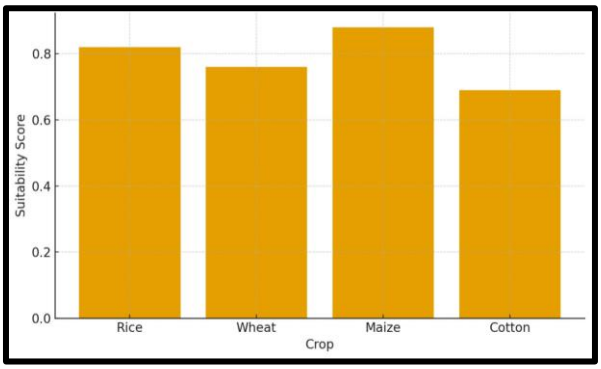

Figure. 7. Crop Suitability Scores Based on weather Forecast

5. Conclusion

The agricultural support system is a novel strategy that uses state-of-the-art technology to transform farming methods and strengthen agricultural communities. This platform's primary goal is to meet the specific requirements of farmers by providing a range of cutting-edge features that are meant to increase sustainability, resilience, and production. The capacity of this technology to offer customized crop suggestions is one of its primary characteristics. Farmers may maximize crop selection and cultivation practices for optimal yield and profitability by using the platform's individualized guidance, which is generated by analyzing a range of parameters including soil quality, climate conditions, and market trends.In addition, the system provides prompt disaster alerts, which are an essential early warning system that notify farmers of impending dangers like severe weather, pest infestations, or disease outbreaks. Farmers may mitigate risks and ensure the resilience of their farming operations by taking proactive measures to safeguard their crops and limit losses, thanks to the timely alerts they get is produce in figure 8.

Furthermore, the technology provides hyper-accurate localized weather forecasts that are customized for particular geographic areas. With this fine degree of forecasting, farmers may maximize resource allocation and enhance overall farm management by making well-informed decisions about irrigation, planting, and harvesting schedules.

Most importantly, having a multilingual chatbot improves accessibility for farmers who have different language requirements. This feature makes sure that all farmers can simply engage with the platform and take use of its abundance of resources and support services, irrespective of their language background. Through the process of removing linguistic obstacles, the chatbot fosters inclusivity and guarantees that no farmer is left behind in the pursuit of agricultural progress.

This well-organized platform's main objective is to encourage farming methods that are resilient and sustainable. The system has the ability to bring about positive change in agricultural communities by providing farmers with the necessary tools and information to make educated decisions, effectively manage risks, and boost productivity. This platform offers a ray of hope for the future of farming, paving the way for a more lucrative and sustainable agricultural industry by encouraging a culture of innovation and cooperation.

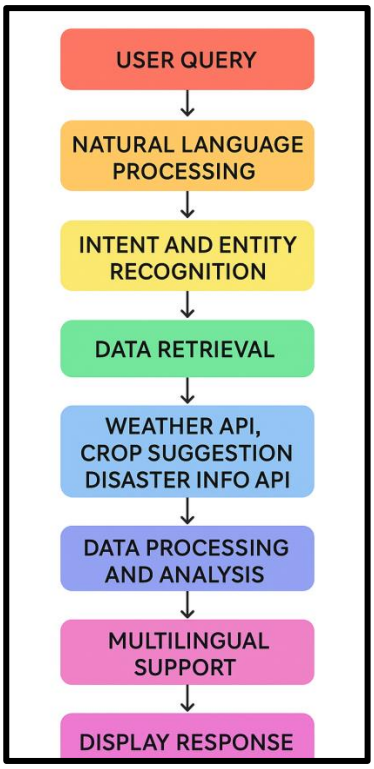

Figure. 8. Conclusion Flow Chart of the Study

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