IOT Based Smart Agriculture on the Cloud

A major project report submitted in partial fulfillment of the requirement for the award of degree of

Bachelor of Technology

in

Computer Science & Engineering / Information Technology

Submitted by

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled "**IOT Based Smart Agriculture on the cloud**" in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Computer Science & Engineering / Information Technology submitted in the Department of Computer Science & Engineering and Information Technology, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **"Daksh Malik (201355)**, **Bhanu Pratap Singh (201434)"** during the period from August 2023 to May 2024 under the supervision of **"Dr. Ravindara Bhatt"** Department of Computer Science & Engineering and Information Technology.

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The above statement is correct to the best of my knowledge.

Dr. Ravindara Bhatt
Associate Professor
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DECLARATION

I hereby declare that the work presented in this report entitled **'IOT Based Smart Agriculture on the Cloud'** in partial fulfillment of the requirements for the award of the degree of **Bachelor of Technology in Computer Science & Engineering / Information Technology** submitted in the Department of Computer Science & Engineering and Information Technology**,** Jaypee University of Information Technology, Waknaghat is an authentic record of my own work carried out over a period from August 2023 to May 2024 under the supervision of **Dr. Ravindara Bhatt** (Associate Professor, Department of Computer Science & Engineering and Information Technology).

The matter embodied in the report has not been submitted for the award of any other degree or diploma.

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ABSTRACT

IoT has greatly transformed agriculture with some remarkable developments. This paper presents the details of design of a cloud based IoT smart agriculture system intended to enhance agricultural yield, natural resources productivity, and sustainability. Therefore, the adopted framework considered variables such as soil moisture, precipitation intensity, number of sunlight hours and wind speed.

This makes their connection possible with a central cloud platform for immediate data analysis and retrieval. Therefore, this amount of data from IoT system would be possible with the scalability and speed capability of the cloud.

Farmers have a chance of making informed decisions even when they are outside their area because it comprises of a cloud-based design while allowing for remote tracking and monitoring The sustainability of this system is also realized because it maintains enough water for sustainability purposes and also promotes maximum utilization of resources with minimal or no negative impacts on agriculture.

The paper will conclude with a discussion of the potential benefits of IoT-based smart agriculture, such as higher yields, lower costs, and environmental protection, and will also discuss challenges and future directions for research in this rapidly growing field, including standardization, and safety measures for larger adoption. among farmers.

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Agriculture is known as the breeding and rearing of domestic animals, vegetables, and mushrooms for human consumption. Examples include tree tops, medicinal plants, and other products that are useful and improve people's lives. Crofting marked a turning point in the development of stable human civilization. The development of domesticated species provided abundant food sources that contributed to the development of civilization. Agriculture has been around for thousands of years.

The Internet of Things (IoT) is the connectivity or connectivity of physical devices. Connected computing devices, digital and industrial devices, human or animal, Processes that can sense, store, and transmit data to unattended networks. Those who will participate. Everything unique is provided. It's progressive analytical and instrumentation programs for prospecting, planning, and dimensioning Information is the perfect system of artificial ideas for communication Business planning.

Typically, traditional farming techniques use a lot of resources and are unsuccessful in shielding a farm from every trouble associated with bad weather. However, to address them, one needs innovative solutions for increased productivity, minimized wastage, and sustainability. Smart Farming which rents on machine learning seems to be an able solution to this problem.

Machine Learning algorithms provide computers with an ability to learn from data and to discover patterns without such supervision. In agriculture, machine learning algorithms analyze large amounts of data a thing which includes soil properties, weather pattern, crop health, and historical yield, as well. Through discovering the regularities and connections in this information, the machines learning programs can assist the farmers to make more intelligent decisions.

1.2 PROBLEM STATEMENT

The problem of smart agriculture based on IoT in the cloud revolves around solving the challenges faced by traditional farming practices and using technology to better manage agriculture Some key problems are Natural factors such as over-reliance on rainfall and draining wells for irrigation, manual control above or below irrigation, environmental conditions snow Lack of real-time monitoring and the need for efficient use of resources meet the growing demand for food due to the growing global population. Using the Internet of Things and cloud-based data analytics, smart agriculture aims to ensure that producers and farmers can reduce waste, increase yields, and achieve more sustainable and efficient crops.

The implementation of AI and IoT in the field of agriculture holds promises of real improvements thanks to the emerging Smart Agriculture systems. But this totality of barriers is what makes such systems a deviant phenomenon with worse ineffectiveness. Lack of manifestation of agricultural data which is fundamental of ML models training is the most problematic in this group of challenges. In some cases the lack of data variety, the aptitude for some of the models to be relatively inaccurate and their usefulness limited , is as a result of the inaccessibility to robust and dependable information on soil composition and weather patterns. The scalability of the ML solutions is another issue that is triggered by lack of resources as it is in the case of smallholder farmers and resource-challenged environments. In addition, realizing the incorporation and close connection of ML-based systems to the rented agricultural infrastructure consisting many different pieces of hardware and software is another challenge caused by the hardware and software components existing in the market.

It also indicates the suitability of the given system, ie. The Indian agriculture industry is stumbling due to a lack of adequate information on the best farming techniques that have the potential to increase yields at relatively low costs. The lack of renewable biodiversity is also a factor driving pastoralists away from agriculture and consequently leading to significant changes in India's economic structure.

1.3 OBJECTIVES

The primary objective of the cloud-based IoT Smart agriculture that exploits the potential of networked technologies is to transform the existing agricultural methods to a more agile and innovative ways with opportunities of higher productivity, sustainability and efficiency. The goal is the integrated approach based on IoT sensors, cloud computing infrastructure, data analysis, and machine learning mechanisms, with the purpose of supervising the management of resources, to reduce the risks, and provide the farmers with the insights. Among the objectives is to initiate the precision farming strategies in order to enable farmers to closely monitor their farms and guide the crops with unique exactness and precision. The placement of IoT sensors all over the farm yields information on major factors including soil moisture, temperature, humidity, and crop health. This data is subsequently stored in the cloud where it is processed continuously. Through innovative analytics approach and machine language technology.

Natural language processing (ML) technology of smart agriculture is of vital significance when it comes to yield prediction enhancement. ML models are capable of predicting crop yields history corresponding to the data on weather patterns, soil conditions, genetics of crops and approaches applied. Through these farm models, farmers can eleate planting plans, allocate inputs in an organized way and make better decisions regarding their harvesting and marketing strategies because they provide real production estimates. Moreover, machine learning systems recognize principal variables of production variability and offer remedy options to minimize risk, as well as maximize production through advising farmers who struggle to get high yields and profit.

Besides smart farming's function through ML to detect diseases, pests and nutrition deficits of crop diseases ML is also among smart farming's purpose. Carry out analysis of raw data collected from drones or sensors.

Moreover, by developing the most advanced resource management technique, smart agriculture turns all productive resources into less waste to take care of the environment. Identification and repair of these process failures and their effects demonstrate the necessity of developing a disaster-resilient systems to prevent future tragedies. These rules look up development rate of crops, weather conditions, and local soil properties, and recommend water use in a way that maximises efficiency while preventing excess runoff and leaching. Moreover, ML models will be effective in identifying particular parts of the field that are faced with unusual deficits or abundance of resources and develop customized solutions to solve the problems that they uncover. This helps to promote the proper distribution of resources and contribute to sustainable practices of agriculture.

1.4 SIGNIFICANCE AND MOTIVATION OF THE PROJECT WORK

Several factors drive the motivation and significance for IoT-based smart agriculture in the cloud, as the following case studies illustrate.

1.4.1 **INCREASED PRODUCTIVITY AND REDUCED WASTE:** IoT technologies in agriculture have been assessed to enable producers and farmers to optimize agricultural processes to reduce waste and increase efficiency.

1.4.2 **REAL-TIME DATA AND AUTOMATION:** IoT devices deployed on farmland collect and analyze environmental data, allowing farmers to respond quickly to changes in the environment. This enables automatic adaptation of farm equipment and improves the overall efficiency of the farm operation.

1.4.3 **ADDRESSING GLOBAL FOOD SECURITY CHALLENGES:** With the world population expected to exceed 9 billion by 2050, food production must increase by 50%, IoT-based smart agriculture aims to address this challenge by modernizing farming methods and improving revenues.

1.4.4 **MARKET COMPETITION:** Farmers who adopt IoT-based smart agriculture compete in the market. The ability to produce very high yields combined with sustainable practices increases the competitiveness of agricultural products in the market. This is especially important in the global market, where consumers value sustainable technologies and improved agricultural practices.

1.4.5 **EMPOWERMENT OF FARMERS:** Farmers are empowered by Smart Agriculture which has ML-based technology, and it gives them suggestions and information either it is from their location or technological expertise. Through this project, farmers are able to base their decisions on reliable information and improve their means of living by giving them access to modern agricultural technologies.

1.5 ORGANIZATION OF PROJECT REPORT

This structure of the project report clearly illustrates how such things as development and testing for the Internet of Smart agriculture over in the Cloud were done. This organization will help an informed reader who wishes to understand the aspects of the project in a logical manner.

CHAPTER 1: INTRODUCTION

The section presents the project, explaining its purpose, importance, and background technology. It gives a brief introduction about IoT and what role it will play in our society.

CHAPTER 2: LITERATURE REVIEW

An examination of existing IoT based smart agriculture on the cloud, cloud platforms, and key technologies. The chapter establishes the theory of this project.

CHAPTER 3: SYSTEM DEVELOPMENT

This chapter contains information that will help you get more insight about the structure of the IoT application. The overall architecture and design of the system are discussed herein.

CHAPTER 4: TESTING

- **TESTING STRATEGY:** A discourse about the overall testing approach adopted, mentioning the respective tools utilized and the bases for their choice.

- **TEST CASES AND OUTCOMES:** An explanation of test cases with respect to smart contracts, user interface aspects, security measures and operational effectiveness issues. A detailed description of the outcomes of each test case.

CHAPTER 5: RESULTS AND DISCUSSION

In other words, this chapter gives an interpretation of results obtained during testing. It highlights the impacts of the results with reference to either the success or the challenges experienced in the building and implementation process.

CHAPTER 6: CONCLUSION

Chapter 6 summarizes the project with major points being the takeaways, what we learn, and the importance of a IoT Based Smart Agriculture System. Additionally, it suggests prospective changes and upgrades that could be implemented in the future.

REFERENCES

Reference listing contains names of sources and related literature used in designing and testing procedures development in the study.

The project report is organized so that it will walk readers chronologically from initiation to testing and conclusions of a project.

CHAPTER 2: LITERATURE SURVEY

2.1 OVERVIEW OF RELEVANT LITERATURE

2.1.1 CROP RECOMMENDATION USING IoT AND MACHINE LEARNING

SUMMARY: This paper proposes a microclimate-based crop recommendation model using IoT devices and machine learning techniques that can reduce farmers' risk, save money and time, and reduce agricultural waste IoT technologies can improve crop management by early warning of stress conditions and diseases. But machine learning improves crop system simulation.

2.1.2 SMART FARMING ARCHITECTURES BASED ON IoT REVIEW

SUMMARY: It presents a comparative study between different smart farming architectures based on IoT, focusing on the protocols and technologies used in these systems. The review work aims to identify the main devices, platforms, and communication technologies used in IoT solutions for smart farming. It highlights the growing importance of IoT in farm management and reveals a significant improvement in the way sensor data are stored and processed.

2.1.3 RENEWABLE ENERGY INTEGRATION INTO CLOUD & IoT-BASED SMART AGRICULTURE

SUMMARY: Renewable energy integration is discussed for water-table pumping and smart irrigations that promote efficiency in energy-saving agricultural practices. Other issues discussed in these articles include the utilisation of IoT and cloud infrastructure in intelligent agriculture practices such as continuous measurement of environmental factors, automatic watering systems and plant wellness evaluation. Renewal energy-based IoT smart farm system coupled with cloud technologies proposed for enhancing the humidity, and the level of moisture in the soil thereby turning water pumping system on when the land is dry.

2.1.4 MACHINE LEARNING APPLICATIONS FOR PRECISION AGRICULTURE

SUMMARY: Machine learning is applied in optimizing agronomic practice, increasing yield, improving resourceless and sustainability (19). Examples are identifying soil properties, forecasting crop yield and plant disease prediction. In addition, these articles detail how deep learning applies to precision farming and creating AI systems that can identify weeds, pests, and diseases. In this study, the researchers will use data-driven information to enhance productivity of the farms, lower operational expenses, and boost security associated with food production within precision farming.

2.1.4 ENERGY EFFICIENT EDGE-FOG CLOUD ARCHITECTURE FOR IoT BASED SMART AGRCULTURE ENVIRONMENT

SUMMARY: A novel scheme for the development of smart agriculture has been proposed by the paper titled "Energy-Efficient Edge-Fog-Cloud Architecture for IoT Based Smarts Agriculture Environment" as a viable strategy for the egress of IoT agriculture data. By segmenting the data accumulation and processing procedure in edge, fog, and cloud layers this architecture improves the energy intake thus provides high-performance for agricultural apps. Energy efficiency is enhanced by putting the real-time processing in the edge and fog layers so that the cloud carries less load.

2.1.5 A SURVEY ON THE ROLE OF IoT IN AGRICULTURE FOR THE IMPLEMENTATION OF SMART FARMING

SUMMARY: Smart farming has three main pillars that includes sensors and actuators, communication hardware, and data acquisition and analysis. This study presents an outline of the IoT ecosystem architecture for smart agriculture that includes various kinds of IoT devices, communication technology and common IoT applications in smart farming. It also considers the issues and future research areas of study in the discipline. This precision agriculture concept encompasses the capabilities of optimized resource usage, increased yield production, and low technologies in smart farming for monitoring cultivation sites, automatic irrigation system and saving natural resource use, i.e., water and electricity.

2.1.6 INTERNET OF THINGS (IoT) FOR SMART PRECISION AGRICULTURE AND FARMING IN RURAL AREAS

SUMMARY: They have relevant data about IoT application in the smart precision agriculture and farming. In their articles, the IoT technology used in farming is discussed as a way of utilizing robotics, drones, IoT and artificial intelligence to improve and optimize food production. Fog computing and Wi-Fi based communication in IoT Based Smart Agriculture and Farming. The study suggests a sustainable network framework for overseeing and regulating rural farming at large. However, they also highlight the application of machine learning to support crop production, conserving resources, as well as making farming more efficient, sustainable and profitable. This study uses information to enhance precision farming, cut on operational expenses and secure food safety for the public in the modern world. The overall findings in regard to smart precision agriculture would mean that internet of things IoT in smart precision agriculture could be useful in improving farm productivity, reducing operating costs and increasing food security in the countryside.

2.1.7 IoT BASED SMART AGRICULTURE SYSTEM

SUMMARY: This shows that the IoT can be employed in smart agriculture and intelligent farming. The articles are about core points of IoT in smart farming, IoT enabled networks types and opportunities offered by IoT technology to improve food industry production. IoT is used in precision farming in ways that enhance efficiency of resource utilization, high crop yields, and low operational expenses. These publications highlight the role of fog computing and WiFI based communication technologies in enabling IoT for smart farms and agriculture. The aim of smart farming is to employ information-oriented perspective for high yield crops per acre, cheaper production costs and greater food availability through sustainable agriculture.

S. no.	per Title [Cite]	Journal/ Conference (Year)	Tools/Technologies / Dataset	Results	Limitations
1	Crop Recom mendation Using IoT and Machine Learning	International Journal of Engi neering Researc h & Technology (2023)	ESP32 development board, KNN, Soil Grid Website.	The KNN algorithm achieve d an accuracy rate of 85% for crop recommendation, indicating good efficiency.	Reliability of IoT Infrastruct ure Cost of Sensors 3.Dependency on GPS
2	Smart farming architectures based on IoT review	ELSEVIER, The Second Internati onal Workshop on Edge AI-IoT for Smart Agric ulture (2022)	(LPWAN), (GECA) ZigBee, MQTT	By providing data-driven solutions that enhance efficiency, productivity, and sustainability	1. Incomplete Coverage 2. Availability of resources Research gaps
3.	Renewable Energy Integration Into Cloud & IoT-Based Smart Agriculture	IEEE Access(2021)	IoT Sensors Cloud Computing Services Farm Management Software Cyber security Tools	These integrated systems hold the potential to transform traditional farming practices into more sustainable, efficient, and data-driven operations.	Requires a combination of technological advancements, policy support, financial incentives, and farmer education
4.	Machine Lear ning Applicati ons for Precisi on Agriculture	IEEE Access (2020)	RNN and SVM used , ensemble learning Used for improving overall performance a nd robustness	Crop yield, soil properties and we ather prediction, d isease and weed p rediction	accurately labell ed dataset, delay result in overripe crop for the farmers

5.	Energy-Efficient Edge -Fog cloud Architecture for IoT-Based Smart Agricul ture Environment	IEEE Access (2020)	1. Heuristic algorithm (EEAIOT-EFC) IBM CPLEX MILP LoRa	1. Energy Efficiency Improv ement 2.Validation of Heuristic Algorithm 3.Network Traffic Reduction	1. Simplified Ass umptions 2. Lack of Real-World Deployme nt 3.Generalizabilit y 4.Specific Applic
6.	A Survey on the Role of IoT in Agriculture for the Implementatio n of smart farming.	IEEE access (2019)	cloud edge computin g,big data analytics, LPWAN and NBiot for communication.	IoT can be used in numerous ways in field of agriculture incl uding climate, plant animal monitoring etc.	sampling bias, li mited generaliza bility, temporal li mitations, social desirability bias.
7.	Internet of Things (IoT) for smart Precision Agri culture and Farming in Rural Areas	IEEE Access (2018)	1.WiLD Network 2.Wireless Sensor Network (WSN): 3.6LoWPAN Border Router (6LBR) 4.MAC (Medium Access Control)	1. Performance Im provements- The proposed MAC and routing solution for IoT has achieved better energy efficiency Fog Computing : Is capable of taking actions with lower delay and saving bandwidth	1. Lack of Real-World Data 2.Scalability Cha llenges 3.Cost Implicatio ns 4.Long-Term Reliability
8.	IOT Based Smart Agricul ture System	EEE Access (2018)	1.Raspberry PI (WIFI) 2.NODEMCU (WIFI) 3.HC-05 module (Bluetooth) 4.MQTT Cloud Server	1. Improved Crop Management 2. Data- Driven Insights. 3. Remote Monitoring	1.Connectivity 2.Cost 3.Maintenance 4.Data Privacy and Security

The literature review table provides recent research efforts exploring machine learning algorithms, IoT, and cloud networks. Together, the studies highlighted in the table provide valuable insights into this growing area of potential applications, tools, techniques, datasets used, availability of results, and limitations.

2.2 KEY GAPS IN LITERATURE

Some key differences can be found in the existing literature.

- **INTEGRATION OF RENEWABLE ENERGY:** Although several papers discuss the use of renewable energy in smart agriculture, more research is needed on integrating renewable energy such as solar and wind energy into IoT-based smart agriculture systems thus helping to meet the energy needs of remote rural areas. Appropriate and potential increase in sustainability of smart agricultural practices.

- **COST-EFFECTIVE SOLUTIONS FOR RURAL AREAS:** Many papers focus on the use of IoT in smart agriculture, but there is a lack of research on cost-effective solutions for rural areas with limited resources, and research is needed to develop low- cost IoT devices and communication technologies That can be used in rural fields.

- **DATA SECURITY AND PRIVACY:** Security and privacy of data collected from IoT devices is a major concern in smart agriculture. Protecting sensitive agricultural data from unauthorized access and surrounding cyber attacks requires research on secure, confidential data collection methods, data collection, storage, and transmission.

- **OPTIMIZING SMALL-SCALE AGRICULTURE:** Much of the existing literature focuses on smart agriculture solutions for large-scale commercial farms. There is a need to research customized IoT-based smart agriculture solutions for small-scale, subsistence farmers taking into account their unique needs, resources.

CHAPTER 3: SYSTEM DEVELOPMENT

3.1 REQUIREMENTS AND ANALYSIS

3.1.1 WHAT IS IoT?

The term "Internet of Things" (IoT) refers to physical objects, devices, vehicles, and other connected devices equipped with sensors, software, and additional functions enabling transactions and data collection, building smart, flexible ecosystems where devices exchange data, communicate, and make data-driven decisions.

Since its inception in the second half of the 20th century, IoT has possessed the technological power to transform industries. The phrase "sensors network" was coined by businessman Kevin Ashton in 1999 to describe a network of physical devices connected with built-in sensors, software, and communications, enabling automatic data collection and sharing. Leading IoT models and applications emerged in the 1990s with the momentum of RFID technology, extending to consumer-facing applications like wearables and smart homes in 2010, while Industrial IoT (IoT) launched in the mid-2010s.

IoT is pervasive across applications, from smart cities to healthcare and technology services. The steady progress in edge computing, particularly with the advent of the 5G network in the late 2010s, further contributes to the constant and improving history of IoT, showcasing its impact on various aspects of our connected society through advanced hybrid technology.

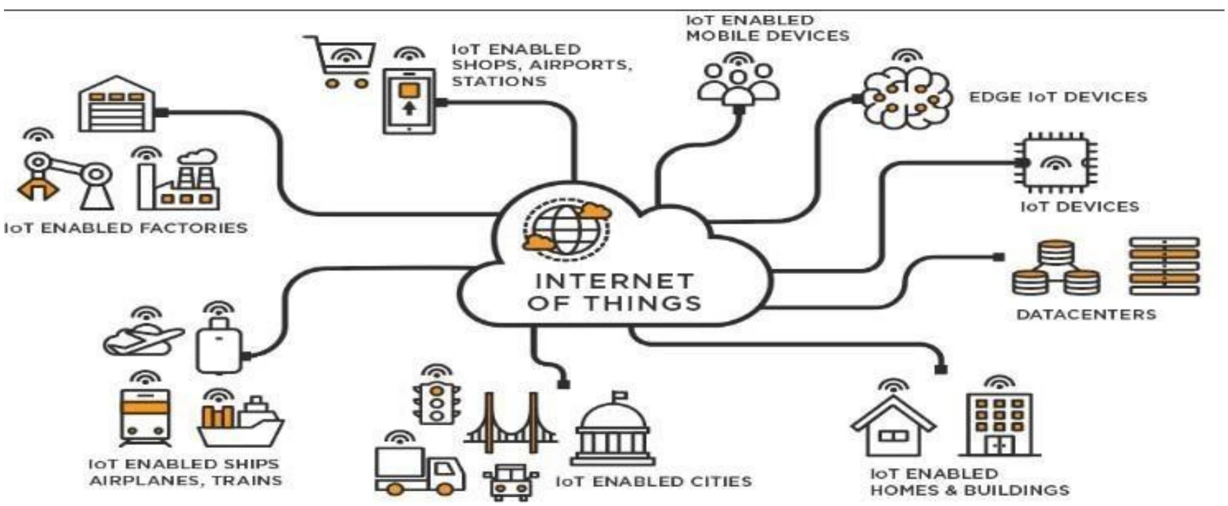


Fig. 3.1: Description of IoT

3.1.1 ESSENTIALS ATTRIBUTES

- **SCALABILITY:** ML-driven Smart Agriculture systems should be automatically able to scale up to cater for the dynamic data volumetric size, computational resources, and user demands. Hence, this factor ensures that the system has the capacity to handle the complexities that the data set size increases as well as still provide an optimal performance.

- **RELIABILITY:** It is a significant factor in the agriculture machinery operation; the system malfunctioning or system failure does not forgive downtime. The ML Smart Agricultural systems should make sure that they are collision-protected, giving as guarantee that they will run smoothly even in the worst conditions or unforeseen events.

- **REAL TIME PROCESSING:** One of most paramount requirements of agricultural decision-making is the real time processing that can make direct interpretation of at-the-place inputs. These timely interventions can be of great importance in crop yield improvement and resource management. ML models must understand, arrange and process agricultural data and display trends and urgent recommendations on time.

- **USABILITY:** A low-threshold for users is one of the core requirements of ML-based Smart Agriculture, because the system is to be easy-to-use and intuitive for people with different levels of technological knowledge. The aim is to set up the user interface design in a way that the farmers will easily roam, look at, and interpret data, this will enable them to fully exploit the system's complex features even if they have no single technical expertise or specialised training.

3.1.2 BENEFITTING HUMANS WITH ITS APPLICATIONS

- **FOOD SECURITY:** Through the adoption of ML-based Smart Agriculture systems, various crucial activities such as crop production and management of resources, and farm techniques are improved, and therefore, in the long run, this will help to feed the world adequately. These global concerns of food insecurity and malnutrition are solved with the expansion of agricultural output in a sustainable manner so that the food supply is sufficient and harmonious.

- **SUSTAINABILITY:** Through the use of ML algorithms there is a reduction in the amount of damage being done to the environment as it allows us to accurately measure the resources being used such as water, fertiliser and pesticides. These technologies help the biodiversity preservation, the control of greenhouse gas emissions, and the natural resource accessibility to future generations through the cuts on the resource wastage and the boost of sustainability.

- **ECONOMIC EMPOWERMENT:** On the other hand farmers can obtain the knowledge they need and make better decisions for the sake of their higher standard of living because of the smart advice and points in farm management coming from the Machine Learning system used in Smart Agriculture. Those networks support development of rural areas as they give boost to the economy, create jobs, and lower poverty by improving agriculture productivity and revenue.

- **CLIMATE RESILIENCE:** Farmers may do some adjustments on their systematic ways of farming, because of machine learning algorithms that can categorize weather patterns and could forecast climate-related risks. With the help of much advanced Smart Agriculture systems by means of ML, it's possible to ensure and keep agriculture viable and sufficient despite, the climatic unpredictability.

- **HEALTH & WELL-BEING:** ML-driven Smart Farming approach enables the production of food products that meets higher in terms of safety and healthiness criteria than is normally achieved with the help of chemical inputs. Organic agricultural methods promote the use of this approach. As a consequence of it, we have less pesticides and other toxins on the food, although there is a great benefit to public health status.

3.1.3 ANALYSIS

TECHNOLOGICAL ADVANCEMENTS: Recent trends in agriculture have led to the development of a smart agriculture model, which in turn utilizes machine learning to operate. For farmers, it becomes possible to employ the cloud computing infrastructure and the machine learning methods to increase their capability of extracting valuable information from data and of making predictions in advance, which were impossible earlier. It increases the chances of taking advantage of the agricultural resources adequately and accurately, thus aiding in the raising of production efficiency and propelling sustainability.

DATA-DRIVEN DECISION MAKING: One of the most prominent benefits of Smart Agriculture embedded with the ML algorithms is that it allows farmers to make informed decisions based on the datasets gained. A result of machine learning may be that farmers will benefit from practical recommendations provided by the analysis of large agricultural databases that include crop health indices, weather patterns, and soil composition. This therefore gives the farmers a decision-making power of when to do the planting, what to be irrigated and what to do with the pests, and where and how to spend the resources with knowledge and as such they produce good results.

CHALLENGES AND CONSIDERATIONS: While the ML- based Smart Agriculture is full of advantages, there are some barriers or things that need to address when implementation is concerned. Among the issues are such as the safety and privacy of data, the digital deepening among farmers and the conformity of the systems with the current farming. Major concerns for ML-guided Smart Agricultural solutions to excel are thus magnified.

3.2 PROJECT DESIGN AND ARCHITECTURE

3.2.1 PROJECT DESIGN

Designing an IoT based smart agriculture system on the cloud consists in integrating several components allowing for real time observation, data gathering as well as making decisions. A typical project design may include the following elements:

- **DEFINE PROJECT OBJECTIVES:** Clearly outline the goals and dreams of the project, including enhancing crop yield, optimizing aid management, or improving sustainability in agriculture.
- **ASSES NEEDS AND REQUIREMENTS:** Conduct a complete wishes evaluation to become aware of the precise demanding situations and necessities of the goal agricultural network or region. Determine the sorts of agricultural information available, current infrastructure, technological talents, and regions in which ML-primarily based totally answers can offer the maximum vast impact.
- **SELECT ML ALGORITHMS AND CLOUD PLATFORMS:** Research and pick suitable ML algorithms for studying agricultural information, including regression, classification, clustering, or deep getting to know algorithms. Choose a cloud computing platform that gives scalability, reliability, and information processing talents appropriate for ML-primarily based totally programs in agriculture, including Amazon Web Services (AWS), Microsoft Azure, or Google.
- **DATA COLLECTION AND PREPARATION:** Develop a scheme for aggregation and selection of agricultural information, which consists of soil requirements, climate patterns, field fitness properties, and past yield details. Please take note that, these types of information come from diverse sources, including IoT sensors, satellites imagery, drones, and agricultural databases, thus leading to a complete dataset for the training of ML models.
- **MODEL DEVELOPMENT AND TRAINING:** Construct ML techniques that are specifically designed to handle the specific agricultural issues, which include production forecasting, pest detection, and irrigation optimization. Machine Learning fashions

classify the usage of the collected agricultural information, improving parameters and overriding the model based on validation results.

- **INTEGRATION AND DEPLOYMENT:** Maintain the fashion of ML to the cloud-based architecture, guaranteeing that the development goes along with the existing agricultural technologies and systems. Use smart solutions in agricultural domain that are based on Machine Learning technologies, developed in the cloud platform and configured by tracking and alerting mechanisms for performance monitoring and problem detection.
- **TESTING AND VALIDATION:** Conduct rigorous trying out and validation of ML-primarily based totally Smart Agriculture structures in real-international agricultural settings, taking part intently with farmers and agricultural stakeholders.Evaluate the accuracy, reliability, and usefulness of the deployed answers, soliciting remarks from end-customers to discover regions for improvement.
- **TRAINING AND CAPACITY BUILDING:** Provide schooling packages and capacity-constructing projects to train farmers and agricultural stakeholders on using ML-primarily based totally Smart Agriculture technologies.Offer technical aid and steerage to make certain that customers can successfully make use of the deployed answers to beautify their farming practices.

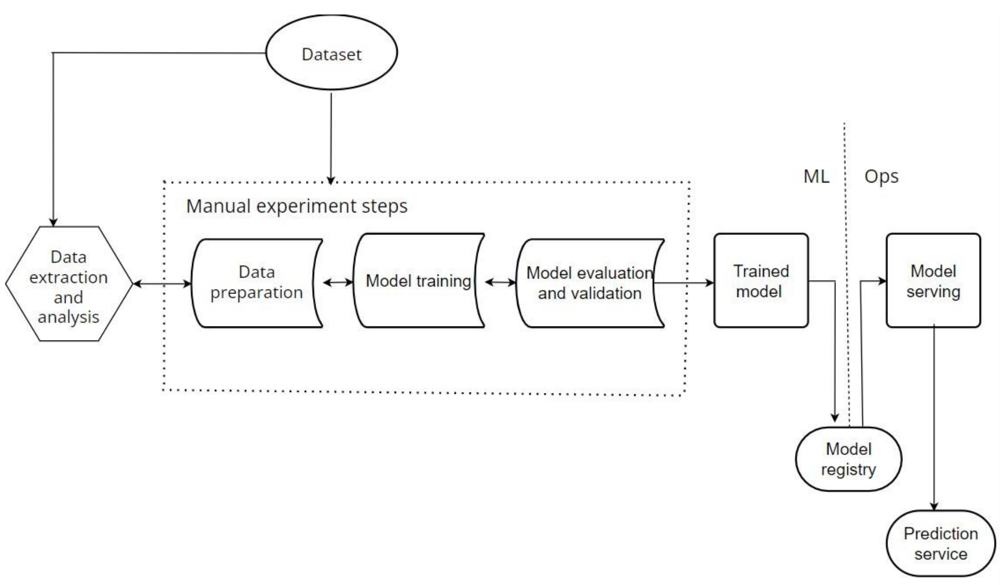


Fig. 3.2: Project design

3.2.2 PROJECT ARCHITECTURE

An IoT based smart agriculture system in the clouds usually utilizes many mechanisms like real-time tracking, and data acquisition for effective decision-making. Based on the provided sources, the following points outline the key aspects of the project architecture:

DATA COLLECTION LAYER:

- IoT Sensors: Deploy sensors for gathering real-time facts on soil moisture, temperature, humidity, and different environmental parameters.
- Data Sources: Aggregate facts from climate stations, agricultural databases, ancient records, and different applicable reasserts to create a complete dataset.

DATA PROCESSING AND STORAGE LAYER:

- Data Ingestion: Ingest uncooked facts from numerous reassets right into a centralized facts repository or facts lake for garage and processing.
- Data Preprocessing: Cleanse, transform, and preprocess the facts to deal with lacking values, outliers, and inconsistencies earlier than in addition analysis.
- Data Storage: Store the preprocessed facts in a scalable and dependable cloud-primarily based totally garage solution, including Amazon S3, Google Cloud Storage, or Azure Blob Storage.

MACHINE LEARNING LAYER:

- Model Development: Develop and teach ML fashions the use of strategies including regression, classification, clustering, or deep studying to deal with unique agricultural tasks.
- Feature Engineering: Extract applicable capabilities from the preprocessed facts to enhance version overall performance and predictive accuracy.
- Model Training: Utilize cloud-primarily based totally ML platforms, including Amazon SageMaker, Google Cloud AI Platform, or Azure Machine Learning, to teach ML fashions at scale the use of dispensed computing.

DECISION SUPPORT LAYER:

- Prediction and Recommendation Engine: Implement a prediction and advice engine to generate insights and guidelines primarily based totally at the output of ML fashions.
- Visualization and Dashboards: Create interactive visualizations, dashboards, and reviews to provide the insights and guidelines in a user-pleasant layout for farmers and agricultural stakeholders.

APPLICATION LAYER:

- Web and Mobile Applications: Develop net and cell programs to offer farmers with get entry to to the ML-primarily based totally Smart Agriculture system, permitting them to view insights, obtainguidelines, and take movement on their farming operations.
- APIs and Integration: Expose APIs for integrating with third-celebration programs, agricultural machinery, and IoT gadgets to permit seamless facts alternate and interoperability.

3DATA PREPARATION

Some steps in processing raw data for smart agriculture based on IoT and storing it at the cloud for ensuring that it is accurate, reliable, and suitable to be used. The following points outline the data preparation process based on the provided sources:

- **DATA COLLECTION:** The first stage is data collection, during which information is gathered by numerous sensors and controls mounted in an agrarian environment. Such instruments collect data related to an array of elements, such as air temperature, ambient and ground moisture, as well as plant condition written.

- **DATA TRANSMISSION:** The collected information is forwarded to the cloud server where it is stored as well as analyzed.Y It is normally carried out by means of wireless and cellular telecommunication like by Wi-Fi, Bluetooth or cellular networking.

- **DATA STORAGE:** A cloud based database/data warehouse will, hence hold this data and make it accessible to the farmers or even any interested party for analysis. In most cases, data are usually stored in simple orderly systems such as relational databases or data lakes .

- **DATA CLEANING:** Before analysis of data, it needs to be cleansed and corrected for possible mistakes and variations. This may include removal of duplicates, correction of data entry errors, and completion of blanks among others.

- **DATA INTEGRATION:** In some instances, it might be necessary to combine the data collected from different sources in order to have full understanding of the agricultural environment. Such operation might use information from distinct sensors, controllers, and even external data such as weather statistics.

- **DATA TRANSFORMATION:** Data cleaning and integration may also be required after which it may be transformed in an appropriate form for analysis. This could include combining the information, computing descriptive analyses as well as creating additional fields of data.

- **DATA ANALYSIS:** This completes the process of data preparation which involves analyzing the data to arrive at important conclusions.7BPACKThese can be based on various forms of statistics, machine learning and other analysis to see the trends, pattern among others that are unusual.

- **DATASET:** This dataset was build by augmenting datasets of rainfall, climate and fertilizer data available for India. We have 2200 rows and 8 columns in the dataset with no missing values. All values in the data are numerical except for the label data.

DATA FIELDS:

N - ratio of Nitrogen content in soil

K - ratio of Potassium content in soil

temperature - temperature in degree Celsius

humidity - relative humidity in %

ph - ph value of the soil

rainfall - rainfall in mm

A	B	C	D	E	F	G	H	I
N	P	K	temperatu	humidity	ph	rainfall	label	
90	42	43	20.87974	82.00274	6.502985	202.9355	rice	
85	58	41	21.77046	80.31964	7.038096	226.6555	rice	
60	55	44	23.00446	82.32076	7.840207	263.9642	rice	
74	35	40	26.4911	80.15836	6.980401	242.864	rice	
78	42	42	20.13017	81.60487	7.628473	262.7173	rice	
69	37	42	23.05805	83.37012	7.073454	251.055	rice	
69	55	38	22.70884	82.63941	5.700806	271.3249	rice	
94	53	40	20.27774	82.89409	5.718627	241.9742	rice	
89	54	38	24.51588	83.53522	6.685346	230.4462	rice	
68	58	38	23.22397	83.03323	6.336254	221.2092	rice	
91	53	40	26.52724	81.41754	5.386168	264.6149	rice	
90	46	42	23.97898	81.45062	7.502834	250.0832	rice	
78	58	44	26.8008	80.88685	5.108682	284.4365	rice	
93	56	36	24.01498	82.05687	6.984354	185.2773	rice	
94	50	37	25.66585	80.66385	6.94802	209.587	rice	
60	48	39	24.28209	80.30026	7.042299	231.0863	rice	
85	38	41	21.58712	82.78837	6.249051	276.6552	rice	
91	35	39	23.79392	80.41818	6.97086	206.2612	rice	
77	38	36	21.86525	80.1923	5.953933	224.555	rice	
88	35	40	23.57944	83.5876	5.853932	291.2987	rice	
89	45	36	21.32504	80.47476	6.442475	185.4975	rice	
76	40	43	25.15746	83.11713	5.070176	231.3843	rice	
67	59	41	21.94767	80.97384	6.012633	213.3561	rice	
83	41	43	21.05254	82.6784	6.254028	233.1076	rice	
98	47	37	23.48381	81.33265	7.375483	224.0581	rice	
66	53	41	25.07564	80.52389	7.778915	257.0039	rice	
97	59	43	26.35927	84.04404	6.2865	271.3586	rice	
97	50	41	24.52923	80.54499	7.07096	260.2634	rice	
60	49	44	20.77576	84.49774	6.244841	240.0811	rice	
84	51	35	22.30157	80.64416	6.043305	197.9791	rice	

Fig. 3.3: Dataset

3.2 IMPLEMENTATION

```
[3] import numpy as np
    import pandas as pd
```

```
[4] crop = pd.read_csv("Crop_recommendation.csv")
    crop.head()
```

	N	P	K	temperature	humidity	ph	rainfall	label
0	90	42	43	20.879744	82.002744	6.502985	202.935536	rice
1	85	58	41	21.770462	80.319644	7.038096	226.655537	rice
2	60	55	44	23.004459	82.320763	7.840207	263.964248	rice
3	74	35	40	26.491096	80.158363	6.980401	242.864034	rice
4	78	42	42	20.130175	81.604873	7.628473	262.717340	rice

Next steps: View recommended plots

```
[5] crop.shape

(2200, 8)
```

```
[6] crop.info()

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 2200 entries, 0 to 2199
Data columns (total 8 columns):
 #   Column       Non-Null Count  Dtype
---  ------       --------------  -----
 0   N            2200 non-null   int64
 1   P            2200 non-null   int64
```

Fig. 3.4: Reading dataset

Exploring data

```
##corr = crop.corr()
##corr
```

+ Code   + Text

```
[9] crop['label'].value_counts()
```

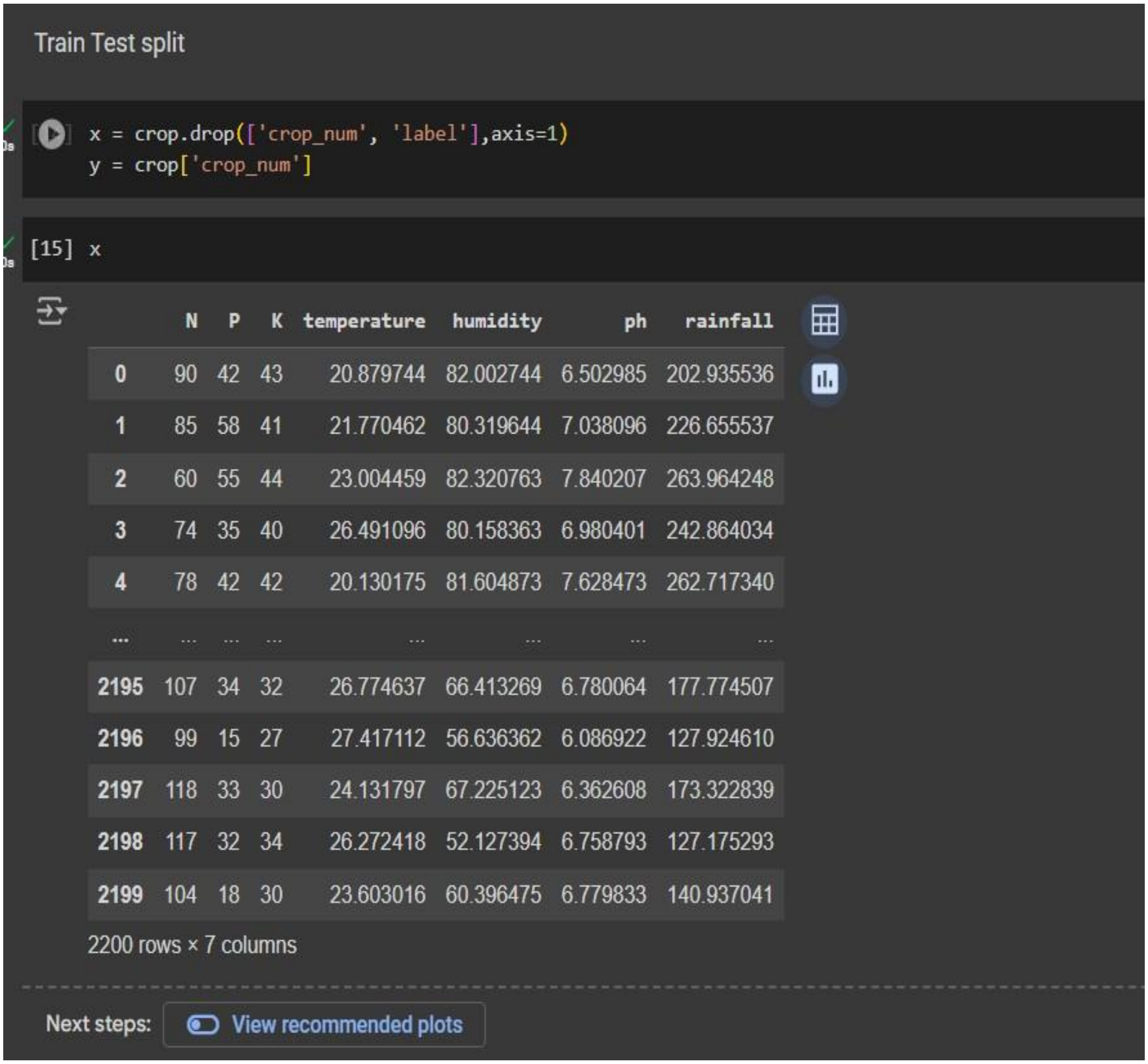
```
label
rice           100
maize          100
jute           100
cotton         100
coconut        100
papaya         100
orange         100
apple          100
muskmelon      100
watermelon     100
grapes         100
mango          100
banana         100
pomegranate    100
lentil         100
blackgram      100
mungbean       100
mothbeans      100
pigeonpeas     100
kidneybeans    100
chickpea       100
coffee         100
Name: count, dtype: int64
```

Fig. 3.5: Exploring data

Encoding

```
crop_dict = {
    'rice': 1,
    'maize': 2,
    'jute': 3,
    'cotton': 4,
    'coconut': 5,
    'papaya': 6,
    'orange': 7,
    'apple': 8,
    'muskmelon': 9,
    'watermelon': 10,
    'grapes': 11,
    'mango': 12,
    'banana': 13,
    'pomegranate': 14,
    'lentil': 15,
    'blackgram': 16,
    'mungbean': 17,
    'mothbeans': 18,
    'pigeonpeas': 19,
    'kidneybeans': 20,
    'chickpea': 21,
    'coffee': 22
}
crop['crop_num']=crop['label'].map(crop_dict)
```

Fig. 3.6: Encoding



Train Test split

```
x = crop.drop(['crop_num', 'label'],axis=1)
y = crop['crop_num']
```

```
[15] x
```

	N	P	K	temperature	humidity	ph	rainfall
0	90	42	43	20.879744	82.002744	6.502985	202.935536
1	85	58	41	21.770462	80.319644	7.038096	226.655537
2	60	55	44	23.004459	82.320763	7.840207	263.964248
3	74	35	40	26.491096	80.158363	6.980401	242.864034
4	78	42	42	20.130175	81.604873	7.628473	262.717340
...	...	...	...	...	...	...	...
2195	107	34	32	26.774637	66.413269	6.780064	177.774507
2196	99	15	27	27.417112	56.636362	6.086922	127.924610
2197	118	33	30	24.131797	67.225123	6.362608	173.322839
2198	117	32	34	26.272418	52.127394	6.758793	127.175293
2199	104	18	30	23.603016	60.396475	6.779833	140.937041

2200 rows × 7 columns

Next steps: View recommended plots

Fig. 3.7: Training and Testing split

```
y.shape
```

```
(2200,)
```

```
[17] from sklearn.model_selection import train_test_split
```

```
[18] x_train, x_test, y_train, y_test = train_test_split(x, y, test_size=0.2, random_state=42)
```

```
[19] x_train.shape
```

```
(1760, 7)
```

```
[20] x_test.shape
```

```
(440, 7)
```

```
[21] x_train
```

	N	P	K	temperature	humidity	ph	rainfall
1656	17	16	14	16.396243	92.181519	6.625539	102.944161
752	37	79	19	27.543848	69.347863	7.143943	69.408782
892	7	73	25	27.521856	63.132153	7.288057	45.208411
1041	101	70	48	25.360592	75.031933	6.012697	116.553145
1179	0	17	30	35.474783	47.972305	6.279134	97.790725
...	...	...	...	...	...	...	...
1638	10	5	5	21.213070	91.353492	7.817846	112.983436

Fig. 3.8: Training data

Training Models

```
[26] from sklearn.linear_model import LogisticRegression
     from sklearn.svm import SVC
     from sklearn.neighbors import KNeighborsClassifier
     from sklearn.tree import DecisionTreeClassifier
     from sklearn.tree import ExtraTreeClassifier
     from sklearn.ensemble import RandomForestClassifier
     from sklearn.metrics import accuracy_score


     # create instances of all models
     models = {
         'Logistic Regression': LogisticRegression(),
         'Support Vector Machine': SVC(),
         'K-Nearest Neighbors': KNeighborsClassifier(),
         'Decision Tree': DecisionTreeClassifier(),
         'Random Forest': RandomForestClassifier()
     }


     for name, md in models.items():
         md.fit(x_train,y_train)
         ypred = md.predict(x_test)

         print(f"{name}  with accuracy : {accuracy_score(y_test,ypred)}")
```

```
Logistic Regression  with accuracy : 0.9636363636363636
Support Vector Machine  with accuracy : 0.9681818181818181
K-Nearest Neighbors  with accuracy : 0.9590909090909091
Decision Tree  with accuracy : 0.9863636363636363
Random Forest  with accuracy : 0.9931818181818182
```

Fig. 3.9: Training models

```
[27] rfc = RandomForestClassifier()
     rfc.fit(x_train,y_train)
     ypred = rfc.predict(x_test)
     accuracy_score(y_test,ypred)
```

```
0.9931818181818182
```

Fig. 3.10: Maximum accuracy

Predictive system

```python
def recommendation(N,P,k,temperature,humidity,ph,rainfal):
    features = np.array([[N,P,k,temperature,humidity,ph,rainfal]])
    transformed_features = ms.fit_transform(features)
    transformed_features = sc.fit_transform(transformed_features)
    prediction = rfc.predict(transformed_features).reshape(1,-1)

    return prediction[0]
```

```python
[29] N = 40
P = 50
k = 50
temperature = 40.0
humidity = 20
ph = 100
rainfall = 100

predict = recommendation(N,P,k,temperature,humidity,ph,rainfall)


crop_dict = {1: "Rice", 2: "Maize", 3: "Jute", 4: "Cotton", 5: "Coconut", 6: "Papaya", 7: "Orange",
                 8: "Apple", 9: "Muskmelon", 10: "Watermelon", 11: "Grapes", 12: "Mango", 13: "Banana",
                 14: "Pomegranate", 15: "Lentil", 16: "Blackgram", 17: "Mungbean", 18: "Mothbeans",
                 19: "Pigeonpeas", 20: "Kidneybeans", 21: "Chickpea", 22: "Coffee"}

if predict[0] in crop_dict:
    crop = crop_dict[predict[0]]
    print("{} is a best crop to be cultivated. ".format(crop))
else:
    print("Sorry are not able to recommend a proper crop for this environment")
```

```
Papaya is a best crop to be cultivated.
```

Fig. 3.11: Prediction system

```python
from flask import Flask, request, render_template
import numpy as np
import pandas as pd
import sklearn
import pickle
import os

# importing model
model = pickle.load(open('model.pkl', 'rb'))
sc = pickle.load(open('standscaler.pkl', 'rb'))
ms = pickle.load(open('minmaxscaler.pkl', 'rb'))

# creating flask app
app = Flask(__name__)

@app.route('/')
def index():
    template_path = os.path.abspath("app.html")
    print("Template path:", template_path)
    return render_template("app.html")

@app.route("/predict", methods=['POST'])
def predict():
    N = request.form['Nitrogen']
    P = request.form['Phosporus']
    K = request.form['Potassium']
    temp = request.form['Temperature']
    humidity = request.form['Humidity']
    ph = request.form['Ph']
    rainfall = request.form['Rainfall']

    feature_list = [N, P, K, temp, humidity, ph, rainfall]
    single_pred = np.array(feature_list).reshape(1, -1)

    scaled_features = ms.transform(single_pred)
    final_features = sc.transform(scaled_features)
    prediction = model.predict(final_features)
```

Fig. 3.12: Code snippets for flask

```python
crop_dict = {1: "Rice", 2: "Maize", 3: "Jute", 4: "Cotton", 5: "Coconut", 6: "Papaya", 7: "Orange",
             8: "Apple", 9: "Muskmelon", 10: "Watermelon", 11: "Grapes", 12: "Mango", 13: "Banana",
             14: "Pomegranate", 15: "Lentil", 16: "Blackgram", 17: "Mungbean", 18: "Mothbeans",
             19: "Pigeonpeas", 20: "Kidneybeans", 21: "Chickpea", 22: "Coffee"}

if prediction[0] in crop_dict:
    crop = crop_dict[prediction[0]]
    result = "{} is the best crop to be cultivated right there".format(crop)
else:
    result = "Sorry, we could not determine the best crop to be cultivated with the provided data."
return render_template('app.html', result=result)


# python main
if __name__ == "__main__":
    app.run(debug=True)
```

Fig. 3.13: Code snippets for flask

```html
<!doctype html>
<html lang="en">
  <head>
    <meta charset="utf-8">
    <meta name="viewport" content="width=device-width, initial-scale=1">
    <title>Bootstrap demo</title>
    <link href="https://cdn.jsdelivr.net/npm/bootstrap@5.3.0-alpha3/dist/css/bootstrap.min.css" rel="stylesheet"
  </head>
  <style>
        h1 {
            color: mediumseagreen;
            text-align: center;
        }

        .warning {
            color: red;
            font-weight: bold;
            text-align: center;
        }
        .card{
        margin-left:410px;
        margin-top: 20px;
        color: white;
        }
        .container{
        background:#edf2f7;
        font-weight: bold;
        padding-bottom:10px;
        border-radius: 15px;
        }
    </style>
```

Fig. 3.14: Frontend code

3.3 KEY CHALLENGES

The key challenges faced in IoT-based smart agriculture on the cloud are as follows:

- **LACK OF INFORMATION AND AWARENESS:** Most farmers do not understand what IoT means for their business. The poor awareness associated with the IoT has resulted in some reluctance among these farmers when it comes to adopting these technologies that are beneficial in many ways.
- **HIGH ADOPTION COSTS:** However, such implementation of IoT in agriculture requires special equipment that may even have high price. Sensors may be cheap; however putting many of them on the farm may cost up to one thousand dollars per season. Automated machinery as well as farm management software are equally expensive to implement. Consequently, farmers often find themselves straining to finance the initial IoT installation.
- **LACK OF INFRASTRUCTURE:** However, many farmers would still be unable to benefit fully from IoT deployment owing to poor communications networks. Such farms are located away from internet access and hence cannot reach the technology. In order to have accurate access to crop data by farmers even in remote locations, connectivity remains crucial meaning problems with connectivity could make advance monitoring system redundant.
- **ENVIRONMENTAL FACTORS:** Extreme weather conditions are among environmental factors that affect the functioning and dependability of IoT-based sensors and devices used in farming. Sensors and other data-carrying hardware may be destroyed by harsh weather, which may result in misleading information as well as system failure.
- **DATA QUALITY AND AVAILABILITY:** The information, together with soil composition, climate patterns, and crop fitness metrics, might also additionally range in best and availability, in particular in far away or underserved regions. Challenges include the lack of complete or reliable information sources, information inconsistency and the restriction of access to the real-time information streams which are the main reasons for the inaccuracy and ineffectiveness of the ML models.

CHAPTER 4: TESTING

4.1 TESTING STRATEGY

Cloud-based testing strategy for smart agriculture based on Internet of Things consists of a number of important components ensuring that the system is efficient and trustworthy. Based on the provided sources, the following points outline the testing strategy:

- **END-TO-END TESTING:** Conduct give up-to-give up trying out to validate the whole ML-primarily based totally Smart Agriculture machine from records ingestion to choice assist and person interface.Test real-international eventualities and person workflows to evaluate machine overall performance, accuracy, and usefulness beneathneath regular running conditions.

- **REGRESSION TESTING:** Implement regression trying out to stumble on and save you regression defects delivered at some point of machine updates, enhancements, or changes.Re-run formerly carried out take a look at instances to make sure that current capability stays intact and unaffected via way of means of code adjustments or configuration changes.

- **PERFORMANCE TESTING**: Perform overall performance trying out to assess the scalability, responsiveness, and throughput of the ML-primarily based totally Smart Agriculture machine beneathneath various masses and conditions.Measure machine reaction times, useful resource utilization, and throughput metrics to perceive overall performance bottlenecks and optimize machine overall performance.

- **INTEGRATION TESTING:** Make sure that the IoT devices, modes of communication, and cloud platforms work together in a way they should. This may be tried by imposing different scenarios on the system and observing its responses.

- **DATA ACCURACY TESTING:** Compare with reference values and established approaches to ensure the correctness of collected data. It is possible to perform cross- checks on the accuracy of the system, say, comparing the sensor reading against that of a reference sensor or through analysis of the data for consistency and patterns.

- **SYSTEM PERFORMANCE TESTING:** Measure the effectiveness of the IoT-based smart agriculture system by considering whether it is capable of attaining the established performance objectives. It is possible to do this by monitoring important indicators e.g. crop yield, irrigation effectiveness and energy consumption among others.

4.1.1 TOOLS USED

Several of these tools on cloud help to trace as well monitor several functions in the activities of a farmer within IOT smart agriculture. Some of these tools include:

4.1.1.1 HARDWARE REQUIREMNET

1. ARDUINO UNO: The Arduino Uno Microchip is an open-source microcontroller board based on the ATmega328P microcontroller and developed by Arduino. cc, originally released in 2010. It is a versatile and widely used board for electronics and coding projects Arduino Uno has some basic features:

- 14 digital input/output pins (6 can be used as PWM outputs).
- Analog input pin
- MHz ceramic resonator
- USB connection
- ICSP theme
- Reset button

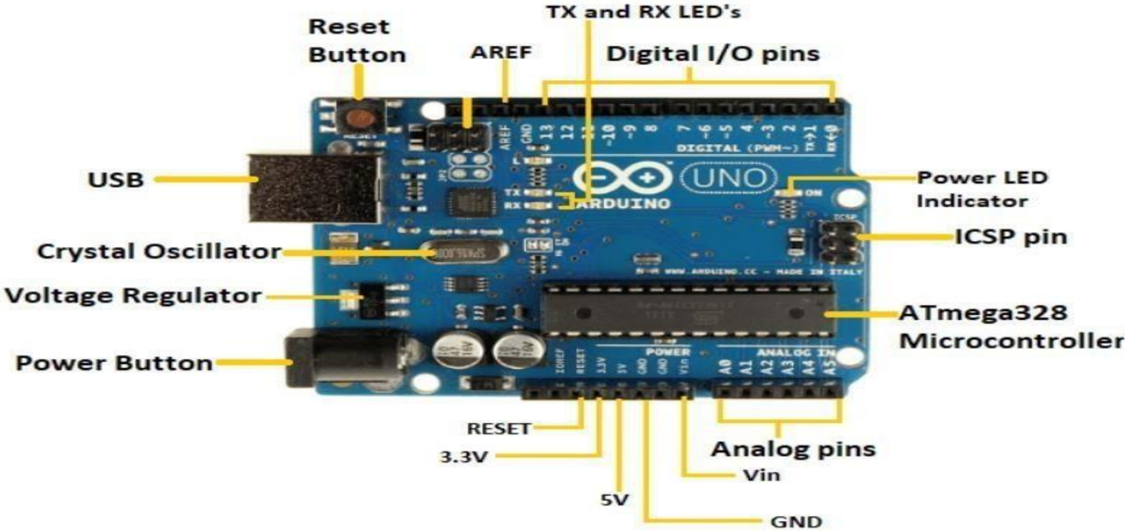


Fig. 4.1: Arduino Uno

2. SOIL SENSOR: Soil sensors play an important role in IoT-based smart farming in the cloud, enabling real-time monitoring of soil conditions and facilitating data-driven decision-making These sensors are like pH levels, temperature, and water with these crops help in analyzing different soil parameters, providing farmers with valuable insights into soil quality and health.

Fig. 4.2: Soil sensor

3. TEMPERATURE SENSOR: Temperature sensors play an important role in IoT- based smart farming in the cloud, as they help monitor and control optimal temperature conditions for crop growth and development These sensors can be integrated into smart agricultural systems, such as IoT-based Smart sensor farm sticks , which use Arduino, cloud computing and solar technology to monitor organic temperatures.

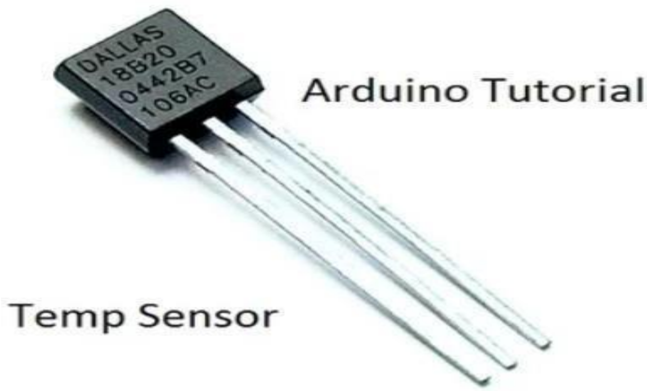


Fig. 4.3: Temperature sensor

4. HUMIDITY SENSOR: Moisture plays an important role in IoT-based smart farming in the cloud, as it helps in monitoring and managing water quality for crop growth and development These sensors can be integrated into various smart agriculture systems,
e.g. IoT-based smart sensor farm sticks that use Arduino, cloud computing and solar technology to monitor organic temperature.

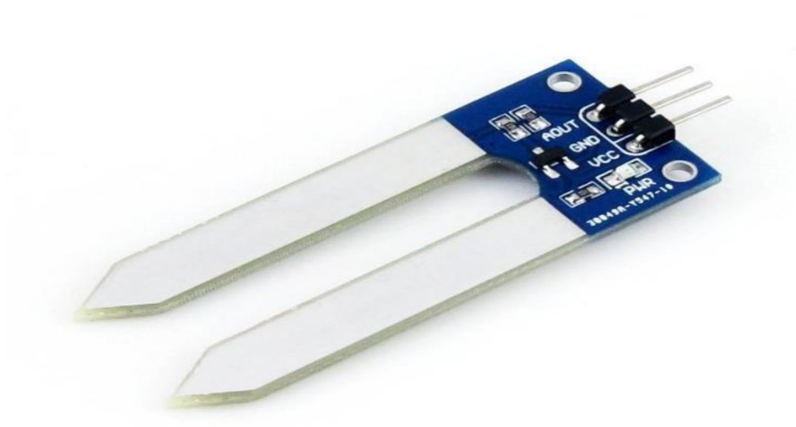


Fig. 4.4: Humidity sensor

5. LED DISPLAY: The use of LED display in cloud-based IoT smart agriculture is not clearly mentioned in the given source. However, LED displays can be used in smart agriculture systems to provide real-time information to farmers and agricultural stakeholders. This screen can display temperature, humidity, soil moisture and other relevant data collected from IoT sensors.

Fig. 4.5: LED Display

4.1.1.2 SOFTWARE REQUIREMENTS

CLOUD-ENABLED IoT PLATFORMS: Smart agriculture uses cloud-enabled IoT platforms to provide real-time data analysis, collection, and collaboration. These forums enable farmers to make informed decisions and improve agricultural practices. MQTT cloud server is used as IoT platform.

DATA ANALYTICS AND MACHINE LEARNING: Data analytics and machine learning are important in IoT-based smart farming in the cloud. These technologies enable valuable insights to be extracted from agricultural data, improving decision- making, resource efficiency, and automation. Using cloud-based IoT data analytics, large-scale data collection and analysis can be applied to farmland with network connectivity information, enabling machine learning systems to accurately and controllably observe, and analyze data sources including IoT sensor data, weather able to do.

IoT APPLICATIONS: IoT applications are crucial in IoT-based smart agriculture in the cloud. The service provides farmers with real-time crop and weather information, allowing them to make informed crop scheduling, disease control, and resource management decisions. Cloud-based IoT applications for smart farming. and optimize aspects of farm operation support to increase productivity, sustainability, and yields.

4.1.2 TESTING PHASES

The testing phases in IoT-based smart agriculture on the cloud typically include the following:

- **FUNCTION AND PERFORMANCE TESTING:** During this stage, the Thing View mobile device tests the functions and efficacy of IoT components, such as the sensors and control systems. The testing is done to make sure that the sensors are sensing the environmental parameters correctly and the system is operating at its predicted levels.

- **DATA TRANSMISSION TESTING:** The second phase entails testing the quality of data links between and among end users and the cloud service provider. This helps to ensure that the data coming from the sensors is moving to the cloud with no delays. Such testing cannot be ignored since it helps to guarantee that credible information will be utilized in analysis and decision making

- **SECURITY TESTING:** The third phase consists of penetration testing, which seeks to highlight possible loopholes in the system. The audit plan should test for the strength of the data encryption, authentication procedures among users and access rights.

- **SYSTEM PERFORMANCE TESTING:** This phase tests the total functioning of the system with special emphasis on factors like speed of reaction, volume of information handled and resources utilized. It enables the system to work in line with the specified performance targets and objectives like real time monitoring and making decisions.

4.2 TEST CASES AND OUTCOMES

Testing results are dependent on a selected testing phase and the purpose of testing that has been done of IoT-based smart farming on the cloud. However, some general outcomes that can be expected from testing IoT-based smart agriculture on the cloud are:

IMPROVED DATA ACCURACY: The sensors' data can be tested for potential corrections of errors or incorrectness. As such, it enhances the reliability and accuracy of the generated data that can be relied upon in planning for agriculture activities within a country.

INCREASED SYSTEM RELIABILTY: The testing of the IoTT device ensures that they are okay while the testing on communication protocols ensures that they are okay while the last one ensures that cloud platforms do not have any problems on their end.

OPTIMIZED AGRICULTURAL OPERATIONS: Some tests can be done and they may highlight some weaknesses like the water management of crops, their health status or how assets are being utilized effectively among others. Doing so facilitates efficient agricultural activities and enhances production of more crops.

IMPROVED USER EXPERIENCE: In turn, testing will be able to find all usability problems with this system, which means it should be comfortable for the farmers and other agricultural stakeholders who are its users.

CHAPTER 5: RESULTS AND EVALUATION

5.1 RESULTS

The assessment process includes a thorough analysis of how effective the IoT Based Smart Agriculture on the Cloud project is, what impact has it made in terms of agricultural practices and whether or not the set objectives were realized. An overview of the findings and assessment is provided below:

1. USER INPUT AND ACCEPTANCE:

- **RESULT:** The farmer's assessment of the usefulness of the smart agricultural system, the potency of its recommended outputs, and the general level of user satisfaction.

- **METRICS:** Find out how often users accept the system, how often they utilize it, and how much smart agriculture advice is really incorporated into certain farm management choices.

- **EVALUATION:** Determine what needs to be developed and how much it will influence farmers' decision-making by using qualitative feedback.

2. OPTIMIZATION OF RESOURCES:

- **RESULT:** Therefore, at the end of the day it involves measuring the extent to which smart agriculture utilizes these inputs such as water, fertilizer, and so on.

- **MEASURES:** This entails contrasting the amounts of inputs squandered pre and post-application of smart agriculture for instance; water.

- **EVALUATION:** Showcase ways in which smart agriculture will enhance sustainability by comparing resource optimization criteria with traditional farming technique.

3. QUALITY AND YIELD OF CROPS:

- **RESULT:** Assess the impact of Smart agriculture on general crop health, vegetative growth rates, and subsequent productivities.

- **METRICS:** Measure deviations in crop yields, quality specifications and market price of the produced produce.

- **EVALUATION:** Demonstrates improved yields and/or quality as a result of comparing harvest outcomes against and without Smart agriculture guidance.

4. MONITORING THE ENVIRONMENT:

- **RESULT:** Consider the extent that an agriculturally-based environment is maintained by smart agriculture through monitoring.

- **METRICS:** Evaluate the responsiveness of the system to changes in environmental aspects including air quality, heat extremes and variations in soil moisture contents.

- **EVALUATION:** Provide evidence of how a perfectly functioning system is upheld and sustained through successful cases of environmental interventions. Smart Agriculture suggestions should serve as a guide.

5. ALERT SYSTEM EFFICIENCY:

- **RESULT:** Assess the ability of the early warning system in reaching farmers with critical information promptly and accurately.

- **MEASURES:** Assess how timely the alert notifications are sent out to farmers, as well as their accuracy.

- **EVALUATION:** Think about instances of fast judgments that averted massive crop losses for the sake of analyzing the functionality of the alarm unit.

6. ADHERENCE TO PRIVACY AND DATA SECURITY:

- **RESULT:** Confidential information about agriculture should be encrypted strongly, and privacy laws of the state must be observed.

- **MEASURES:** Evaluate the effectiveness of encryption, perform regular security checks, and ensure compliance with applicable data security legislation.

- **EVALUATION:** Validate whether Smart agriculture adheres to the required levels of security and privacy, so as to reassure users about their information safety.

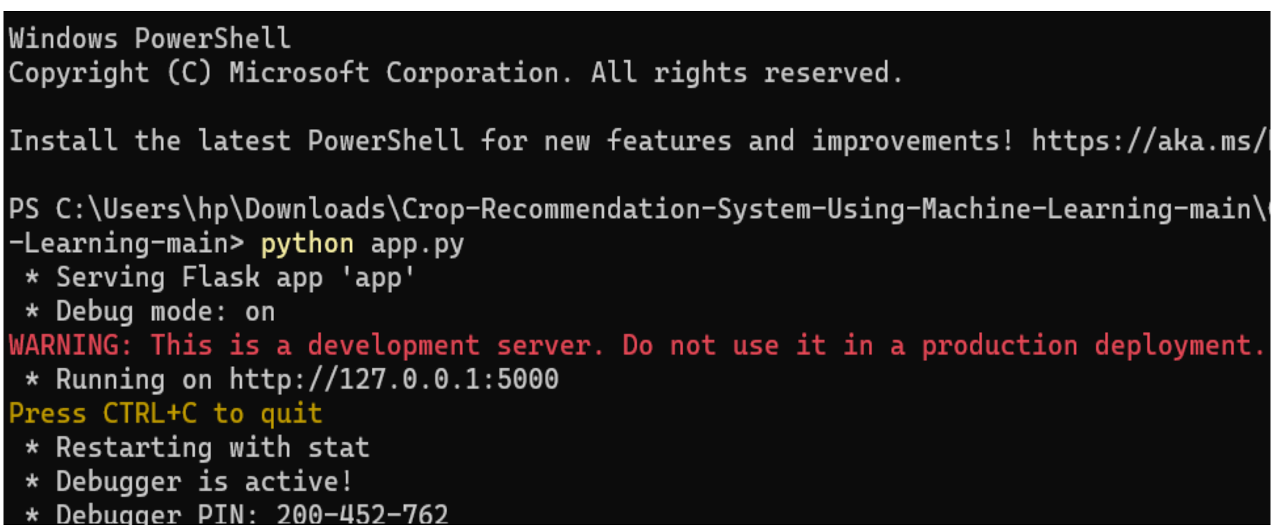


Fig. 5.1 Terminal code snippet

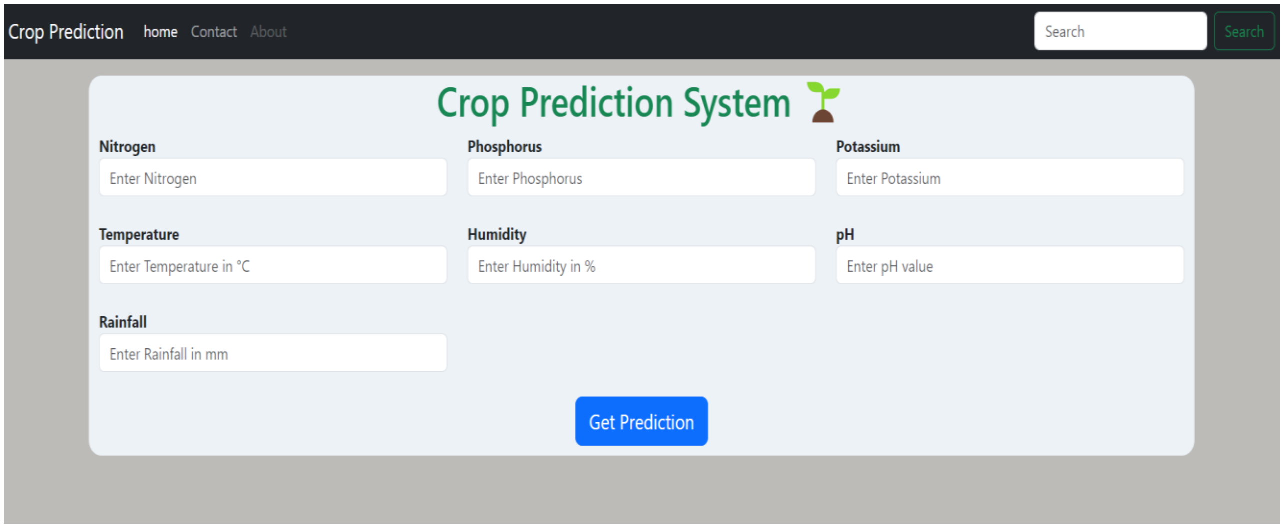


Fig. 5.2: Input from User

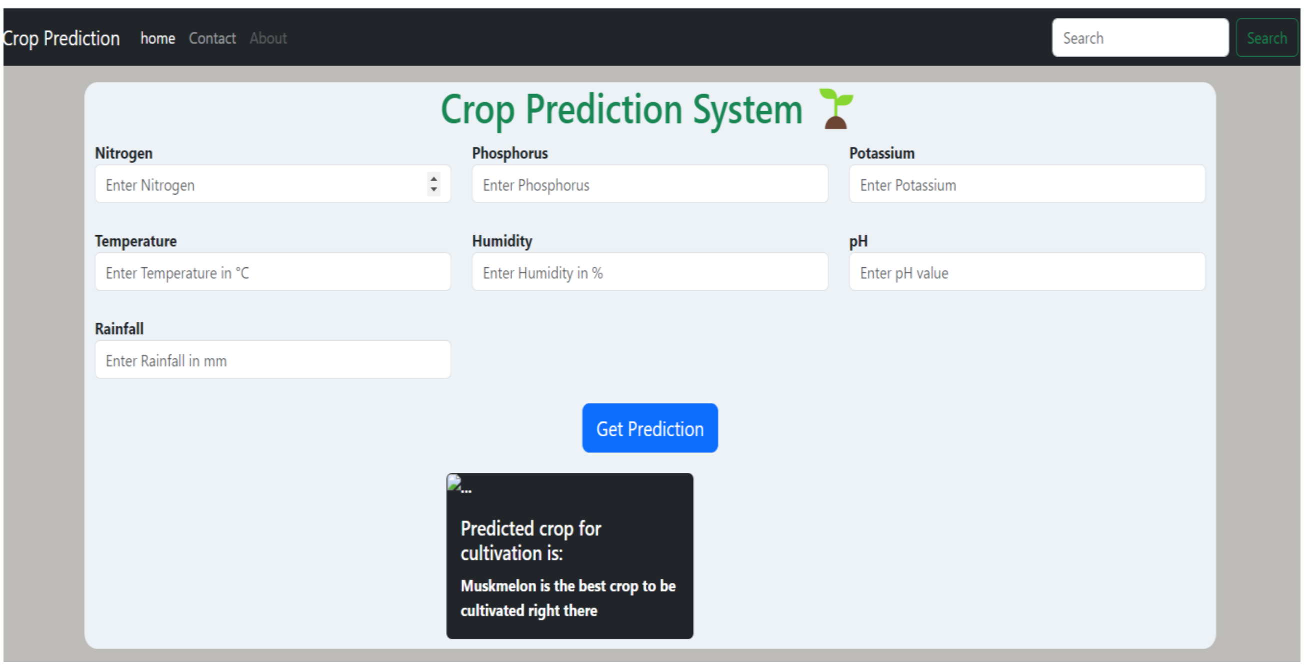


Fig. 5.3: Output

5.2 COMPARISON WITH EXISTING SOLUTIONS

5.2.1 CONSTANT MONITORING OF ENVIRONMENT IN REAL TIME:

Smart agriculture: Such sensors continuously monitor ambient conditions like temperatures, humidity, moisture content in air, and many others.In most of this instances; however, these operations involve periodical observing which may never indicate direct alteration surrounding.

5.2.2 MAKING DYNAMIC SUGGESTIONS WITH MACHINE LEARNING:

This is an example of a smart agriculture where intelligent crop recommendations are deduced from historical data and contemporary situation in this case. However, most options have been extremely rigid due to a particular schedule or regulation.

5.3.3 PRECISION FARMING AND RESOURCE OPTIMIZATION:

The collected information enables smart agricultural to give advice in relation to excess water use and too much fertilizers. By doing this, traditional strategies might utilize resources in extremes and create uninformed impacts on different subjects.

5.3.4 WIRELESS LINK ESTABLISHMENT AND DISTNACE ACCESS:

Smart Agriculture: For highly efficient site monitoring and even off-site data delivered into cloud-based platforms, either a wire or wireless connection enables smart agriculture. Alternatively, traditional methods would comprise of physical site surveys and data collection by hand.

5.3.5 ALERT AND PROACTIVE INTERVENTION SYSTEM:

Smart Agriculture: The provision of an early warning system for farmers on unfavorable weather condition enables them to act immediately and save their crops. However, other approaches might not immediately give off alerts requiring response as situations develop retroactively.

5.3.6 ADOPTION AND TNTERFACE USER-FRIENDLINESS:

Smart Agriculture: It provides an accessible user interface using web/mobile platform for the customer intelligence. There are a good number of alternatives, but their user interface may be too complicated thus unappealing to users who are not technical at all.

5.3.7 COMPILANCE AND DATA SECURITY:

Smart Agriculture: Smart agriculture adheres to safety and data security in order to maintain confidentiality and sanctity of agricultural sensitive information. On the other hand, some systems might prove unreliable in strictly observing data privacy rules and this raise concerns on issues of privacy and compliance.

5.3.8 ADJUSTABILITY AND PREPAREDNESS:

Smart Agriculture: In addition, smart agriculture is built as an expandable system that involves growing the number of users and sensing devices in accordance with changes in farming needs. Some of them are similar to others that will not function properly under scalable large farms and big data volumes.

CHAPTER 6: CONCLUSIONS AND FUTURE SCOPE

6.1 CONCLUSION

RESULT: Therefore, advanced machine learning models were used to design a crop suggestion system whose inputs yielded recommendations aimed at improvement of farm management.

- **IMPACT ON FARMING:** For instance, system control of crops' type, selection based on old and present information will highly enhance agriculture, and conservation of resources.

- **USER ENGAGEMENT:** This allows the user to easily interact, enabling farmers in crop selection as well as resource utilization.

- **TECHNOLOGICAL ADVANCEMENTS:** This is proof that contemporary methods such as IOT devices, machine learning algorithms, and data analytics can be applied to agriculture to ensure sustainable and efficient farming.

- **DATA-DRIVEN DECISION MAKING:** Telemetry is an analytical tool that enables farmers to make enlightened choices in one particular subject area hence empowerment.

- **MOBILE APPLICATION INTERFACE:** Mobile farmers' friendly app for data accessing and management. Warning of critical events/Anomalies alerts and notifications.

- **USER FEEDBACK AND SATISFACTION:** The positive response of farmers who got helped by the new process. Higher satisfaction is caused by better crop management and less workload.

6.2 FUTURE SCOPE

The prospect for Smart Agriculture App in the future may be extremely promising. The subsequent domains offer prospects for additional improvement:

1. IMPROVED MACHINE LEARNING MODELS: Use of more sophisticated algorithms, many dataset from farmers and others should constantly help improve the machine learning models. Consider other methods in deep learning for producing more precise forecasts.

2. EXTENDED SENSOR NETWORK: Enlarge the network's coverage area in order to include diverse breeds of crops, and get knowledge about existing climatic conditions.

3. MOBILE APPLICATION FEATURES: Therefore, there is need to add some few qualities into the web or in the application for instance sending alerts in real time, personalized recommendations and dashboard that can monitor multiple smallholder farmers' plots simultaneously.

4. COMUNITY & COLLABORATIVE FARMING: Seek methods of forming community-based activities that will enhance solidarity among farmers in sharing of knowledge and decision making with each other in the agricultural system for sensitizing community.

5. CLIMATE RESILIENCE AND ADAPTABILITY: The recommendation system should include information about adaptive strategy and climate change. It will help farmers address their issues with lasting changes of climate.

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