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Artificial Intelligence Applications for Innovative Farming and IoT-Based Agriculture

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ABSTRACT

With the rise of Internet of Things (IoT) technology, there has been a profound transformation in various aspects of daily life. Among the many areas benefiting from IoT, smart agriculture stands out as a field of significant interest for researchers. Leveraging IoT and Machine Learning (ML), innovative research in this domain has been flourishing.

IoT-based smart agriculture offers a range of benefits, from optimizing input costs to reducing losses and enhancing resource efficiency. By harnessing data-driven farm management strategies, agricultural productivity can be significantly improved. The IoT generates vast amounts of data with diverse attributes, influenced by factors such as time and location. Effective analysis and processing of this data are crucial for implementing intelligent farm management practices.

As more data is collected, the high-performance computing capabilities of ML unlock new possibilities for data-intensive scientific endeavours. This synergy between IoT and ML holds promise for further advancements in agricultural productivity and sustainability.

Keywords: Detection, Intelligent agriculture, Internet of Things (IoT), Machine learning, Precision farming

INTRODUCTION

Agriculture holds a paramount position in India, serving as a vital source of raw materials for numerous industries and addressing global food requirements.

Innovative agricultural practices are enhancing crop yields and minimizing irrigation wastage, gradually increasing profitability. In the proposed model in FIG-1, a smart irrigation system utilizes a machine learning algorithm to predict the water requirements of crops. This involves considering three crucial factors: moisture levels, temperature, and humidity in agricultural areas. Sensors for temperature, humidity, and moisture are strategically placed in the fields, with the data processed by a microprocessor and transmitted to a cloud-connected Internet of Things device. The decision tree method, a robust machine learning approach, is employed to leverage this data effectively.[1][2]

FIG-1- Agricultural Architecture [3]

The aim of the Internet of Things is to automate processes while reducing the need for human-to- human communication. The Internet of Things (IoT) uses electronic sensors to gather data for the automation process, which is then processed by the controller and finished by the actuators. The objective of the Internet of Things in agriculture is to automate farming operations and associated processes to enhance overall efficiency. Conventional approaches to managing crops, cattle, weeds, soil, water, plants, and tracking animals are inefficient and not entirely automated. They also result in higher labor expenses, higher electricity usage, and more human involvement. Numerous scholars have directed their attention on intelligent systems that enhance output and efficiency while monitoring and controlling agricultural parameters. Measurement data is gathered by intelligent systems.Automating is the main goal of the Internet of Things.[2] The advancement and adoption of IoT and machine learning-driven Smart Agriculture technologies are transforming the agricultural sector, leading to higher crop yields and reduced expenses. As evidenced by price increases and driven by population expansion and urbanization, the farm industry has seen a constructional revolution in recent years. It is without a doubt true that for the agriculture industry to flourish, government investment is necessary. [16][2] While technological progress appears to be advancing globally, decent progress in the agricultural sector is also required. The World Bank estimates that if the current rate of population growth continues, food consumption will rise by 50% by the year 2050. Internet of Things. For instance, in the medical field, a linked gadget can assist doctors in keeping an eye on patients both inside and outside of hospitals.[1][3]

1. LITERATURE REVIEW

Two tiers make up this article. One is an explanation of the algorithm that is specific to agriculture; level two is divided into three broad categories: soil management, water management, and crop management. Management of crops are divided into three categories: crop production, crop quality, and weed and disease detection. The study was conducted using Scopus, Web of Science, and Pub Med, with the focus being on articles published between 2000 and the present. [16][11]

The article's layout appears well structured and thorough. Section 1 starts by summarizing various machine learning models found in literature reviews, followed by evaluations of crop, water, and soil management. In Section 2, the focus shifts to how artificial intelligence and the Internet of Things are applied in sustainable agricultural practices. Lastly, Part 3 wraps up with a discussion that likely integrates findings from the literature review and practical applications, offering insights into future directions and potential challenges in sustainable agriculture.

Overall, the article's organization seems logical and geared towards providing a comprehensive understanding of sustainable agricultural practices, from theory to application and concluding with thoughtful analysis. [5][2]

A machine learning system is deployed to predict crop production, as outlined in the research published in The International Journal of Science and Technology in Engineering. The study emphasizes the utilization of the Random Forest algorithm to forecast agricultural yield using available data. The research, which was presented at the International Conference on Informatics and Computer Communication (ICCCI), focuses on leveraging machine learning to forecast agricultural production based on climatic conditions. In this study, a user-friendly web application named Crop Advisor has been developed as a software tool to predict the influence of meteorological conditions on crop yields. In order to anticipate agricultural production using existing data, the study focuses on applying the Random Forest algorithm. In order to predict agricultural production depending on meteorological conditions, the research focuses on using machine learning. It was presented at the International Conference on Informatics and Computer Communication (ICCCI). The software tool used in this study to forecast how weather patterns would affect agricultural yields is called agricultural Advisor, and it is an easy- to-use web program.[4][2]

2. VISUAL ABBREVIATION

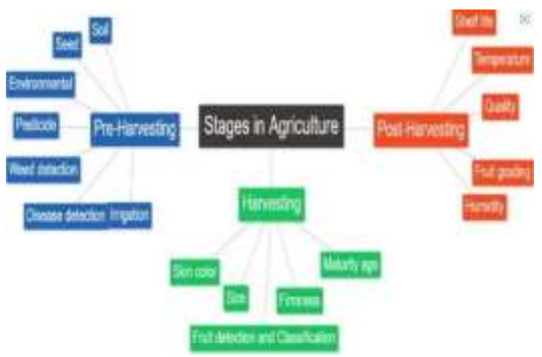

FIG-2-Visual Abbreviation [10]

Farmers often follow the processes listed below when carrying out agricultural operations. Step 1: Selecting a Crop

Step 2: Preparing the Land Step 3: Seeding

Step 4: Fertilizing and Watering

Step 5: Crop Maintenance (applying pesticides, pruning crops, etc. Step 6: Harvesting

Step 7: Post-Harvest Activities

The duties connected to agriculture are divided into major subareas based on the algorithm mentioned above. These four agricultural work sub-domains are depicted in FIG-2). Crop maintenance then becomes imperative, encompassing activities such as pest management, pruning, and weed control, aimed at protecting plants from threats and fostering healthy growth.

Eventually, as crops reach maturity, harvesting marks the culmination of months of dedication, requiring precision and timing to gather produce at its peak. However, the journey doesn't conclude there; post-harvest tasks like sorting, cleansing, and packaging are vital to maintain quality and prepare crops for market or consumption. [10][11]

3. LINKED PAPERWORKS

This section highlights current research being done on the application of irrigation systems in agriculture. They have improved the prediction aspect by using AI approaches. An irrigation sensor based on a smartphone was created by researchers. The smartphone's digital camera is employed to convert RGB images into grayscale for estimating the ratio of wet to dry areas in soil, facilitating soil moisture detection. Subsequently, the gateway sends this moisture-to- dryness ratio to the water motor controller. To manage sensor activities (such as waking up) and put sensors in sleep mode, an application for mobile devices (APP) is developed. When making irrigation decisions, the majority of previous irrigation systems did not take meteorological forecasting data—such as precipitation—into account.[5] Large areas of farmland can be mechanized by using the irrigation technique that the authors of have suggested in order to reduce water waste. Each sensor mote within an Internet of Things system typically comprises a microprocessor, a variety of sensor types (spanning from simple temperature sensors to cameras), actuators, and wireless interfaces.[1] Utilizing data on soil moisture, humidity, and air temperature, the system determine show much water the crop actually needs. The framework employs a machine learning method to compare sensor- derived perceived values with a predefined limit value, which is then analyzed further.

Subsequently, the machine learning system cross-references the obtained result with the forecast, deciding whether to initiate the water supply. Upon receiving immediate notification on their phone, the user can choose to activate the water tap.[3]

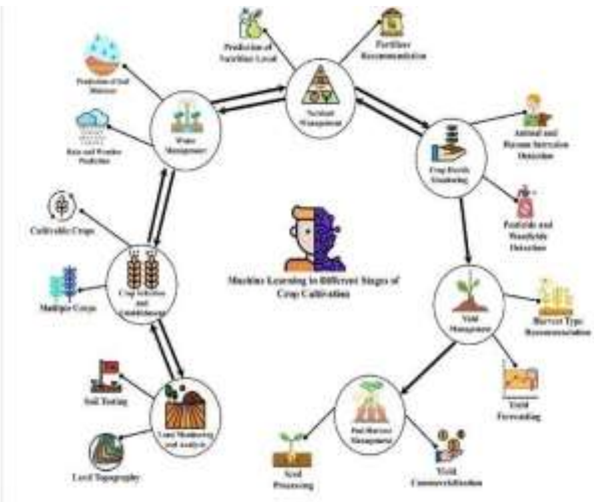

FIG-3-AI in the field of agriculture [12]

This machine learning model to analyze meteorological data and forecast the best time to plant crops in FIG-3. The proposed model utilizes a range of machine learning approaches, including decision trees, support vector machines (SVMs), and K- nearest neighbors (KNNs). In their study, the authors introduce a different machine learning (ML) model incorporating partial least squares regression (PLSR) and the adaptive neuro-fuzzy inference system (ANFIS) to forecast crop water demand. This technique can predict the water requirement of a crop for one week. Patil et al. presented an automated machine learning method for identifying grape plant diseases. They employed the Hidden Markov Model (HMM) and three parameters: moisture, humidity, and leaf wetness. The authors investigated the utilization of machine learning techniques for estimating. [13][15]

4. SUGGESTIVE MODEL

In order for the computer to identify patterns, supervised machine learning methods provide it with previously labelled data for which the answers are engaged in it. It examines various data types, examines the solutions to various issues, and determines any patterns that may be there. We refer to this stage as training the data. The accuracy of the results will increase with the volume of data. Testing the data is the next step in the supervised machine learning process.

During this stage, the machine is given a problem to solve. Knowing the pattern of issue solving as well as potential solutions, the machine provides the best feasible solution.

Regarding a system, the data flow diagram shows which way the data is flowing. All of the system's entities' inputs and outputs are provided. The model of data flow that

FIG-4 illustrates the suggested system. [2][8]

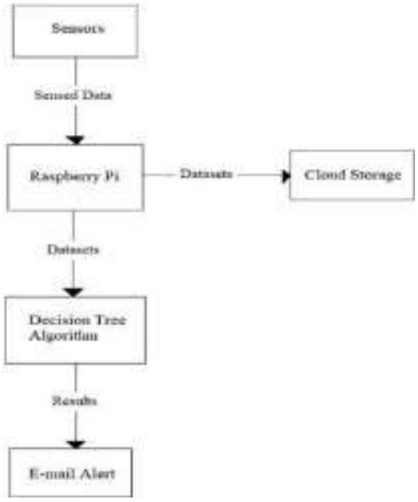

FIG-4-Data Flow Diagram for Suggestive Model [2]

a) **Out of all the supervised learning algorithms**, the decision tree method is considered effective and straightforward. Unlike other supervised learning algorithms, it is versatile and can handle both regression and classification tasks. The main objective of this algorithm is to derive simple and interpretable decision rules from historical or training data to train a model capable of predicting the value or class of the target variable. To forecast the class label of a record, the process starts at the root node of the decision tree, where each attribute value of the record is validated against the root attribute. [7][2]

b) **Design**, the proposed system design primarily includes temperature, soil moisture, and humidity sensors, with the Raspberry Pi playing a central role. It serves as both a web server and storage for field datasets. Data detected by the sensors is transmitted to the Raspberry Pi, where it undergoes storage and processing. The datasets are then analyzed using the decision tree algorithm to generate accurate predictions. The farmer receives an email notification containing the results of the water supply. Additionally, all information received by the Raspberry Pi from the sensors is stored in a cloud database for future reference.[2][5]

c) The decision tree method is supplied with **datasets** that comprise values for soil moisture, humidity, and temperature. The datasets offer a range of variables from diverse field conditions to effectively train the model. The soil moisture content and humidity are shown as percentages, while the temperature is shown in degrees Celsius. Air pressure and wind speed are quantified using specific units, while cloud cover is typically described using qualitative terms. The level of air pollution is assessed through various metrics, whereas precipitation is measured in millimeters or inches. Additionally, solar radiation is typically measured in watts per square meter, whereas visibility is often described in kilometers or miles.[3][5]

5. USE OF MACHINE LEARNING IN AGRICULTURE- BASED IOT

Machine learning (ML) offers a novel method for emulating human learning processes, knowledge acquisition, continuous performance enhancement, and distinctive advancement for machines. In recent years, ML has showcased significant success in algorithms, theories, and applications when integrated with other agricultural methodologies to optimize productivity and reduce costs. ML applications in agriculture encompass various domains, including weather prediction, crop quality assessment, disease and pest detection, irrigation management, soil analysis, and weed identification. Post-harvest, ML can be utilized to evaluate the freshness of agricultural products, such as fruits and vegetables, as well as to assess shelf life, product quality, market trends, and other pertinent factors.[4]

Various machine learning algorithms, including support vector machines (SVM), naive Bayes, discriminant analysis, K-means clustering, fuzzy clustering, Gaussian mixture models, artificial neural networks (ANN), decision-making techniques, and deep learning, are among the key methodologies applicable in IoT-enabled agriculture. [1][4][9]

A) Phyto management: Utilizing greenhouse technology, the integration of machine learning and the Internet of Things creates a regulated environment conducive to crop cultivation. Conventional agricultural methods struggle to accommodate the diverse environmental conditions affecting different plant species at various growth stages within protected agriculture. Therefore, achieving enhanced precision in monitoring and control becomes crucial due to the dynamic nature of crop growth factors in controlled environments. Numerous studies have explored the design and testing of various monitoring and control systems for adjusting temperature, humidity, light intensity, CO2 concentration, and other environmental factors within the Internet of Things framework, offering both technical and financial advantages. The concept aims to leverage sensors, actuators, and IoT technology to supervise and regulate environmental parameters tailored to specific plant species.[1][7]

B) Control of Crops and Yields: Machine learning-driven yield mapping can be implemented on farms by utilizing data collected through an IoT network, incorporating GPS- linked yield monitoring. Based on the different types of agricultural land, the yield data revealed by the gathered date will be plotted. Furthermore, machine learning (ML) systems and IoT can be employed for predicting and improving agricultural output. Farmers typically rely on consultations with agricultural experts to inform their decisions. These systems are also accessible to farmers who may not have extensive computer literacy. ML systems are utilized in crop production, leveraging existing knowledge to generate insights for informed decision- making, thereby enabling profitable crop management practices for farmers. Inspired by the achievements of expert systems, numerous analogous systems have been developed.[1][7][8]

C) Handling Soil: Soil management can be addressed through diverse ML- driven approaches. Wireless sensor nodes strategically positioned across the area collect soil data. Subsequently, this collected data can be utilized to train supervised ML algorithms, facilitating the classification of various soil types or the prediction and evaluation of soil characteristics.Additionally, prevalent ML techniques like K-nearest neighbor, support vector regression (SVR), Naive Bayes, among others, can be employed to estimate soil moisture levels based on precipitation and evaporation hydrological data.[1][7][5]

D) Disease Coordination: Combining machine learning with the Internet of Things facilitates disease management and detection in agricultural areas. This integrated approach not only protects crops from diseases but also reduces labor expenses by promoting the judicious use of pesticides. Such technology aids farmers in data collection and scheduling irrigation, herbicide, and fertilizer applications accurately. Through accurate disease identification, targeted pesticide application, and precise irrigation scheduling, grape yield and quality have improved while pesticide usage has decreased. Additionally, architectural and deep learning techniques can be employed to identify and classify growth stages of various plants. [3][17] The audio cues in these factories are produced by camera sensor nodes driven by IoT technology, strategically positioned in crop fields, and dynamically moving across different sections of the farm in response to real-time visual data they capture.[1][7]

E) Managing Weeds: Weed control is essential in agriculture, and research has explored using machine learning for weed mapping. One proposed method involves employing an unmanned aerial vehicle (UAV) to map weeds in a field and capture images for enhanced effectiveness. When combined with an Internet of Things (IoT) network to control the UAV, sophisticated IoT technologies such as Narrowband IoT (NB-IoT) can handle and process large volumes of data efficiently.[1][7]

F) The Water Resources Management: Numerous methods have been employed to regulate water distribution in agricultural areas and employ machine learning to evaluate water quality. Intelligent systems could potentially be developed to identify environmental factors, soil temperature, and moisture levels through Internet of Things sensors. Subsequently, utilizing this data, these systems could also compute outdoor relative humidity. [1][7][5]

G) Animal Monitoring: Animal monitoring in agricultural settings is vital, and researchers have employed IoT sensors for tracking animals, with distinct studies dedicated to classifying various animal species. By integrating IoT and ML solutions, this challenge can be effectively addressed. IoT sensors detect animal presence, while and precise irrigation scheduling, grape yield and quality have improved while pesticide usage has decreased. Additionally, architectural and deep learning techniques can be employed to identify and classify growth stages of various plants. [3][17] The audio cues in these factories are produced by camera sensor nodes driven by IoT technology, strategically positioned in crop fields, and dynamically moving across different sections of the farm in response to real-time visual data they capture.[1][7]

6. SMART FARMING'S ADVANTAGES

Here we'll talk about a

How agriculture is being impacted by IoT:

Numerous parts of agriculture might be transformed by technologies and the Internet of Things. Specifically, there are six ways that IoT might enhance agriculture. Advancements in renewable energy technologies have the potential to revolutionize the energy sector, providing sustainable solutions to pressing environmental challenges. Specifically, there are seven key areas in FIG-5 where renewable energy innovations could significantly transform the landscape of power generation and consumption. From solar and wind power to hydroelectric and geothermal energy, these technologies offer promising avenues for reducing carbon emissions and promoting a greener future for generations to come. [12]

FIG-5- Merits of IoT for agricultural applications

- **Massive amounts of data**, such as weather patterns, soil quality, crop growth

progress, and animal health, are gathered by smart agricultural sensors. This information may be utilized to monitor employee performance, equipment efficiency, and other aspects of your company's overall health.[17]

- **Reduced manufacturing** risks and better internal process control. A better product distribution strategy may be planned when you can predict the output of your production. Knowing the exact quantity of crop you will harvest can help ensure that your goods do not remain unsold.[17]
- **Cost control and waste reduction** are made possible by the enhanced production control. You can reduce the likelihood of losing your produce by being able to identify any irregularities in the health of your animals or the growth of your crops.
- **Enhanced productivity** through automation of processes in business. Many activities in your production cycle, like as fertilization, irrigation, and pest management, may be automated with the use of smart devices.[18]
- **Increased product quantities** and quality. Automating the production process might help you gain more control over it and uphold greater standards for crop quality and development potential.[15][1]

7. AGRICULTURE AND THE INTERNET OF THINGS

Smart sensor and integrated Internet of things applications for precision farming. Smart sensors that are based on the Internet of Things are capable of precisely tracking environmental variables including humidity, wetness, and temperature. [17][12] Certain sensors use the amount of water and nitrate in the soil to evaluate its quality. With a high-resolution camera and a GPRS system, plant diseases and insect pests may be identified. Surveillance using unmanned aerial vehicles (UAVs) aids in tracking crop growth and agricultural field topography. Mass flow sensors that are automated can be used to assess crop productivity. In the healthcare sector, wearable devices can track vital signs and monitor patient activity, enhancing overall health management. Additionally, remote patient monitoring systems enable healthcare professionals to remotely monitor patients' health conditions and intervene promptly when necessary. Tele medicine platforms facilitate virtual consultations, providing convenient access to healthcare services for patients in remote areas. Advanced imaging technologies such as MRI and CT scans enable accurate diagnosis and treatment planning for various medical conditions. [5][9][18]

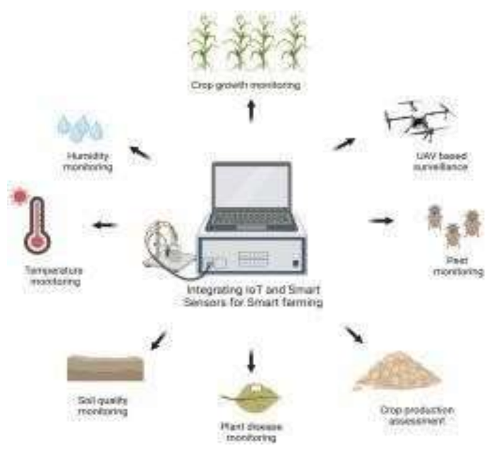

FIG-6- Integrating IOT and smart sensors for smart farming [9].

Utilizing smart sensors and integrated Internet of Things (IoT) technologies, precision farming is facilitated. These IoT-based smart sensors provide precise measurements of environmental parameters like temperature, humidity, and moisture. Some sensors gauge soil quality by analyzing water and nitrate levels. Identification of insect pests and plant diseases is made possible through a GPRS system and high-resolution camera.Livestock monitoring systems utilize wearable sensors to track vital signs and activity levels, providing real-time health and behavior data. Furthermore, satellite imagery and GPS technology are employed for pasture management and animal tracking, ensuring optimal grazing practices and herd management. [9][1]

8. ADVANCED FARMING SYSTEM

The proposed smart farming platform aims to collect, transmit, and analyze various physical parameters—such as soil moisture, air temperature, humidity, water level, water flow, luminous intensity, and combustible gas levels— to ensure crop security. This data, combined with weather predictions, is used to efficiently manage irrigation. The system architecture comprises three levels: data gathering, data processing, and application layers. Applying precision agriculture principles, we assess the available water reserve (RU) based on soil texture (including lime, clay, sand, and organic matter) for the upcoming days.[5][8][14]

Regarding soil moisture and anticipate precipitation, the information produced by the algorithm and device is saved in a MySQL database on the server to conserve water and energy see in FIG-7 Before any data streams are sent to Google Collab to use artificial intelligence algorithms, they are all kept on Google Drive.[5][12]

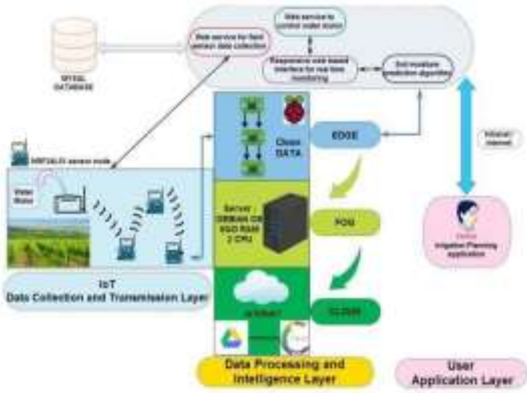

FIG-7-: Global View of our proposed operational architecture [5]

9. CONCLUSION

India's economic prosperity is largely dependent on the agricultural industry. There seem to be a number of issues plaguing the conventional agricultural industry, which includes farmers. Similar to insufficient agricultural growth and insufficient weather. Apart from offering farmers informed guidance regarding suitable crops for specific locations, the integration of real-time sensor data with machine learning algorithms will empower farmers to make fertilizer recommendations based on various factors like soil quality and climate conditions. Moreover, XG Boost stands out among the machine learning algorithms tested, achieving the highest accuracy of 99.31% in providing suggestions. Employing sophisticated machine learning algorithms to predict agricultural yield and quality could improve crop planning decisions. Specifically concerning crop prediction, the Naive Bayes classification Model within the Prediction Module yielded a Cohen's Kappa score close to 95%. The R-Squared value we obtained for the Random Forest Regression Model for the Crop Yield Prediction Module is greater than 81%.Future crop and yield estimates would be more accurate with well-researched historical crop data and accurate climate parameter forecasts. The generated webpage is also user- friendly and has the potential to be made even more educational by giving the user access to more helpful information about intercropping, fertilizers, etc. Chatbots and speech recognition software can be added to create a more engaging user interface. In conclusion, smart farming and IoT-based agriculture, powered by machine learning applications, offer a promising path towards a more efficient, sustainable, and resilient agricultural sector.

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