**IOT-BASED SMART AGRICULTURE WITH CLOUD COMPUTING**

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**ABSTRACT**

IoT is a ground-breaking technology that reflects the direction of communications and computers. The majority of people on all continents depend on agriculture. Smart IT technologies are therefore required to migrate alongside conventional agricultural practices. Utilizing contemporary technologies allows for cost, maintenance, and performance monitoring control. In modern agriculture, satellite and aerial photography are crucial. IoT allows farmers to remotely monitor their crops and equipment by using phones and computers. Precision agriculture sensor monitoring networks are widely used to measure agri-related information like temperature, humidity, soil PH, soil nutrition levels, water level, etc. The most cutting-edge idea in the current internet era is the internet of things. It offers assistance to presumably all global domains. One of these industries using the IoT to make agriculture smart is agriculture. Numerous IoT applications may be seen in the agricultural sector, which will benefit farmers in unknown ways and ultimately contribute to the successful growth of the country.

**Keywords**— Internet of Things (IoT); Cloud Computing; LiFi; Gprs; Agriculture Monitoring, Irrigation, Routing Protocol.

**INTRODUCTION**

The foundation for the development of the country is agriculture. Due to its exceptional agricultural lands and other resources, India is known as an agricultural country. These days, factors like temperature and soil moisture have an impact on agriculture's development, including disease, productivity, and yield production. Issues related to agriculture have been a hindrance to the country's progress. The present conventional procedures for agriculture need to be modernized. The population of India is directly or indirectly dependent on agriculture to the tune of 60–70% (estimated value). That has an impact on India's economic development and food security. With the aid of precision agriculture, crop growth may be easily monitored or observed based on data received from a crop field (soil condition and meteorological information). This method, also known as satellite farming or site-specific crop management (SSCM), is not capable of manually gathering environmental data due to the difficulty of the task. Due to a lack of fully functioning soil testing labs throughout the states of the country, new farmers are entering the field without understanding of the properties of the soil. In order to manage crops in a controlled environment, new trends in agriculture are necessary. Consider greenhouses. The most recent development in the internet industry is the Internet of Things. The "Internet of things" (IoT) is an idea that makes it possible to connect physical objects that have sensing, actuating, and computing capabilities by giving them the ability to cooperate on a job while still being connected to the internet. With the backing of sensor, selectors and bedded microcontrollers the purpose of creating good object is fulfilled. These good objects collect knowledge from the surroundings of development, process them, and initiate applicable conduct. Therefore, the Internet of effects can bring awful support and helps humans in leading a wise and smart husbandry. With IoT, growers will simply get a timely cultivating guideline relating to the parameters similar as fungicide operation, seasonal factory conditions and also regarding natural disasters and recovery styles. Main advantage of synergizing husbandry with IoT, is elimination of mortal- to- mortal commerce and mortal- to- computer commerce. So now what's the significance of IoT in husbandry? The result is Homemade data collection; absolutely it's a threat for growers and also to processes from the crop field. So it's delicate for growers to get optimal situations of effectiveness. To break this difficulty, IoT( Internet of effects) is only the result. It plays vital part in collecting information. IoT has been formerly in raising with new multiple ways. Connecting husbandry to the internet is one of the important conditioning of the proper operation of IoT device. It presumes the connection to be wireless, which is classified, grounded on energy consumption, uplink data rate & downlink data rate, packet size, device per access point, topology, frequency band range and channel range.

# IOT ENABLING TECHNOLOGIES

Internet of Things has the following technologies:

# Wireless Sensor Networks (WSN)

A WSN consists of a set of sensors or nodes that are linked to track different types of data.

# Cloud Computing (CC)

This is called on-demand computing, where system resources and data are shared among the users who request them. It can be represented in various forms such as IaaS, PaaS, SaaS.

# Big Data Analytics

It is the concept of processing large data sets that have various forms of data types.

# Communication Protocol

Correspondence conventions are the foundation of IoT frameworks. They empower availability of different applications and furthermore information trade over the organization.

# Embedded Systems (ES)

It is a blend of equipment and software, that are expected to do a particular errand. It upholds the association of different sensors over IoT.

# APPLICATIONS OF IOT IN SMART AGRICULTURE

Albeit the utilization of savvy agribusiness isn't well known in India, still it shows dynamic abilities for supporting horticulture. It upholds the plant development and advancement in numerous ways. Some of such applications are recorded underneath to upgrade plant development:

# Monitoring of Climate Conditions

# Environment and weather patterns are the essential variables to be noted during horticulture. Shrewd farming utilizing IoT utilizes a few sensors for observing the environment states of the environmental elements. The undertaking of the sensor is to gather the information across the field send it to the cloud. The cloud is stacked for certain fundamental estimations which will then be contrasted and the detected information. In view of the examination, we will actually want to plan the climatic circumstances and pick the expected harvest for development. A few instances of such farming IoT gadgets are all METEO, Brilliant Components, and Pycno.

# Agriculture Drones

# One of the most amazing utilizations of IoT in agribusiness are Robots. Drones give pictorial and flying guides about the plants, in this way causing the rancher to comprehend what harvest is in bad shape. Drones likewise assess the wellbeing state, water system, checking of progress, splashing, and planting of each harvest. Drones are useful in saving time and exertion. The robots are contained two sorts: ground-based and flying based drones. Both are utilized for crop wellbeing appraisal, water system, planting, and soil and field examination. Ranchers need to pick the level or ground goal of the field for which the Robots must be utilized. Then, at that point, the Robots take the photos of the yields and assists the rancher with giving quick help for the expected harvests.

# Livestock Monitoring

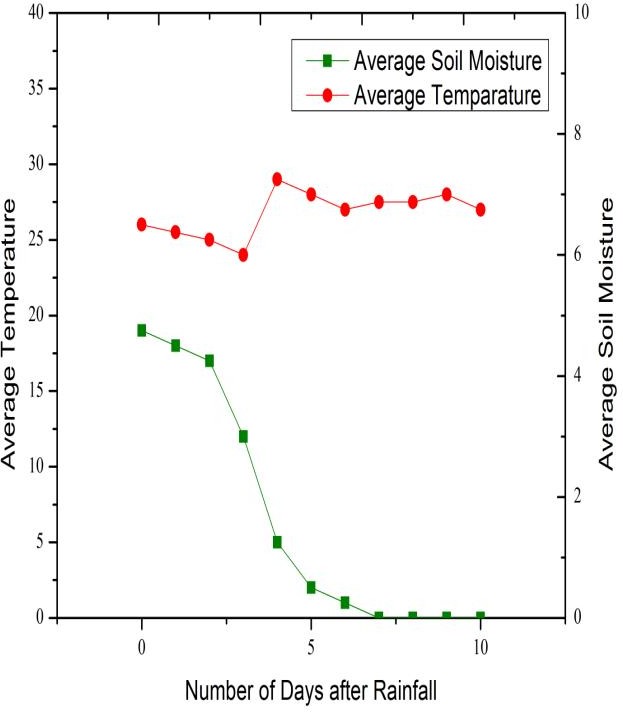
Domesticated animals Checking is the approach to following the condition of the crowds. The wellbeing of the creatures is followed utilizing the IoT gadget and observed for the indications of sickness. The sensors associated with the creatures will gather information about the area and prosperity of the creatures. The sensors could in fact follow the condition of pregnancies of dairy cattle and cozy the condition of the steers which is going to convey.

# Smart Greenhouses

Greenhouse farming is a technique that boosts the yield of crops, vegetables, fruits etc., Ecological boundaries are constrained by Nurseries in two ways; either through manual mediation or a relative control system. Notwithstanding, since manual intercession has inconveniences like creation misfortune, energy misfortune, and work cost, these strategies are less viable. A brilliant nursery through IoT implanted frameworks screens wisely as well as controls the environment. In this way wiping out any requirement for human mediation. Various sensors that action the ecological boundaries as per the plant necessity are utilized for controlling the climate in a savvy nursery. Then, a cloud server makes for remotely getting to the framework when it interfaces utilizing IoT.

**Crop Water Management**

Water is the fundamental asset for performing agribusiness. Every one of the rural exercises depend on the satisfactory inventory of water. Thus it is fundamental for the rancher to guarantee sufficient stock of water to the harvests. This strategy utilizes the Internet Guide Administration (WMS) and Sensor Perception Administration (SOS) for guaranteeing appropriate water supply for the water system of the yields. Hence this IoT lessens water wastage. The accompanying chart shows the variety of temperature and soil dampness with the expansion in the quantity of long stretches of precipitation. Arduino Mega 2560 is utilized in the exploration. DS18B20 sensor is utilized to quantify the temperature of the dirt. Likewise, a dirt dampness sensor is utilized for estimating the dirt dampness. From the investigation made, it is seen that as the temperature builds the dirt dampness diminishes.



# Fig.1 Variation of temperature and soil moisture with the increase in the number of days of rainfall

# SENSORS USED IN IOT FOR SMART AGRICULTURE:

* Location sensors use the GPS satellite signals to find latitude, longitude and altitude within the feet. It requires three location sensors to be fixed, since for triangulating the position.
* Optical sensors are used to measure the clay, organic matter and moisture content of the soil. these sensors are generally fixed to the drones.
* Electrochemical sensors provide the essential information about the pH and soil nutrient level.
* Mechanical sensors are used to find out the mechanical resistances of the soil.
* Dielectric soil moisture sensor measures the moisture level of the soil, by using the dielectric constant.
* Parrot sensors are used to monitor the plant’s temperature, moisture, soil salinity. The information is sent to the farmers’ mobile phone.

Spruce is a sensor device, which is used for irrigation control. The data is saved in the cloud server and the user can access it at anytime and anywhere.

* Koubachi is used for sprinkling water to the plants in the garden. It acts a node that collects data from multiple sensors like air temperature, soil moisture, sun light etc.

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| **S.No** | **Applications of IoT** | **Sensors used** | **Measures** | **Uses** |
| 1 | Monitoring of Climate Conditions | Temperature sensor, Light Dependant Resistor, sound and CO sensor | Rainfall, Wind speed and direction, Temperature, relative humidity, light intensity and CO level | Reduces labor costs, Effective decision making, Ease of time, Utilization of resources |
| 2 | Agriculture Drones | NDVI Sensor, Phantom 4 Pro V2.0 Drone, Matrice 210 Drone, Zenmuse XT2 Thermal Camera, AGRAS MG-1S Drone | Irrigation problems, soil variation, and pest and fungal infestations | Increase crop production and crop growth |
| 3 | Crop Water Management | Ultrasonic sensors for water level, Temperature and relative humidity sensor, Soil Moisture sensor, | Focus on climatic circumstances | Understand the soil properties, Demand of water supply for various plants, Control the water wastage, |
| 4 | Smart Greenhouses | Temperature Sensor, Arduino compatible Mini Luminance Sensor, light sensor and actuators | Temperature, humidity, Water content, Light level, CO2 level, Soil water potential | Efficient plant growth, Controlled temperature |
| 5 | Livestock Monitoring | Connected sensors | Measures the heart rate, blood pressure, respiratory rate, temperature, digestion, and other vitals of the livestock | Saves time, prevent health issues of cattle at earlier stage, Track the location of livestock |

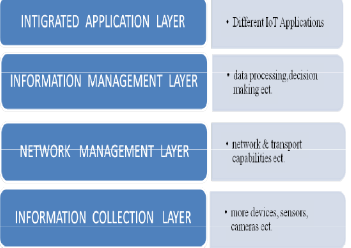
**Table (1): Sensors used in IoT for Smart Agriculture**

# BENEFITS OF IOT IN SMART AGRICULTURE

* IoT makes it possible for copious amounts of data to be gathered via sensors, improving control over internal operations and lowering production risks.
* IoT makes it possible to monitor the farming environment effectively.
* IoT makes it possible for farmers to remotely monitor their farms from a variety of locations. Real-time decisions can be taken from any location. Through careful monitoring of planting, watering, pesticide treatment, and harvesting, IoT ensures higher crop output.

**FOUR LAYERS IOT-AGRICULTURE ARCHITECTURE**

The analysis of the literature review results in the proposition of a conceptual model for smart agriculture. Give us a brief overview of the IOT's overall structure first. IOT primarily has a three-layer structure in practice, making up several physical devices. Since it is regarded as a user interface layer, the first layer is the integrated application layer, which is used in applications connected to agriculture. It uses farmers' personal equipment and cell phones to monitor the agricultural land and is user-free. The farmers can decide to protect their crop as healthy and increase food production output based on this layer. The second layer is information management, which includes duties like data formation and classification, creation, monitoring, and decision-making, among others. In this layer, certain functions are maintained and carried out. The network management layer, which is the third layer, represents communication technologies such Bluetooth Low Energy, Zigbee, Bluetooth Low Energy, GSM, WiFi, and Gateway. Information collecting is the fourth layer, which includes all different kinds of sensors, cameras, etc. These are used to gather crop data for more effective and convenient field monitoring in the agricultural sector.



**Fig.2 The four layers IoT structure**

Every approach has a standard procedure that involves placing a number of sensors in the agricultural field to collect data on variables like temperature, humidity, soil PH, and light intensity. An IP address will be given to each device on the network in order to identify it. For instance, the network's temperature sensor will be identified within the communication network with item ID T1. IoT items can be addressed via IPV6 and IPv4.Each object in the network has a distinct identity thanks to identification mechanisms. Smart sensors, actuators, and wearable sensing devices are all examples of IoT sensors. Through a gateway connected to the internet via WiFi or another communication network, the sensed data from the crop field is delivered to a cloud. The data is supplied to farmers' PCs or smartphones from the cloud. This data can be analyzed to help farmers make the right decisions.

**ANALYSIS AND COMPARISION OF IOT HARDWARE REQURIEMENT**

**Device:** Devices that perform sensing, actuation, control, and monitoring tasks are used in IOT systems. IOT devices can exchange data with other connected devices and applications based on temporal and spatial constraints (i.e. memory, processing speed, communication latencies, and deadlines), or they can gather data from other devices and send it to a base station server and from there to a cloud server using a gateway, or they can perform some tasks locally and other tasks within an IOT infrastructure. A single IOT device may have many wired and wireless interfaces for connecting to other IOT devices. I/O interfaces for sensors, Internet connectivity interfaces, memory and storage interfaces, and audio/video interfaces are a few of them.

**Communication:** The communication block facilitates communication between devices and distant servers. The majority of IOT communication protocols are compatible with the data link layer, network layer, transport layer, and application layer.

**Services:** IOT systems can perform tasks like device modeling, device control, data posting, data analytics, and device discovery.

**Management:** The management block can do a variety of tasks, including managing an IOT system and looking for its underlying governance.

**Security:** Security blocks can perform tasks including authentication, authorization, privacy, message integrity, content integrity, and data security. The IOT system is secured by a security barrier.

**Application:** The Application layer is the most crucial layer for users. This layer offers the necessary modules for controlling and keeping an eye on various IOT system components. Applications enable users to observe and assess the system status at the current stage of operation, and occasionally anticipate the future.

Some of the wireless sensors are listed out below and explained briefly

**i. 802.11 – Wi-Fi**

A group of Wireless Local Area Network (WLAN) communication protocols is known as IEEE 802.11. For instance, 802.11a uses the 5 GHz spectrum, 802.11b and 802.11g the 2.4 GHz band, 802.11n the 2.4/5 GHz band, 802.11ac the 5 GHz band, and 802.11ad the 60 GHz range. These specifications offer data speeds ranging from 1 Mb/s to 6.75 GB/s. Wi-Fi has a communication range of between 20 meters (indoors) and 100 meters (outdoors).

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|  | **WIRELESS TECHNOLOGIES** | | | | | |
| **PARAME**  **TERS** | **Li-Fi** | **Wi-Fi** | **WiMAX** | **LR-WPAN** | **Bluetooth** | **LoRa** |
| Standard | IEEE 802.15. 7(out of date) (for  VLC) | IEEE 802.11a/b/c | IEEE 802.16 | IEEE 8205.15.4 | IEEE 802.15.1 | Lora WA N R1.0 |
| Frequency band | 10\*1000 times frequency of radio(3KHZ- 300GHZ) | 5-60GHZ | 2-66GHZ | 2.4GHZ | 2.4 GHZ | 868/900MHZ |
| Data rate | 224Gb/s | 1Mb/s- 6.75 Gb/s | 1Mb/s-1 Gibb/s | 40-250  Kb/s | 1-24 Mb/s | 0.3-50Kb/s |
| Transmission  range | 10 m above | 20-100m | <50Km | 10-20m | 8-10m | <30Km |
| Energy consumption | Low | High | Mediu m | Low | Medium | Very Low |
| Cost | Low | High | High | Low | Low | High |

**Table (2): comparisons of wireless communications**

**ii. 802.16 – WiMax**

A set of wireless broadband standards known as IEEE 802.16. The WiMAX (Worldwide Interoperability for Microwave Access) standards offer data rates of 1.5 Mb/s to 1 GB/s. (802.16 m) offers a data throughput of 100 Mb/s for mobile stations and 1 GB/s for stationary stations. Specifications can be found on the IEEE 802.16 working group website (IEEE 802.16, 2014).

1. **802.15.4 – LR-WPAN**

Low-Rate Wireless Personal Area Networks (LR-WPAN) specifications are part of IEEE 802.15.4. 802.15.4 creates high-level communication protocols like ZigBee. LR-WPAN offers data rates of 40 Kb/s to 250 Kb/s. LR-WPAN offers low-cost, slow connectivity to power-restricted devices. The LR-WPAN has a high data rate frequency of 2.4 GHz and a low frequency data rate of 868/915 MHz.

**iv. 802.15.1 – Bluetooth**

Bluetooth uses the IEEE 802.15.1 standard. Bluetooth enables data transmission between mobile devices over a short distance (8–10 m). A low-cost, low-power wireless communication technique is Bluetooth. Communication via a personal area network (PAN) is defined by the Bluetooth standard. It makes use of the 2.4 GHz spectrum. The 1 Mb/s to 24 Mb/s Bluetooth data rate range is available. The extremely low power and inexpensive form of Bluetooth is called Bluetooth Low Energy (BLE or Bluetooth Smart). In 2010, BLE and Bluetooth v4.0 were combined.

**v. 1.5.6. Lora WAN R1.0**

In order to support the Internet of Things (IoT), the open and nonprofit LoraTM Alliance recently created the Low Power Wide Area Networks (LPWAN) standard protocol. Interoperability across diverse operators under a single open, international standard is the primary goal of this protocol. Data rates for LoRaWAN range from 0.3 kbps to 50 kbps. ISM bands at 868 MHz and 900 MHz are used by LoRa. According to post capes, LoRa can communicate between linked nodes up to 20 kilometers away in open spaces. The linked node's battery typically has a very long lifespan of up to 10 years.

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| **IOT Platforms** | **Real time data capture** | **Data**  **Visuali zation** | **Cloud service type** | **Data Analyt ics** | **Developer cost** |
| Ubodots [(http://ubidots](http://ubidots/).com/) | Yes | Yes | Public | Yes | Free |
| Thing Speak  (https://thingspeak.com/) | Yes | Yes  (MATLAB) | Public | Yes | Free |
| ThingWorx  (www:thingworx.com/) | Yes | Yes | Private (IaaS) | Yes | Pay per use |
| Xively  (https://xively.com/) | Yes | Yes | Public (IoTaaS) | No | Free |
| Plotly  (https://plot.ly/) | Yes | Yes  (MATLAB) | Public | Yes | Free |
| Nimbits (www.nimbits.com/) | Yes | Yes  (MATLAB) | Hybrid | Yes | Free |
| Connecterra  (www.Connecterra.io/) | Yes | Yes | Private (IaaS) | Yes | Pay per use |
| Axeda  [(www.ax](http://www.axeda.c/)e[da.c](http://www.axeda.c/)om) | Yes | Yes | Private (IaaS) | Yes | Pay per use |
| Phytech (http://www.phytech.com/) | Yes | Yes | Private (IaaS) | Yes | Pay per use |
| Aekessa (www.arkessa.com) | Yes | Yes | Private | Yes | Pay per use |
| Yaler  (https://yaler.net) | Yes | Yes | Private | Yes | Pay per use |

**Table (3): Comparison of the IOT cloud platforms may be used for agricultural domains: a case study.**

**MATHEMATICAL EXPLANATION FOR HIGH YIELD PROCESS**

Most of the mathematical explanations are carried out for better yield production. For instance, rice and wheat formula is

Yield = no. of plants/m2×no. of effective fillers/plants× no. of grains/plants×% of filled grains × test weight/1000× 10,000/1000.

Where yield analysis is done with two parameters. The relation between Biological yield and economic yield is

Biological yield× K = economic yield

The biological yield of a crop is the amount of dry matter it generated, and the economic yield is the portion of the biological yield that is consumed by humans. There are two key factors that must be considered in order to achieve high manufacturing yield:

(i) Soil moisture

(ii) Temperature.

Both the temperature and the soil's moisture content must be between 18 and 25 °C and 15 and 60%, respectively.

Y = T×M×A×100

T = temperature optimal range 180-25c M = soil moisture optimal range 15-60%

A = area of crop field

This equation is used to finalize the yield of the crop field. When these values are increased or decreased (violating the optimal range) means, there is a chance of minimal production yield. It seems must be within optimal range only.

An enormous exploration exertion is as yet required albeit the designs portrayed in before segment make IOT idea basically practical. Specialized issues related with current IOT models are explored in this part. To meet all essential parts that are missing in existing design, later on, an original idea of IOT engineering was created. Before the IOT will be generally acknowledged and sent in every one of the spaces, an adequate comprehension of modern qualities and prerequisites on elements like expense, security, protection, and chance must be examined. Allow us to examine a couple of issues in such manner:

1. Keeping up with cost-is a more critical limit in case of farmers. So on solicitation to show up right now, examiner center around developing new sagacious agribusiness IoT designing with added benefits.
2. The size of the original data may be too great for the current database management system to handle in real-time. Idealized solutions must be found. IOT-based data would be generated quickly. The acquired data cannot be handled by current RAID technology at the receiver end. IOT-based data service-centric design needs to be updated to address this issue.
3. Data is an unprocessed truth that, in most cases, does not follow irrelevant handouts. Data is a major factor in IOT decision-making. The pool of data is what gives data worth. Only with the proper application of mining can significant information from data be analyzed and understood. Big data is sufficient for tackling regression problems of a similar nature. A suitable architecture framework can perform data mining, analytics, and therefore decision-making services. Big Data analytics could be pooled using data mining.
4. Designing a Service-Oriented Architecture (SOA) for the Internet of Things is difficult because service-based objects may run into performance and financial concerns. SOA was required to accommodate the system's high device density, which causes scaling problems. Data management, processing, and transfer problems are now handled as a burden by service provider.

Another significant concern is the level of service. A developer must focus on QoS factors in order to obtain an optimal QoS range. With IOT, a staggeringly large number of nodes are anticipated. The ability to retrieve all attached hardware and data is required. An essential requirement for effective point-to-point network design is unique identification. Each node in the IPv4 protocol is identified by a 4-byte address. Since there won't be any more IPv4 addresses available in a few years, a new addressing scheme called IPv6 has been devised. The IPv6 area is the area where the most caution is required and appropriateness of architectural proficiency is a requirement in order to pursue device naming and identifying capability.

# CONCLUSION

In this research, various IoT-supported technologies and IoT applications in smart agriculture are examined. The advantages of IoT in agriculture are discussed in this study. IoT is a new concept in the world, so it is more important than ever to understand its concepts. A simple guide to helping farmers increase productivity and care for their crops effectively has been made public. IOT-enabled devices can improve the precision and effectiveness of agricultural practices. The first area of agriculture where IOT can be used is water and energy. Water and energy are the most crucial inputs for agriculture, and their costs can make or break the industry. Water is wasted as a result of faulty irrigation systems, ineffective field application techniques, and the planting of crops that require a lot of water in the wrong growth environment. Pumps, boosters, lighting, etc. all require electrical energy to operate. Agriculture can use water more intelligently by using IOT to monitor and adjust water volume, position, timing, and flow duration. The second is crop monitoring: the application of fertilizers, pesticides based on crop and soil health, and insect management are the main issues in this area. With the aid of IOT, effective energy consumption for pumps, boosters, lighting, and other purposes is also done. IOT enables the deployment of sensors and image-capture devices in crop fields that are connected to the internet so that the proper decision may be made. IOT can be used to utilize pesticides and fertilizers more effectively. Finally, it should be noted that the best Agri-IoT architecture needs to be created, one that has low costs, low device power consumption, superior decision-making capabilities, QoS service, optimal performance, and is simple enough for farmers without technical training to grasp. The accuracy rates for all the applications discussed above are 98%. By doing this, the farmer can increase crop productivity, enhancing national well-being.

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