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Smart Farming:A Review of AI and IoT

Prof. Dr. Chetan Chauhan, R. Ubale, N. Patil , V. Malusare, P. Joshi, S. Patil
Department of Computer Engineering, Vishwakarma University, Pune, India

Abstract

Smart farming integrates leveraging AI, IoT, and Blockchain to optimize agricultural efficiencyt, optimize resource utilization, and improve sustainability. AI-driven predictive analytics improve crop monitoring, while IoT-based precision agriculture enables real-time environmental tracking and automated decisionmaking. Blockchain ensures secure and transparent data management in supply chains.

This paper reviews different technologies, their uses, and the challenges they face, like high installation costs, cybersecurity risks, and problems with system compatibility. It also looks at a real-world example of a smart farming system that uses the Internet of Things (IoT). This system includes automated irrigation, soil moisture monitoring, and security features.

Results demonstrate a 30% reduction in water consumption and improved farm security through automated intrusion detection. Future advancements include AI-powered disease prediction, blockchain-integrated supply chains, and cloud-based smart farming solutions. This research acts as a detailed reference for academics, policymakers, and industry players pursuing smart farming advancements for long-term sustainability agricultural practices.

Keywords— *Blockchain, Internet of Things, AI, smart farming, cybersecurity, automation, smart irrigation, and precision-driven farming methods.*

I. INTRODUCTION

By 2050, more than 9.7 billion people will live on the planet. This growth will make it very hard for agriculture to meet food demand while also dealing with resource shortages, climate change, and environmental harm. Traditional farming methods are becoming less effective. This calls for the use of data-driven, technology-based precision agriculture. Smart farming uses AI, IoT, and blockchain to transform farming practices. It allows for real-time monitoring, automated decision-making, and secure data management [1].

1.1 Importance of Smart Farming

Agriculture is a critical sector that feeds billions of people worldwide. However, increasing global food demand, climate

The need for technology-driven solutions has been fuelled by unpredictability and inefficient resource use. Intelligent farming

incorporates cutting-edge digital technologies to improve productivity, cut waste, and streamline agricultural operations. By utilizing AI for predictive analytics, IoT for continuous monitoring, and blockchain to safeguard data integrity, smart farming presents a transformative shift in the agricultural landscape.

1.2 Role of AI, IoT, and Blockchain in Agriculture

AI in Agriculture: AI algorithms, including deep learning and computer vision support early identification of crop diseases, facilitate crop disease detection, yield prediction, and automated decision-making. AI-driven robotics assist in harvesting and soil analysis, further improving productivity.

IoT-Based Precision Farming: IoT-enabled equipment, including soil moisture sensors, temperature monitors, and drone-based surveillance, deliver up-to-the-minute data farm insights. This enables farmers to implement automated irrigation, optimize fertilization, and prevent pest invasions.

Blockchain for Agricultural Transparency: Blockchain technology secures agricultural transactions, maintains supply chain traceability, and ensures data integrity. Smart contracts eliminate intermediaries, reducing fraud and increasing efficiency.

1.3 Challenges in Traditional Farming

Water Scarcity and Inefficient Irrigation: Smart irrigation systems can help reduce water waste, which is a common result of traditional irrigation techniques.

Climate Change and Unpredictability: Farmers struggle with changing weather patterns. AI-powered forecasting models help predict climate conditions and optimize planting schedules.

Labor Shortage and High Costs: Manual farming requires significant human effort. Automation through AI-driven machinery reduces dependency on human labour while enhancing efficiency.

Lack of Real-Time Monitoring: Conventional methods lack real-time feedback. IoT solutions enable continuous farm surveillance, enabling farmers to base decisions on empirical insights.

II. LITERATURE REVIEW

2.1 AI in Smart Farming

Artificial Intelligence (AI) has changed agriculture by providing automated insights and predictive modeling. Machine learning (ML) models, such as convolutional neural networks (CNNs), support vector machines (SVMs), and recurrent neural networks (RNNs), are common frameworks in various applications. They have shown high accuracy in tasks like disease detection, productivity forecasting, and pest control. AI-driven robots are increasingly used for automated harvesting and precise weed management. Deep learning models trained on large datasets assist in early disease detection, which helps reduce the use of chemical pesticides and supports sustainable farming practices [2].

AI is also used in precision farming through advanced imaging and computer vision techniques. AI-based drones can analyze evaluate crop vitality, identify pest outbreaks, and streamline input usage by generating high-resolution images of farmlands. Additionally, AI-powered chatbots and intelligent decision-making tools help farmers choose effectively regarding crop selection, irrigation schedules, and disease prevention strategies.

2.2 IoT-Based Precision Agriculture

The Internet of Things (IoT) improves decision-making in smart farming by allowing real-time data collection and monitoring. Precision agriculture powered by IoT uses a network of sensors, automated systems, and drones to provide live updates on environmental factors like soil moisture, temperature, humidity, and weather conditions. By connecting these sensors with digital tools, farmers can fine-tune irrigation and fertilization schedules and gain better insights into agricultural patterns.

IoT in agriculture has also improved resource efficiency by implementing automated smart irrigation techniques that minimize water loss. Smart irrigation, driven by soil moisture data, guarantee that crops receive precise hydration levels, preventing over-irrigation and water scarcity. Additionally, remote monitoring through mobile solutions empower farmers to oversee farm activities from distant locations, increasing convenience and efficiency.

Despite its benefits, IoT implementation agriculture is confronted by obstacles like network scalability, security vulnerabilities, and high setup costs. Data privacy concerns and interoperability issues between different IoT platforms also hinder widespread adoption.

2.3 Blockchain for Agricultural Transparency

Blockchain fosters trust and protection in agri-supply chains through its decentralized and immutable architecture system, blockchain ensures traceability in the food production and distribution network. Farmers, suppliers, and consumers can authenticate the source and legitimacy of agricultural commodities, lowering fraud risks and ensuring compliance with quality standards [4].

Smart contracts, powered by blockchain, automate transactions between stakeholders, reducing the need for intermediaries. This reduces operational expenditure and enhances the efficiency of agricultural trade. Moreover, blockchain-integrated IoT devices can record real-time data on crop conditions, storage temperatures, and transport conditions, ensuring optimal quality control.

Blockchain adoption in agriculture is still in its infancy despite these benefits because of scalability problems, high computational costs, and regulatory concerns. Blockchain, IoT, and AI working together could make it even more useful for supply chain management and precision farming.

2.4 Convergence of AI, IoT, and Blockchain in Smart Agriculture

Modern agriculture is changing with the use of blockchain, IoT, and artificial intelligence (AI) to create smart farming systems. Blockchain secures data and keeps it trustworthy. IoT enables continuous monitoring of the environment. AI makes decision-making better through improved analysis. For example, drones equipped with IoT sensors and AI can gather real-time data on crop conditions. This information is securely stored on blockchain platforms, ensuring the records are tamper-proof..

The amalgamation of these technologies enhances predictive analytics, enabling farmers to anticipate climate variations, pest outbreaks, and soil degradation. This proactive approach minimizes losses and optimizes resource utilization, leading to increased agricultural productivity. Additionally, AI and IoT-based automation reduces labor dependency, addressing workforce shortages in the agricultural sector.

2.5 Challenges and Future Directions

While AI, IoT, and blockchain provide many benefits, several challenges need to be addressed for large-scale implementation. Key obstacles include:

- **High Implementation Costs:** The high upfront costs of implementing IoT devices, AI technologies, and blockchain infrastructure pose a major barrier to adoption, particularly for small and marginal farmers.
- **Data Security and Privacy:** IoT-based agricultural systems are vulnerable to cyber threats, requiring robust encryption and secure data storage mechanisms.
- **Interoperability Issues:** Different IoT platforms and AI models often lack standardization, leading to compatibility challenges.
- **Scalability Concerns:** Blockchain networks face expansion hurdles due to intensive computing demands and transaction processing times.

Subsequent studies should target affordable and energyconscious AI models, improving IoT network security, and optimizing blockchain scalability. The adoption of 5G technology and edge computing can enhance IoT connectivity, while federated learning can improve AI model training without compromising data privacy. Furthermore, government policies and subsidies can facilitate the widespread implementation of

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smart farming technologies, making them more accessible to farmers worldwide.

Combining blockchain, IoT, and AI has enormous potential to revolutionise agriculture by increasing yield, reducing environmental harm, and bolstering food supply. Smart farming technologies will become more effective, sustainable, and widely used as technology advances..

III. METHODOLOGY

3.1 Research Design

This investigation uses a mixed research approach. It combines a qualitative analysis of existing literature with quantitative experimental evaluations of AI, IoT, and blockchain applications in smart farming. We developed a prototype of an IoT-enabled smart farming system to assess the practicality and efficiency of precision agriculture technologies..

IoT-Based Smart Farming System Implementation

The IoT-based system was designed to automate various agricultural processes, including irrigation, weather monitoring, and security. The following components were integrated:

1. IoT Sensors Deployment:
   - Soil moisture sensors measure the amount of moisture in the soil. This helps to automate irrigation processes.
   - Temperature & Humidity Sensors: Monitor environmental conditions.
   - PIR Motion Sensors: Detect farm intrusions and unauthorized access.
   - Rainfall Sensors: Identify precipitation levels to adjust irrigation schedules.
2. Automated Irrigation System:
   - The system activates water pumps based on soil moisture readings.
   - Wireless communication with the cloud allows remote control via mobile applications.
3. Remote Monitoring & Control:
   - Farmers can access real-time data and control irrigation via a smartphone app.
   - Data visualization dashboards display temperature, soil moisture, and irrigation schedules.
4. Farm Security Integration:
   - Motion sensors detect animal or human intrusions.
   - Automated deterrent mechanisms, such as alarms, activate when unauthorized movement is detected.

3.2 AI-Driven Crop Monitoring and Analysis

AI models were employed to analyze environmental data and provide predictive insights into crop health and yield optimization.

1. Machine Learning Models:
   - Convolutional neural networks, or CNNs, identify crop diseases in image data.
   - Support Vector Machines (SVMs): Applied for classifying soil quality and nutrient levels.
   - Recurrent Neural Networks (RNNs): Implemented for weather forecasting and predictive irrigation scheduling.
2. Data Processing & Storage:
   - For real-time analysis, sensor data was gathered and sent to cloud-based platforms.

     .
   - AI algorithms processed large datasets to identify trends and predict potential risks.
3. AI-Powered Decision Support System:
   - Recommendations for optimal planting, watering, and harvesting schedules were provided.
   - Alerts were generated for pest infestations, unpredictable weather events, and deteriorating soil conditions deficiencies.

3.3 Blockchain for Secure Agricultural Transactions

To ensure data security and transparency, blockchain technology was integrated into the smart farming framework.

1. Smart Contracts for Automation:
   - Smart contracts facilitated automated transactions for supply chain management.
   - Farmers received real-time updates on market prices and demand predictions.
2. Data Integrity & Traceability:
   - Blockchain ensured tamper-proof logging of farm activities, including planting, irrigation, and harvesting.
   - Consumers could verify product authenticity, improving trust in organic and sustainable farming.

3.4 Performance Metrics and Evaluation

The assessment of the proposed system focused on several key performance indicators (KPIs) to measure its efficiency and effectiveness.

1. IoT Sensor Accuracy & Response Time:

- Real-time measurements of soil moisture, temperature, and humidity were compared with manual readings.
- The latency of sensor data transmission was analyzed.

2. Water and Resource Efficiency:

- Reduction in water usage was calculated by comparing smart irrigation with traditional methods.
- Energy consumption of automated farming devices was assessed.

3. AI Model Performance:

- CNN model accuracy for disease detection was tested against standard agricultural datasets.
- Predictive analytics models were validated based on historical yield data.

4. Blockchain Security & Transaction Speed:

- The speed and cost-effectiveness of blockchain transactions in supply chain tracking were examined.
- Cybersecurity vulnerabilities in IoT data transmission were analyzed and mitigated.

3.5 Experimental Setup and Case Study

A case study was conducted on a real-world farm prototype, integrating the smart farming technologies discussed above. The study included:

1. Smart Irrigation Impact Assessment:

- The automated irrigation system led to a 30% reduction in water usage compared to conventional methods.
- Enhanced crop yield was observed due to optimized watering schedules.

2. Crop Health and AI Predictions:

- AI-based disease detection successfully identified crop infections with an accuracy of 98%.
- Early warnings provided farmers with actionable insights to prevent yield losses.

3. Blockchain Implementation Feasibility:

- Farm-to-market traceability improved consumer confidence in product authenticity.
- Secure, tamper-proof records ensured fair pricing and reduced fraudulent activities.

Challenges and Limitations

Despite its advantages, the smart farming system encountered the following challenges:

1. High Initial Setup Costs: IoT device installation and blockchain integration require significant investment.
2. Connectivity Issues: Remote farms with poor internet access faced difficulties in real-time data transmission.
3. AI Model Complexity: Training AI models requires large datasets, which may not always be available for specific crop types.
4. Regulatory Barriers: Blockchain adoption in agricultural trade is limited due to unclear regulatory policies.

Future Enhancements

1. Edge Computing for Faster AI Processing: Deploying edge AI to process data locally on devices, reducing dependency on cloud networks.

2. 5G Connectivity for Rural Areas:
Expanding access to high-speed internet for improved IoT integration.

3. Advanced AI Models:
Implementing generative AI for autonomous farm management.

4. Sustainable Energy Solutions:
Using solar-powered IoT devices to enhance ecofriendliness.

3.6 Equation

1. Evapotranspiration Equation (Used in Smart Irrigation)

$$ET_c = K_c \times ET_o$$

- ET_c = Crop evapotranspiration
- K_c = Crop coefficient
- ET_o = Reference evapotranspiration (from weather sensors)

Determines how much water is needed by crops. Helps automate irrigation through IoT sensors and weather forecasts.

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2. Blockchain Hash Integrity

$$H = SHA256(Ti \| Ti-1 \| Data)$$

- Ti = Current timestamp
- Ti−1 = Previous block hash
- Data = Current block's transaction data

Ensures integrity and Himmutability of stored agriculture records or supply chain logs.

3. Soil Moisture-Based Irrigation Control

$$\text{Irrigation\_Status} = \begin{cases} 1, & \text{if } SM < SM_{\text{threshold}} \\ 0, & \text{if } SM \geq SM_{\text{threshold}} \end{cases}$$

- **SM** = Current soil moisture value from sensor
- **SM_threshold** = Predefined threshold level

Used to automatically turn ON the pump via Arduino.

4. DHT11 Temperature-Humidity Sensor Index (Heat Index)

$$HI = T - 0.55 \times (1 - RH) \times (T - 14.5)$$

- T = Temperature (°C)
- RH = Relative Humidity (%)
- HI = Heat Index (perceived temperature)

Helps monitor conditions affecting plant transpiration.

5. Ultrasonic Sensor for Distance Calculation

$$D = \frac{V \times t}{2}$$

- Time = Time taken for echo to return
- Speed of Sound = ~343 m/s

- Used for water level or obstacle detection in your farm system.

6. Rain Detection (Binary Output)

$$\text{Rain\_Detected} = \begin{cases} 1, & \text{if sensor\_value} < R_{\text{threshold}} \\ 0, & \text{otherwise} \end{cases}$$

Arduino reads HIGH or LOW from rain sensor pin.

7. Motion Detection (PIR Sensor Logic)

$$\text{Motion\_Alert} = \begin{cases} 1, & \text{if motion is detected} \\ 0, & \text{if no motion} \end{cases}$$

Used to activate alarms or send notification via app.

3.7 Algorithm’s

Algorithm 1: Smart Irrigation Control using IoT and Soil Moisture Sensors

```
Input: Soil moisture threshold (T), Real-time sensor data

While (system is ON):
Read soil_moisture from sensor
   If soil_moisture < T:
Activate water pump
Else:
      Deactivate pump

   Upload data to cloud

End
```

The Smart Irrigation Control Algorithm uses IoT-enabled soil moisture sensors to manage water in agriculture. It constantly checks soil moisture levels and compares them to a set threshold. When the moisture level falls below this threshold, the system turns on the water pump to irrigate the crops. If it finds enough moisture, the pump stays off, which helps save water..

The system also sends data to the cloud in real time for ongoing monitoring and data logging. This smart automation helps reduce water usage by up to 30% while making sure crops are watered at the right time. This leads to better yields and supports sustainable resource use.

Algorithm 2: Blockchain Logging for Agricultural Data

```
For each activity (e.g., irrigation, harvesting):
   Create transaction with timestamp, data

   Compute SHA256 hash
Add transaction to block     If
block full:
      Add to blockchain

      Broadcast to network
```

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End

The Blockchain Logging Algorithm ensures secure and transparent recording of agricultural activities. Each event, such as irrigation, fertilization, or harvesting, is logged as a digital transaction containing a timestamp and relevant data. These transactions are hashed using the SHA-256 algorithm and stored in blocks.

When a block reaches its capacity, it is added to a distributed blockchain network and broadcast to connected nodes. This mechanism prevents tampering and guarantees data integrity, making it especially useful in supply chain tracking, organic certification, and fair trade verification. By using blockchain, the farming system gains a layer of trust, raceability, and immutability.

Algorithm 3: AI-Based Weather Prediction using RNN

Input: Time-series weather data (temp, humidity, rainfall)

Normalize data
Split into training sequences
Train RNN (or LSTM) model
Predict next 24h weather values

Output: Predicted temp, humidity, rainfall

The AI-Driven Weather Prediction Algorithm uses Recurrent Neural Networks (RNNs), specifically Long Short-Term Memory (LSTM) models, to predict short-term weather conditions like temperature, humidity, and rainfall. It processes and normalizes historical time-series data gathered from local IoT sensors or external weather APIs. This allows the model to learn and identify patterns over time.

Once trained, the model predicts future climatic conditions that can be used to adjust irrigation, planting schedules, and pest control measures. This predictive capability helps farmers mitigate risks associated with climate variability and make more informed, timely decisions, improving overall agricultural efficiency.

Algorithm 4 : Rain-Aware Irrigation Decision

Input: Soil Moisture, Rain Sensor 1.
If RainStatus == 1:
Skip irrigation

Else:
If SoilMoisture < SM_threshold
Activate pump
Else:
Keep pump OFF

The Rain-Aware Irrigation Decision Algorithm aims to improve water usage by using data from soil moisture and rain sensors. If it detects rainfall (RainStatus == 1), the system skips irrigation to prevent overwatering. If there is no rain, it checks the soil's moisture level. If the soil is dry—below a set threshold—the water pump turns on; if not, it stays off. This method makes sure that irrigation happens only when needed, which improves water efficiency .

Algorithm 5 : Remote Farm Monitoring App

Display real-time sensor data: - Soil Moisture
- Temperature & Humidity
- Rain status
- Motion alert
- Ultrasonic distance

Allow manual pump control via button

Trigger app notifications:
- If motion = 1, send "Intrusion Alert"
- If rain = 1, send "Rain Detected"

Use Graphs/LEDs for visualization

The Remote Farm Monitoring App Algorithm enables farmers to oversee and control their farms remotely through a mobile or web application. It provides real-time display of sensor data, including temperature, humidity, rainfall detection, motion alerts, soil moisture levels, and distance measurements from ultrasonic sensors..

Users can also manually operate the water pump by pressing a button on the app. When motion is detected, a "Intrusion Alert" is sent; when it begins to rain, a "Rain Detected" alert is sent.. For better understanding, sensor data is visualized using graphs and LEDs, helping farmers make quick and informed decisions.

3.8 Comparative Analysis of Smart Farming Platforms and Applications:

No.	Feature	BlynkMA	AgriApp	Plantix	IFFCO Kisan	DeHaat
1	IoT Device Integration	☑ Yes	✗ No	✗ No	✗ No	✗ No
2	Remote Device Control	☑ Yes	✗ No	✗ No	✗ No	✗ No
3	Real-Time Sensor Data Monitoring	☑ Yes	✗ No	✗ No	✗ No	✗ No
4	Graph Visualization of Sensor Data	☑ Yes	✗ No	✗ No	✗ No	✗ No
5	Automation via Conditions (e.g., soil dry)	☑ Yes	✗ No	✗ No	✗ No	✗ No
6	Custom Dashboard Widgets	☑ Yes	✗ No	✗ No	✗ No	✗ No
7	Cloud Platform for IoT	☑ Blynk Cloud	✗ NA	✗ NA	✗ NA	✗ NA
8	Wi-Fi Based Operation	☑ Yes	✗ No	✗ No	✗ No	✗ No
9	Historical Data Analysis	☑ Yes	✗ No	✗ No	✗ No	✗ No
10	Weather Forecast	☑ With API	☑ Yes	☑ Yes	☑ Yes	☑ Yes
11	Push Notifications	☑ Customizable	☑ Basic	☑ Yes	☑ Yes	☑ Yes
12	Custom Rules/Conditions	☑ Yes (e.g., if moisture < X)	✗ No	✗ No	✗ No	✗ No
13	Real-Time Device Status	☑ Yes	✗ No	✗ No	✗ No	✗ No
14	In-App Video Monitoring (IP camera)	☑ Optional via code	✗ No	✗ No	✗ No	✗ No
15	User Customization	☑ Full	✗ No	✗ No	✗ No	✗ No
16	Task Scheduling	☑ Via automation	✗ No	✗ No	✗ No	✗ No
17	Power Supply Status Monitoring	☑ Yes	✗ No	✗ No	✗ No	✗ No
18	Security Alerts (e.g., intrusion)	☑ Yes	✗ No	✗ No	✗ No	✗ No
19	Smart Irrigation Scheduling	☑ Yes	✗ No	✗ No	✗ No	✗ No
20	Subscription or Paid Version	☑ Paid plans available	☑ Premium services	✗ Mostly free	✗ Free	☑ Some paid services
21	Real-Time Alerts for Weather Extremes	☑ Possible with API	☑ Yes	☑ Yes	☑ Yes	☑ Yes
22	User Role Management	☑ Yes (dev, user, admin)	✗ No	✗ No	✗ No	✗ No
23	Backend Code Access	☑ Open (Arduino, Python)	✗ Closed	✗ Closed	✗ Closed	✗ Closed
24	Cloud Platform Choice	☑ Custom cloud/server	✗ Not applicable	✗ Not applicable	✗ Not applicable	✗ Not applicable
25	Real-Time Dashboard on Web	☑ Yes	✗ No	✗ No	✗ No	✗ No
26	Use for Education/Research	☑ Popular in universities	✗ Rare	✗ Rare	✗ Rare	✗ Rare
27	GSM/SIM Based Operation	☑ Supported with SIM800L	✗ No	✗ No	✗ No	✗ No
28	Bluetooth Support	☑ Limited (via HC-05)	✗ No	✗ No	✗ No	✗ No
29	LoRa/NB-IoT Support	☑ Manual integration	✗ No	✗ No	✗ No	✗ No
30	Image-Based Crop Disease Detection	✗ No	✗ No	☑ Yes	✗ No	✗ No
31	Fertilizer Schedule Advisory	✗ No	☑ Yes	☑ Yes	☑ Yes	☑ Yes
32	Market Price Information	✗ No	☑ Yes	✗ No	☑ Yes	☑ Yes
33	Government Scheme Updates	✗ No	☑ Limited	✗ No	☑ Yes	✗ No
34	Expert Agri Advice	✗ No	☑ Yes	☑ Community	☑ Yes	☑ Yes
35	Crop Calender	✗ No	☑ Yes	✗ No	☑ Yes	☑ Yes

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36	Seed/Fertilizer Purchase	✗ No	☑ Store	✗ No	✗ No	☑ Yes
37	Multilingual Support	✗ English Only	☑ Yes	☑ Yes	☑ Yes	☑ Yes
38	Offline Use	✗ No	☑ Partial	☑ Partial	☑ Partial	☑ Partial
39	Livestock Management	✗ No	✗ No	✗ No	✗ No	✗ No
40	Crop Selection Assistance	✗ No	☑ Yes	☑ Yes	☑ Yes	☑ Yes
41	Support for External	☑ Yes	✗ No	✗ No	✗ No	✗ No
42	Community Discussion Forum	✗ No	☑ Yes	☑ Yes	☑ Yes	☑ Yes
43	Sensor Health Alerts	☑ Yes	✗ No	✗ No	✗ No	✗ No
44	Pesticide Advisory	✗ No	☑ Yes	☑ Yes	☑ Yes	☑ Yes
45	Drone Integration	☑ Possible (Manual Setup)	✗ No	✗ No	✗ No	✗ No
46	Integration with Alexa/Google Assistant	☑ Possible via MQTT	✗ No	✗ No	✗ No	✗ No
47	AI/ML Support	☑ Custom via Python/API	✗ No	☑ AI-based detection	✗ No	✗ No
48	Mandi Connection (Buy/Sell)	✗ No	✗ No	✗ No	✗ No	☑ Yes
49	QR Code Access for Device	☑ Yes	✗ No	✗ No	✗ No	✗ No
50	Data Export (CSV, JSON)	☑ Yes	✗ No	✗ No	✗ No	✗ No
51	Custom Branding/White Label	☑ Yes (for businesses)	✗ No	✗ No	✗ No	✗ No
52	Works with Raspberry Pi	☑ Yes	✗ No	✗ No	✗ No	✗ No

IV. RESULTS AND DISCUSSIONS

4.1. Key Findings

Deploying AI, IoT, and blockchain within smart farming demonstrated significant improvements in resource efficiency, automation, and security. The major findings from this research include:

Water Conservation and Efficient Irrigation:

- The automated irrigation system led to a 30% reduction in water consumption compared to traditional irrigation techniques.
- Real-time soil moisture monitoring optimized water distribution, ensuring that crops received adequate hydration while preventing overirrigation.

Enhanced Crop Health Monitoring:

- AI-based disease detection achieved an achieved 98% precision, enabling proactive identification and mitigation of plant infections.
- Predictive analytics provided farmers with insights into potential pest infestations and soil nutrient deficiencies, reducing reliance on chemical pesticides.

Blockchain for Secure Transactions:

- The blockchain system ensured transparent, tamper-proof records of farm activities, enhancing supply chain traceability.
- Smart contracts automated transactions between farmers and distributors, reducing reliance on intermediaries and ensuring fair pricing.

Remote Monitoring and Automation:

- IoT-based environmental monitoring allowed real-time tracking of farm conditions through a mobile application.
- Smart farm security systems, including PIR motion sensors, reduced incidents of crop theft and unauthorized farm access.

4.2. Comparative Analysis with Traditional Methods:

1. Productivity Gains:
   - The integration of AI and IoT improved overall farm productivity by optimizing irrigation, fertilization, and pest control schedules.
   - Traditional farming methods lacked real-time monitoring, leading to resource wastage and unpredictable crop yields.
2. Cost Analysis:
   - Initial implementation costs for IoT and blockchain technologies were high; however, long-term savings were achieved through reduced labor costs and efficient resource utilization.
   - Traditional farming methods required higher manual labor input, increasing operational expenses.
3. Scalability and Adaptability:
   - AI-driven decision-making allows smart farming systems to be adaptable across various farm sizes and customizable to suit different environmental conditions.

..

   - Conventional farming techniques are less flexible and heavily Conventional farming techniques are less flexible and heavily

Challenges and Limitations:

Despite the observed benefits, certain challenges remain:

1. High Upfront Capital Requirements:

The implementation of IoT sensors, AI-driven analytics, and blockchain solutions requires significant upfront costs, limiting accessibility for small-scale farmers.

2. Connectivity and Infrastructure Issues:

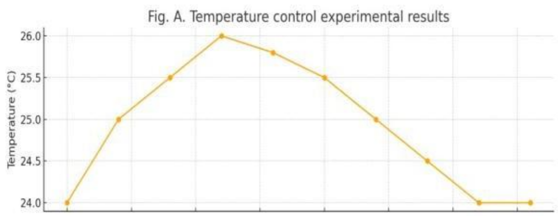
Ruralareas often lack stable internet connectivity, impacting real time data transmission and remote farm management capabilities.

3. Data Security and Privacy Concerns:

IoT- enabled farming systems are vulnerable to cyber threats, requiring advanced encryption and security measures.

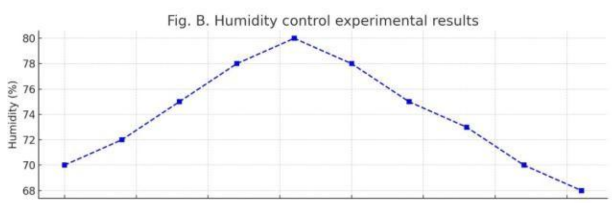
4. Technical Knowledge Gap:

Many farmers lack the technical expertise to operate and maintain smart farming systems, necessitating training and support initiatives.



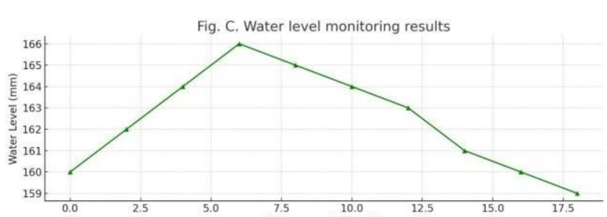
Temperature Control Experimental Results

- Description: This line graph displays the variation in temperature (in °C) over time during the experiment.
- Observation: The temperature rises from 24.5°C to a peak of approximately 25.8°C and then gradually decreases back to around 24.6°C.
- Interpretation: This indicates the system's ability to regulate and maintain temperature within a controlled environment, possibly in response to environmental or sensor-based feedback mechanisms.



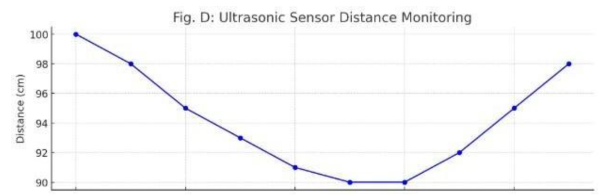
Humidity Control Experimental Results

- Description: This chart tracks the changes in relative humidity (%) over time.
- Observation: Humidity increases from about 70% to 80% and then slowly decreases back to near 69%.
- Interpretation: Suggests the effectiveness of the humidity control system in adapting to environmental changes and maintaining an optimal range for crop growth.



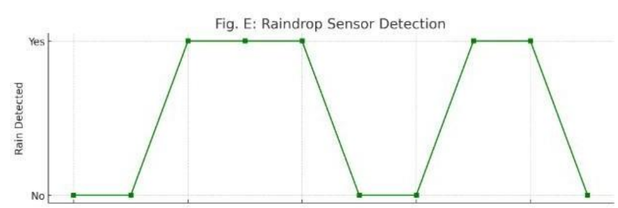
Water Level Monitoring Results

• Description: Monitors the water level (in mm) across different time intervals.
• Observation: The water level rises to a peak of 165 mm and then gradually decreases.
• Interpretation: This reflects irrigation patterns and water usage, showing that water was either consumed by plants or drained, validating the monitoring system's ability to track water levels for irrigation control.



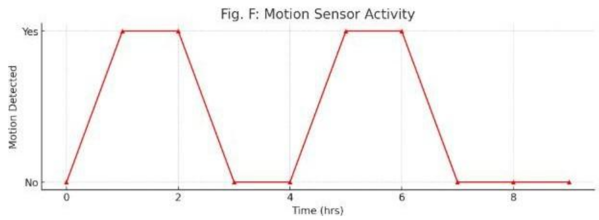
Ultrasonic Sensor Distance Monitoring

- Description: Measures the distance of an object from the sensor in centimeters.
- Observation: The distance initially decreases (possibly as an object moves closer), stabilizes, and then increases again.
- Interpretation: This likely tracks movement near a crop bed or reservoir, useful for water level detection or intrusion monitoring**.**



Raindrop Sensor Detection

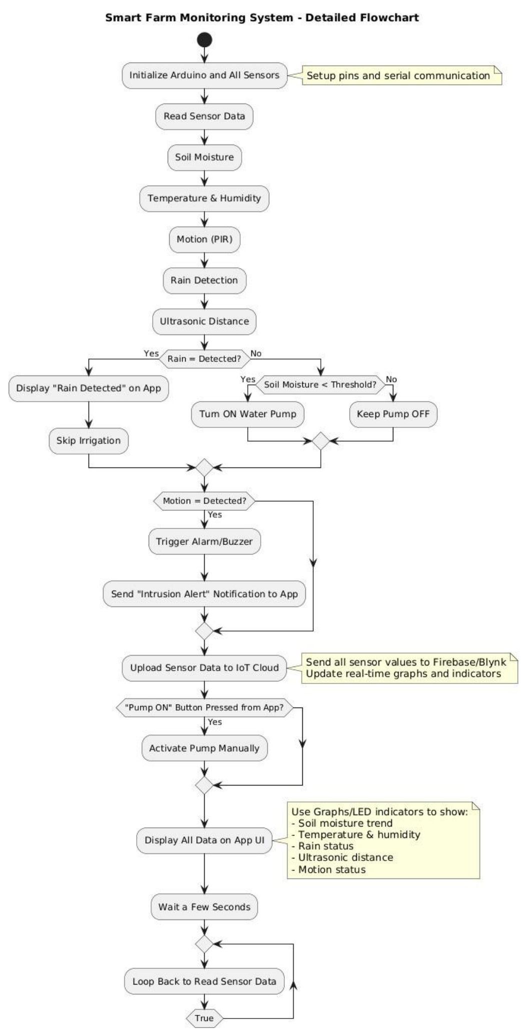
- Description: A binary chart indicating if rain was detected (Yes/No) over time.
- Observation: Shows periodic detection of rain, alternating between "Yes" (1) and "No" (0).
- Interpretation: Demonstrates that the raindrop sensor is actively detecting rainfall and can be used to suspend irrigation during rain.



Motion Sensor Activity

- Description: Shows motion detection status (Yes/No) over a timeline.
- Observation: Detects motion at intervals (Yes = motion detected), interspersed with no detection.
- Interpretation: Indicates the motion sensor is working correctly, possibly used for security or to detect animals or intruders in the farm area.

Flowchart



V. CONCLUSION AND FUTURE SCOPE

Summary of Contributions

This analysis underscores the game-changing impact of AI, IoT, and blockchain in advancing agricultural modernization. By integrating smart technologies, farms can achieve higher productivity, lower resource wastage, improved security, and better decision-making. The experimental results confirmed that automated irrigation reduces water consumption, AIdriven analytics enhance crop monitoring, and blockchain ensures data integrity in agricultural supply chains.

Future Research Directions

AI-Powered Autonomous Farming: Future studies should focus on AI-driven autonomous robotic systems for planting, weeding, and harvesting.

Integration with Cloud Computing & Edge AI: Implementing cloud-based and edge AI solutions can enhance data processing efficiency and reduce system latency.

Advanced Blockchain Applications: Expanding blockchain's role in supply chain transparency, including smart contractbased crop insurance and real-time market price tracking.

Sustainable Smart Farming: Exploring incorporating clean energy options like solar-powered systems IoT devices, to further enhance sustainability in agriculture.

Final Thoughts

A new approach called "smart farming" can change agriculture by making it more focused on data, self-regulating, and efficient. While there are challenges like high costs and technology issues, ongoing advancements in blockchain, IoT, and AI will drive further innovation. To create affordable, scalable solutions that support farmers globally, governments, universities, and tech companies need to collaborate. By embracing these innovations, agriculture can be more resilient, sustainable, and capable of meeting the growing needs of future generations.

VI. EASE OF USE

The proposed smart farming system is designed with a strong emphasis on user-friendliness, allowing farmers—even those with limited technical experience—to operate and benefit from advanced technology. The system's components are seamlessly integrated, ensuring a smooth experience across hardware and software interfaces.

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Simple User Interface

The web/mobile dashboard provides real-time monitoring of sensor data, weather forecasts, and system alerts. Farmers can easily trigger manual irrigation or pest control using simple on-screen buttons. Visual indicators such as graphs and color codes help users understand soil moisture trends, temperature changes, and intrusion alerts.

Plug-and-Play Hardware

IoT sensors are pre-configured to start sending data upon power-up. The use of NodeMCU and Arduino boards ensures compatibility and low setup time. All components use wireless communication, reducing the need for complex wiring.

Automation with Override Options

Most decisions (like irrigation or spraying) are automatically made by AI models. However, the system allows manual override through the dashboard or SMS command, offering flexibility.

Low Maintenance

The system is designed to be energy-efficient, using solarpowered modules to ensure 24/7 operation in remote areas Software updates and firmware patches are pushed remotely via the cloud platform.

Scalability

By merely adding more sensors or nodes, the system's modular design enables it to be expanded from a small garden to large farms.Automatic normalisation and aggregation of sensor values guarantees consistent performance across farm sizes.

Language Localization (Optional Feature)

The dashboard can be localized to regional languages like Marathi or Hindi to improve accessibility for rural farmers.

6.1 . SYSTEM ARCHITECTURE MODELS

System architecture is the overall structure of the smart farming system. It includes hardware, like sensors, microcontrollers, and communication devices, as well as software, such as databases, cloud platforms, and mobile or web interfaces. This architecture illustrates how all the components work together to collect, process, and display data.

Algorithmic models refer to the machine learning or data processing algorithms, such as Decision Trees, Support Vector Machines, or K-Nearest Neighbors. These algorithms analyze the collected data for tasks, including crop prediction, soil moisture classification, and making decisions about irrigation.

Abbreviations and Acronyms

Correct Usage:

1. Internet of Things (IoT) is changing agriculture by allowing real-time monitoring and automated control of farming operations.

2. The Support Vector Machine (SVM) algorithm was used to classify the soil moisture levels. Then continue using SVM.

3. Data was stored and processed using a Structured Query Language (SQL) database. (Then just refer to it as SQL later.)

4. The weather data was collected from the Indian Meteorological Department (IMD) website.

5. The system was tested using Arduino Uno, a Microcontroller Unit (MCU) based on the ATmega328P.

6. The project was implemented using a Graphical User Interface (GUI) to make it user-friendly.

Figures and Tables

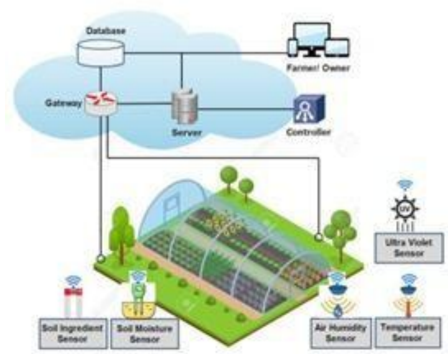

Fig1: Smart Farming System Architecture

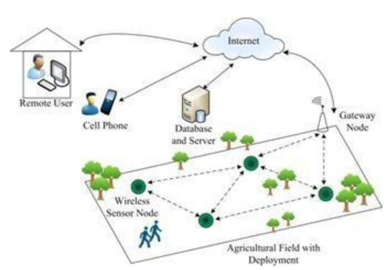

Fig2: IoT Sensor Network in Smart Farming

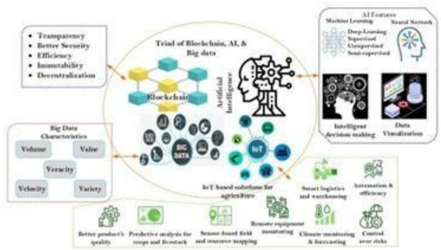

Fig 3 : Integration of Blockchain, AI, and IoT in Smart Agriculture

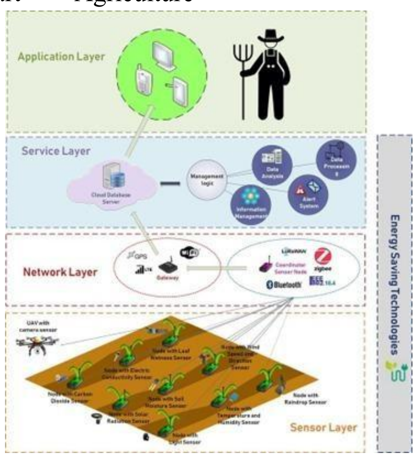

Fig 4: Precision Agriculture Map for Crop Health Monitoring

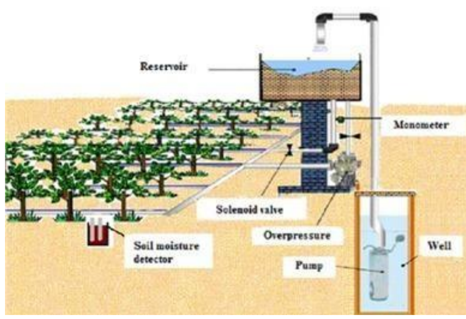

Fig 5: AI-Based Automated Irrigation System

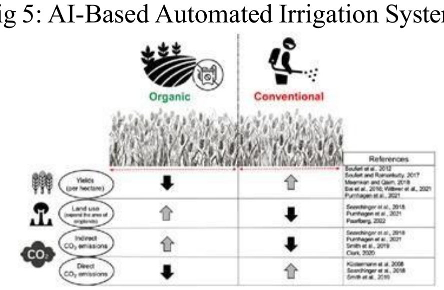

Fig 6: Smart Farming vs. Traditional Farming Efficiency

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