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REVIEW PAPER

Smart Agriculture Systems: Integrating AI and IoT for Sustainable Crop Production

Krishanu Adhikari[1], Abhrajit Dutta[1], Soumili Naiya[1], Sagar Banik[1] and Deb Prasad Ray[2*]

[1]Department of Agriculture, Brainware University, Barasat, Kolkata, West Bengal, India

[2]ICAR-National Institute of Natural Fibre Engineering & Technology, 12, Regent Park, Kolkata, India

*Corresponding author: drdebprasadray@gmail.com (**ORCID ID:** 0000-0002-6676-4498)

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ABSTRACT

AI and IoT are changing precision agriculture, process automation, irrigation optimization, predicting the health of crops and animals, improving the supply chain, and making things more sustainable. AI and IoT technology help with big problems like a lack of agricultural supplies and a growing global population. AI, IoT, remote sensing, and GIS-powered precision agriculture goes beyond traditional farming to use data-driven strategies that make the most use of resources, increase crop yields, cut down on waste, and make farming more sustainable. This adjustment not only makes things work better, but it also encourages eco-friendly farming practices, which makes agriculture more resistant to climate change and resource depletion and lowers the growing need for food. Using AI and the Internet of Things (IoT) in precision farming has made it much easier to keep an eye on crops, manage resources, and make decisions. When used on the FAOSTAT dataset, a suggested precision farming (PF) method does better than the current classification methods, getting 98.65% accuracy, 98.32% precision, and 97.65% recall in just 0.23 seconds. This method also shows off the tools and methods that are important for PF and the tools that are used in modern farming in real time. When you combine IoT devices with machine learning, you can look at data in real time. This makes things more efficient, has less of an effect on the environment, and produces more. This is good for the environment and makes money. Using both in situ and mobile sensors is very important for predicting yields and making decisions based on those predictions. Also, radio frequency variables are needed to make wireless sensor networks (WSNs) work better in farming. But they are still worried about privacy issues, the intricacy of the technology, and the high expenses of putting it into practice.

HIGHLIGHTS

- AI -IoT optimize irrigation, cutting production costs significantly.
- AI detects early diseases, reducing yield losses effectively.
- IoT sensors enable automated decision via ARM processors.
- Fuzzy logic and neural networks boost sensor communication.
- Blockchain enhances wireless networks for food security.

Keywords: AI, Geographic Information Systems (GIS), Internet of Things (IoT), and Wireless Sensor Networks (WSNs)

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Since it started in the 1980s, precision farming has used technologies like GPS, remote sensing, and data analysis to make the most of resources and sustainability (Mulla and Khosla, 2016). Changes like automation and variable rate applications have made processes work better (Kumar *et al.* 2021). The goal of site-specific management in precision agriculture is to get the most crops while having the least impact on the environment (Moretti *et al.* 2023). Smart technologies like AI, the Internet of Things (IoT), and big data are necessary for solving problems like climate change and making things run more smoothly. By 2050, the world will need a lot more food than it does now (Shaikh et al. 2022; Qazi *et al.* 2022). But problems with technology and teaching make it hard to use (Elahi *et al*. 2020).

Application of AI occurs in farming

Artificial intelligence (AI) copies how people make decisions to solve hard problems in many fields, such as agriculture. It makes things more efficient by boosting performance, simplifying processes, and automating tasks (Spanaki *et al.* 2021). AI helps farmers choose what crops to grow, how to take care of the land, how to get rid of pests, and how to predict how much they will produce (Javaid *et al.* 2023).

Deep learning, the Internet of Things (IoT), and robotics are examples of AI technologies that keep an eye on farm data and make the farm more sustainable and profitable. AI also makes the agricultural supply chain more efficient and less wasteful, making tasks like crop rotation and watering more precise (Ahumada and Villalobos, 2009; Ben Ayed and Hanana, 2021).

Application of AI Can Do in Farming System

Keeping an eye on the health of crops: The quality and nutrient contents of the soil affect how well crops grow, yet deforestation has made the soil worse. AI-based tools like Plantix, made by PEAT, use photo recognition to find soil problems, pests, and diseases so that farmers may make better choices regarding fertilizer, pest control, and disease management and get more crops (Kacho *et al.* 2018).

Taking care of the soil

Soil has to provide important nutrients including water, nitrogen, phosphorus, and potassium for crops to grow. The quality of the nutrient directly affects how well it is absorbed, which in turn affects sustainability and production. Using manure, compost, and different ways of tilling the soil can make it better and slow down its degeneration. AI helps by making soil maps, which give farmers a better idea of how the soil is structured and help them plan their crops and manage their property better.

Managing Pests

Insect pests that infest crops cause big losses in farming. To fix this, computer applications like TEAPEST use neural networks and fuzzy logic to find pests and recommend ways to get rid of them. This makes pest control more successful. By making sense of complicated data, these technologies help people make better decisions and find long-term ways to protect the environment and farming.

Illness Management

Farmers can use computer-aided methods to find and get rid of agricultural illnesses, which can hurt their yields. Fuzzy logic models, such as (Tilva *et al.* 2013), for leaf wetness and neural network-based models, help farmers find and treat diseases more quickly, which helps them lose less crops and act more quickly (Bannerjee *et al.* 2018).

Yield Prediction

Crop yield forecasting is vital for distribution, pricing, and harvest planning. Farmers may use predictive models to look at things like weather, soil conditions, and pest control to help them get more out of their resources and make more money. Using an artificial neural network with backpropagation, predictions are created based on soil characteristics to help in crop management and making decisions. (Bannerjee *et al.* 2018).

Robots in Farming

Artificial intelligence (AI) robots are changing farming by automating tasks including planting, weeding, monitoring crops, and harvesting. These robots make farming more efficient, more productive, and less expensive for workers. They improve crop management, increase yields, and

enable more profitable and sustainable farming ways by making sure things are correct and lowering the chance of human error.

DIFFERENT AI METHODS

Fuzzy logic

Fuzzy Logic (FL), Zadeh in 1965 handles problems that are complicated, unclear, or not straight by making decisions based on different levels of truth. FL is often used in farming to make things like crop monitoring, aerial imaging, and UAV navigation better. It also helps scientists learn more about how plants grow and how the weather impacts crops, which makes it easier to make decisions about farming (Manas Wakchaure *et al.* 2023).

Artificial neural network

Artificial neural networks (ANN) is a new area of study that is based on how the human brain functions and is meant to solve difficult problems. Artificial neural networks (ANNs) use input, hidden, and output layers to look at data and come up with answers. Elizondo *et al.* say that they are used in farming to predict when flowers will bloom and keep track of when crops are ready to harvest, like with soybeans.

Genetic algorithm

John Holland came up with Genetic Algorithms (GA) in the 1960s. They use natural selection to find the best solutions. GA makes it easier for mobile robots to move around on farms for tasks like planting and harvesting. Multi-path planning reduces collisions and travel time for robot fleets, which improves field coverage, lowers labor costs, and increases output.

What IoT Does for Farming

Artificial intelligence (AI) and sensors have changed the way businesses may collect and analyze data in real time. Wearable medical equipment keeps an eye on vital signs, and AI finds problems so that they can be diagnosed quickly (Kayad *et al.* 2020). In smart cities, AI analyzes sensor data from traffic and environmental monitoring to get the most out of resources. When used with AI, sensors like LiDAR and radar make it possible for self-driving cars to drive safely (Elahi *et al.* 2020). Sensors in farming can tell what the weather is like, which helps with observation and decision-making. A lot of sectors are being changed by AI, IoT, and sensors working together.

Uses

More and more, farmers are using IoT technology to keep an eye on crucial parameters and handle data. It makes it possible to control and identify devices from a distance, which improves efficiency, accuracy, and usefulness. When paired with sensors and actuators, IoT makes self-driving cars, smart cities, and smart grids possible.

Wireless Sensor Networks are Used in Precision Agriculture

Precision agriculture uses the latest technology to keep an eye on how plants grow and how resources like water and fertilizer are spread over large regions. A Wireless Sensor Network (WSN) system collects data using software that is specific to each land area. A central control unit manages this system. It is best to collect data often, but in steady settings, less may be enough (Naresh and Munaswamy, 2019).

The WSN System Architecture is as follows

Wireless sensor networks (WSNs) have challenges with size, power use, and heat dissipation. We need security procedures that are fast, resource-conscious, and effective. Formal verification makes assurance that these protocols are safe and trustworthy. This work is mainly about checking cryptographic methods for setting up keys, moving them around, and authenticating nodes in different types of WSNs (Fig. 1) (Naresh and Munaswamy, 2019).

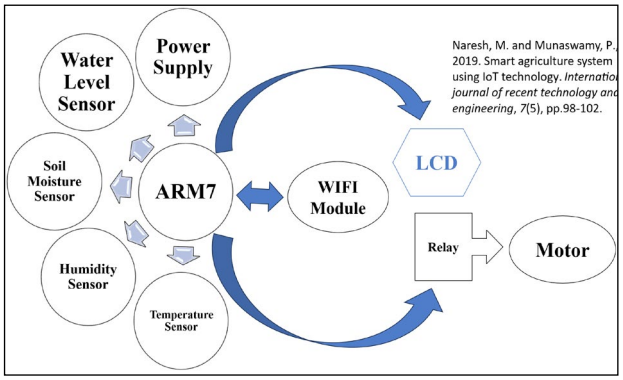

Fig. 1: Block Diagram of the System

Sensor for moisture

A soil sensor is made to find out how much moisture is in the soil. It gives you both basic and complex output choices. The advanced output gives more accurate data, although the basic output can be less accurate. The sensor works by looking at samples of the soil, which might be affected by the weather. When the soil is dry, the sensor's current flow is very low or doesn't happen at all. This could cause an open circuit (Fig. 2) (Naresh and Munaswamy, 2019).

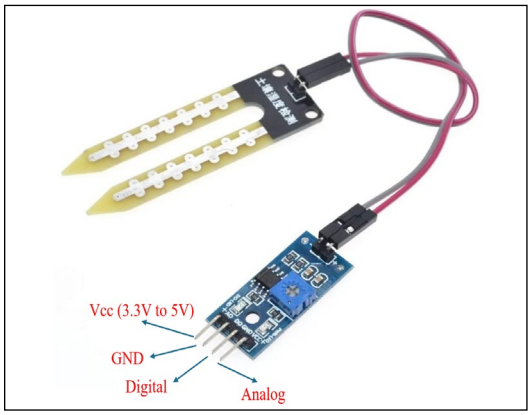

Fig. 2: Sensor for moisture

Sensor for Humidity:

The HR202 is a humidity sensor that has a circuit built in that checks for moisture in the air. This sensor is made of organic macromolecular components and can be used in places like hospitals, storage facilities, workshops, and the textile industry. It gives you an output based on the temperature and the relative humidity (RH %). The sensor works well when the temperature is between 20 and 95% RH (Fig. 3) (Naresh and Munaswamy, 2019).

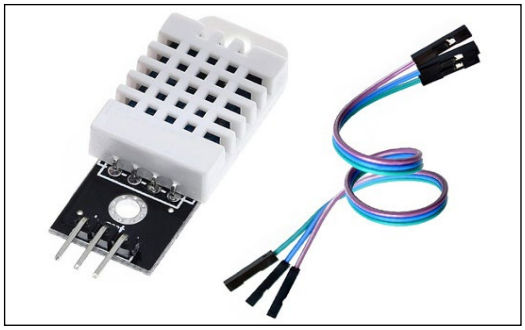

Fig. 3: Sensor for Humidity

Sensor for Temperature

The LM35 is a built-in sensor that can monitor temperature and give an electrical output that is directly related to the temperature in °C. It gives very accurate temperature readings, which makes it perfect for use with a temperature controller (Fig. 4) (Naresh and Munaswamy, 2019).

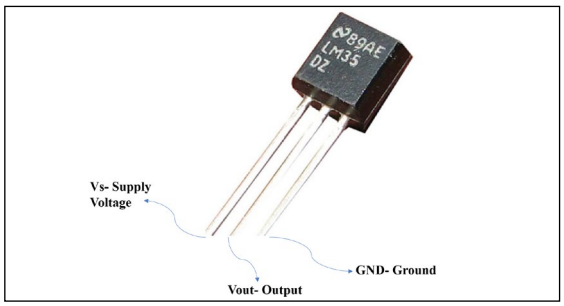

Fig. 4: Temperature Sensor

ARM Processor:

The ARM7 processor is what connects all the parts of the development kit. It has 64 pins, each of which has a different job. The LPC 2148 CPU controls the sensor thresholds and the motor's ON/OFF function, which governs how water is spread out. IoT updates the temperature data every minute. The LM35 sensor measures temperature and changes it from Kelvin to Fahrenheit or Celsius. The system keeps an eye on the temperature, humidity, and water levels. If the humidity goes over a certain level, it sends out an alert. The IoT gateway sends out new data, and transistors make sure that the data flows smoothly (Fig. 5) (Gutiérrez *et al.* 2013).

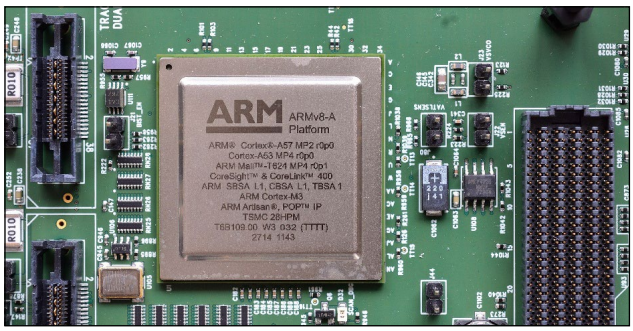

Fig. 5: ARM Processor

Water Level Sensor

Float balls, often called water level buoy sensors, are cylindrical, floating objects constructed of hard or soft materials. These non-electrical gadgets serve as visual indicators for surface marking and fluid level monitoring. They can also be used in switch

mechanisms or clear fluid tubes for systems that control and keep an eye on fluids (Fig. 6) (Naresh and Munaswamy, 2019).

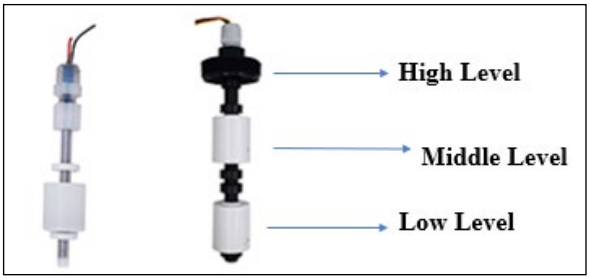

Fig. 5: Sensors for Water Level

The humidity sensor has a wide measuring range, quick response time, resistance to contamination, and good reliability. It also uses very little power, making it a fantastic value for money. The water level indicator measures the amount of water used for irrigation. When the water reaches the predetermined level, the motor turns on, and the data is sent via the Internet of Things (IoT) (Fig. 6) (Naresh and Munaswamy, 2019).

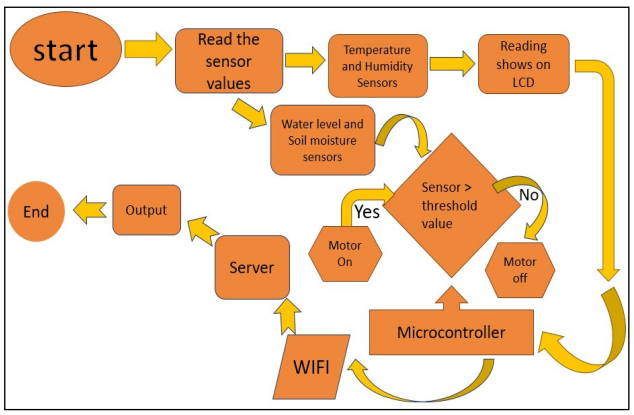

Fig. 6: Flow chart

How do sensors talk to each other?

Wireless communication technologies for the physical layer

The smart agriculture architecture focuses on wireless communication methods that let field devices and Internet Gateways talk to each other without any problems. These technologies are very important for keeping an eye on things and sharing data in farming operations. This method makes farming more efficient, sustainable, and data-driven (Fig. 7) (Qazi *et al.* 2022).

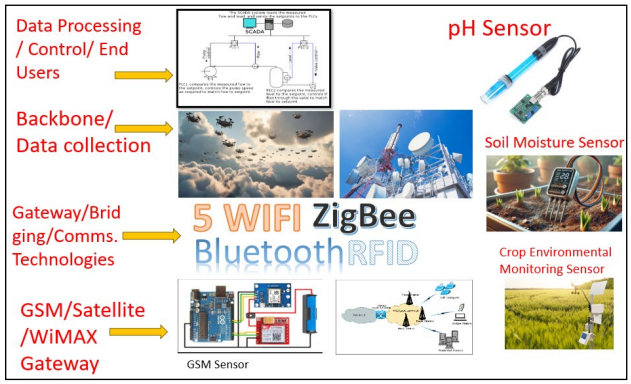

Fig. 7: Technology Without Wires

Rfm69

The RFM69 standard is another physical layer technology that can be used to connect IoT sensor nodes, along with LoRa. It can connect up to 65,000 nodes and send and receive data at speeds of up to 100 Kbps across a distance of up to 0.5 km (Partel *et al.* 2019).

Bluetooth

Bluetooth is a wireless communication option for sensor nodes that uses very little power. It has a range of 50 meters, can connect up to 7 nodes, and has a data throughput of 1 Mbps. It uses the least amount of power, which makes it perfect for applications that don't need a lot of range (Munir *et al.* 2018).

Zigbee

Zigbee (IEEE 802.15.4) is a wireless communication system that uses very little power. It can connect to up to 65,000 nodes at a distance of up to 1 km and send data at speeds of up to 1 Mbps. It works in the ISM band and uses 2.4 GHz, 868 MHz, and 915 MHz as its common frequencies. Its intelligent application farming was shown in this band (Chikankar *et al.* 2015).

Wireless Fidelity (Wi-Fi)

Wi-Fi is a wireless communication technology from the IEEE 802.11 family that works well for things that need to send a lot of data quickly, like streaming video indoors. Wi-Fi Hallow (802.11ah) can enable speeds of up to 290 Mbps for IoT applications, but its range is only about 100 feet. But Smart Agriculture Systems don't usually need

speeds that high. Wi-Fi has been successfully used in a number of real-world systems (Singh *et al.* 2021).

Cellular Tech

Cellular technologies, such as 4G LTE, 5G, and Beyond 5G (B5G), are necessary for linking IoT sensors and smart farming machines across long distances, which is important for big farms and drones (UAVs). These networks let data be sent in real time, including video from agricultural drones, which makes smart farming more efficient. They also make it easier for systems to connect to the Internet and change based on real-time data, including weather updates. LoRa and ZigBee offer low-power, scalable solutions, but 5G/B5G offers faster data speeds and more reliability. These technologies are likely to take over smart agriculture systems in the future (Balogh *et al.* 2020; Qazi *et al.* 2022; Monteleone *et al.* 2020).

The combination of AI and IoT in precision farming

AI-driven precision agriculture is changing modern farming by making better use of resources, improving crop management, and promoting sustainability. As environmental concerns and the world's population expand, AI integration in farming offers good ways to make farming more sustainable.

Using robots and automation in farming

Automation and robotics are changing farming for the better by making it more productive and sustainable. Robots with sensors and computer vision can help with selective harvesting, weeding, and pest management. AI-powered self-driving cars can help with planting and harvesting. These technologies help farmers be more environmentally friendly by cutting down on waste, labor costs, and the use of herbicides gas.

Smart Harvesting

Smart harvesting, which is made possible by IoT and wireless sensors, makes harvesting easier and less expensive. These sensors gather information on temperature, humidity, soil moisture, and plant growth so that the data can be analyzed and yield predictions can be made in real time. People are also working on making agricultural robots that can harvest fruit, which is a step forward for smart farming. Some of the biggest problems include reducing damage to crops during harvesting and making vision systems better so they can find impediments and hidden fruits.

Intelligent Water Management

Smart water management makes crops grow better, saves water, and has less of an effect on the environment. The Smart Water Management Platform (SWAMP) makes precision agriculture better by making systems easier to use and more flexible. AI and deep learning combined with the Internet of Things (IoT) make the best use of water that is good for the environment. Research also looks into IoT options for precision agriculture, such as sensors and wireless devices. Some of the biggest problems include making better water quality sensors and finding ways to use sensors that change based on the situation to provide more accurate data across a wider area.

Pictures from space

Satellite images are very important for keeping an eye on the growth of crops, the moisture in the soil, and the health of the crops as a whole. High-resolution satellites like Landsat and Sentinel can watch over broad areas in a variety of wavelengths, such as visible, infrared, and thermal. But weather can affect the quality of the data.

Predicting Disease

To make crops that can withstand disease and pests, research is very important. Early warning systems and forecasting models like EWS for wheat rust and Shift for Zymoseptoria tritici have worked well. SVMs and ANNs are examples of machine learning approaches that make forecasting better but are hard to use (Beyer *et al.* 2022).

Advantages of utilizing AI and the Internet of Things in farming

AI and IoT in agriculture want to help 2 billion more people by 2050 by solving problems like managing water, using too many chemicals, and getting more crops (Acharya *et al.* 2022). IoT and data analytics make food security operations more efficient, make

better use of resources, and help people make better decisions (Elijah *et al.* 2018).

Discovery of disease and lack of supplements

Insects and weeds hurt plants by taking away their resources (Sharma and Shivandu, 2024). Machine vision can automatically find weeds, even when they seem like crops, which is a really effective way to do it. Monitoring insects is a safer way to use less pesticides. Machine vision can also find diseases and nutritional shortages, which makes plants healthier and increases their output (Sharma and Shivandu, 2024).

Improve the skills of people in rural areas

Smart Cultivating using Agribusiness 4.0 technologies focuses on improving agricultural productivity by carefully planning, researching, and checking to get the best input-output ratio (Javaid *et al.* 2022). It uses information on things like the weather, soil quality, and the introduction of new crops to help farmers make smart decisions that increase productivity and cut down on waste (Javaid *et al.* 2022).

Farming with precision

Precision farming uses real-time data and prediction models to get the most out of water, fertilizer, and pest management. This leads to significant cost savings and environmental benefits by using less water and chemicals (Javaid *et al.* 2022). Agriculturists also use zero-tillage farming, which involves planting directly into prior trim buildups to reduce soil disturbance, maintain soil health, and increase yields (Javaid *et al.* 2022). Maintainable escalating approaches point to increment agrarian generation whilst decreasing natural influence, making strides biological system wellness, and responding to climate alter issues (Javaid *et al.* 2022).

Looking into the data

IoT and smart sensors give real-time data that helps with precision farming and predictive analytics (Javaid *et al.* 2022). Predictive models make planning and risk management easier by helping to predict when crops will be ready to harvest, when pests will be a problem, and when illnesses will spread. These technologies combine new ideas with old farming methods to improve productivity, quality, and response time (Javaid *et al.* 2022).

Use of drones

Drone technology has changed farming in a big way by making it possible to check on the condition of crops, keep an eye on areas, plant seeds, fertilize, and analyze land (Javaid *et al.* 2022). Drones assist farmers make accurate, data-driven decisions that improve crop management, resource use, and yields. They have thermal and multispectral sensors (Javaid *et al.* 2022).

How well AI-based logistics works

Fetched connected to time: Longer coordination time increases costs and costs (Ramirez-Asis *et al.* 2022).

Taken a toll associated to squander: More time lowers the quality of agricultural goods, which hurts ranchers (Ramirez-Asis *et al.* 2022).

Venture return: This looks at the returns from the computed framework over the course of five years (Ramirez-Asis *et al.* 2022).

Fetched of speculation over extended periods: Yearly ventures are necessary to improve framework proficiency (Ramirez-Asis *et al.* 2022).

Beginning speculation fetched: Talks about the straightforward fetched at the start of the system.

AI-based frameworks have a higher initial speculative fetched, but they operate better in terms of framework efficacy, quality, and long-term returns than alternative strategies.

Technology for gathering energy

Energy harvesting methods have made IoT devices in agriculture more sustainable by letting them use renewable energy sources like solar electricity (Hussein *et al.* 2024). This makes sure that IoT devices work all the time, even in places where the electrical grid is hard to get to. It also has less of an impact on the environment and makes less use of traditional power sources (Hussein *et al.* 2024).

There are a lot of problems with using AI and IoT in farming, especially in developing nations. Some of the main problems are that there isn't enough good data available, it costs a lot, there isn't enough competence, and the digital infrastructure isn't very good. Farmers typically have trouble with

things like data privacy, job loss, and the capacity to communicate and work together. Unpredictable weather and climate change make farming much harder. Small-scale farmers have trouble with money and don't have the technical skills they need. Government help, cheap tools, education, and community facilities are some of the things that can help. Ethical, safe, and open use of AI is important, as is increased training, digital literacy, and infrastructure to make smart technologies work for long-term and effective farming. Problems with getting AI and IoT to work together.

The World Water Assessment Project (WWAP) says that the world's population will expand by 33% by 2050. This will make more food and water needed. Smart farming, which uses IoT and AI, can make farming more sustainable and efficient, but the high prices of devices and infrastructure make it hard for small farms to get started (Qazi *et al.* 2022; Umamaheswari *et al.* 2022; Wu *et al.* 2010). The biggest problems in using AI and IoT are

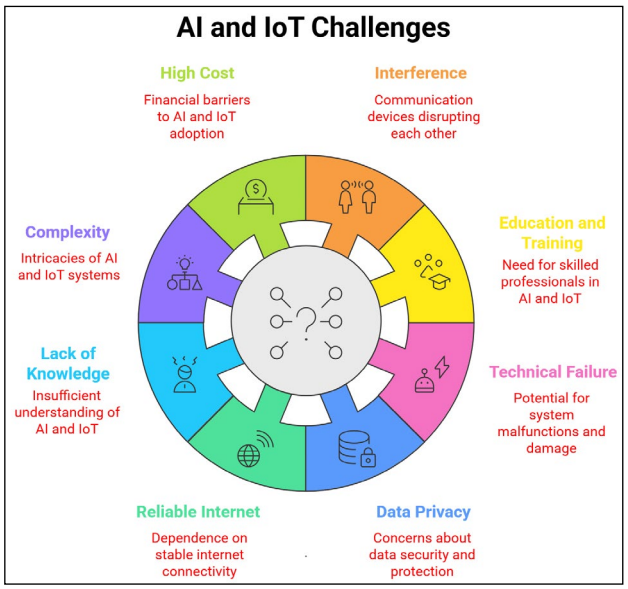

Fig. 8: Problems with AI and IoT

High Cost: (Fig. 8) Setting up smart farming infrastructure costs a lot of money, and many small farmers have trouble using new technologies. Larger farms can afford more complex systems, while smaller farms may be slower to embrace AI (Kumar *et al.* 2022; Jarinaa and Manida, 2023). Government financing and better productivity, including AI-powered disease diagnosis and better irrigation, can assist cover costs (Qazi *et al.* 2022).

Data Privacy: Cyberattacks, such as Denial-of-Service (DoS) attacks and data breaches, can affect autonomous farming equipment like UAVs and smart tractors, putting important agricultural data and systems at risk (Qazi *et al.* 2022). IoT devices used in farming can be hacked, which puts private data at danger, costs money, and allows unfair market manipulation (Farooq *et al.* 2019; Samtani *et al.* 2020).

Technical Failure and Result Damage: Smart farming decision support systems generally get their information from Internet of Things sensors. If any technology breaks down and sends out incorrect signals, crops might be in a lot of trouble. Data that isn't correct could hurt crops a much. For example, a smart irrigation system that doesn't work right and gives plants too much or too little water could hurt their growth. Since IoT devices need to work correctly to give accurate, real-time agricultural data, making sure they are reliable is still a big worry. To keep these systems running smoothly and protect agricultural productivity, they need to be maintained and have ways to find errors (Kumar *et al.* 2022).

Interference Between Communication Devices: Farmers need to know how to set up, use, and comprehend the data from IoT devices like drones and soil sensors (Misra *et al.* 2022). Smart farming needs communication technologies like Sigfox, ZigBee, LoRa, and Wi-Fi, but they can get in the way of each other, which can cause problems with connectivity and data accuracy, which slows things down (Kumar *et al.* 2022).

Education And Training: The application of AI in farming involves moral issues around data privacy, ownership, and the proper use of technology. Many small farmers don't have the education or training they need to use new technologies, even when they are available. Businesses, governments, and farmers need to work together to make smart farming easy to get and cheap (Kumar *et al.* 2022).

Quality of Hardware: Smart farming is affected by a variety of problems with the quality and price of hardware. The perception layer of the IoT architecture includes a lot of sensors that IoT devices use. Some of these sensors could be damaged by weather events like rain, storms, high temperatures, and strong winds. To ensure smooth

data flow, both the quality of the communication infrastructure and the durability of the devices must be increased. To make sure that data is collected correctly and that the system works well, sensor node interference must be kept to a minimum. To make sure that smart farming technologies perform well, communication networks need to be improved and sensors need to be made more durable (Kumar *et al.* 2022).

Lack of technical skills: Agricultural extension needs to build its capacity in order to stay in business. Farming needs technical abilities, and a lack of operational experience can hurt the overall performance of agriculture. The purpose of capacity building is to help an organization better manage its operations, solve problems, and reach its developmental goals. looked at skill development in rural areas, focusing on how skill-based technological advances have made it necessary to hire highly skilled personnel. Farming requires strong muscles, good thinking, and good social skills. But farmers still have a hard time implementing new techniques and technologies because they don't have enough information (Khan and Ismail, 2018).

What the Future Holds: AI and IoT in Farming of the Future

Almost all devices are predicted to be connected to the internet by 2025, which will greatly increase the use of IoT. Cisco thinks that by 2030, there will be 500 billion IoT-connected devices. Telefonica thinks that 90% of cars and an average of 15 devices per person will be connected. IoT encourages new ideas in industry by allowing research to cross disciplines and turning the world into a smart, connected area. Companies will put money into IoT improvements, which will improve QoE and QoS. Some of the most important uses are in healthcare, smart industries, and farming. Security, data analysis, and spectrum scarcity are still problems, but AI-driven solutions are being developed to improve resource sharing and adaptation in IoT devices (Zikria *et al.* 2021).

Ai and Iot in Agriculture: A New Way to Farm

Getting young people involved in farming is important for long-term success, especially in underdeveloped countries where farming is still a key source of revenue. Young people are drawn to smart farming practices since they are flexible and offer rewards. This makes them want to work in this field. This change not only protects people's jobs, but it also encourages modern farming methods, which will help these areas stay viable and prosper economically in the long term (Thilakarathne *et al.* 2021).

IoT integration with blockchain and the food supply: Industry 4.0 has made IoT a key part of digital transformation, moving from collecting data to providing actionable insights. Combining IoT with AI, cloud computing, and blockchain makes things work better. Blockchain makes it easier to trace agricultural products, makes transactions safer, makes things more clear, and makes sure that rules are followed. It also helps the global economy by making things easier to do online (Alobid *et al.* 2022; Awan *et al.* 2021).

Vertical Farming with Soilless Culture System: Because of the lack of arable land and the increasing growth of cities, vertical hydroponic systems for urban farming have become popular. It uses smart technologies to make plant development as efficient as possible while using less area, water, transportation expenses, and pesticides. This helps solve problems with geography and resources. Aeroponics, which sprays nutrients into roots, and aquaponics, which combines hydroponics with aquaculture by utilizing fish waste to feed plants, are two more new ways to grow plants. Food production is having problems since more and more people are moving to cities. By 2030, 60% of the population is predicted to reside in cities, and by 2050, 68% will. IoT can help with vertical farming, hydroponics, and desert agriculture, which are all long-term solutions (Khan and Ismail, 2018).

Robots for Agriculture: Agricultural robots make farm work easier, which cuts down on physical labor and saves time. They use AI to improve monitoring, harvesting, and weed management while making sure the crops are of good quality. These robots sort and pack food quickly, which increases output. Automation makes farming more efficient and eco-friendly by using resources more effectively, having less of an impact on the environment, and encouraging sustainable farming (AlZubi and Galyna, 2023).

5G and IoT in Future Farming: Research in emerging areas is adapting technology to meet the demands of local farmers. This makes it necessary to combine IoT and 5G for farming that is strong and tech-driven. The MERLIN project in India showed how AI may help make decisions by using cloud databases and machine learning. The use of 5G and 6G in Colombia has helped digital agriculture through networked devices and automation (Van Hilten and Wolfert, 2022). These new technologies help close the digital gap and improve precision farming. 5G-enabled IoT is better than 4G because it lets data move faster and automates tasks, which makes things more efficient. Costs are currently too high for small farms to use them, but as costs go down and competition in the market increases, more people will be able to use them. Smart agriculture will be even better with better connectivity, less latency, and better QoS (Mehta, 2023).

Incorporation and Progression of Empowering Technologies: Smart agriculture uses IoT, Cloud, AI, 5G/6G, blockchain, and Edge computing, with IoT at its core. These new ideas help people work reachable food needs around the world. Improvements in 5G make it easier for IoT to be used, which lowers expenses. AI, ML, and DL help monitor crops by analyzing data, which is the next step in farming with Industry Rod (Thilakarathne *et al.* 2021).

Data-Driven Insights and Analytics: Big data analytics looks at a lot of different kinds of data very quickly to find trends, patterns, and connections. In farming, it helps farmers make better decisions by giving them access to cloud-based information systems and decision support tools for optimizing crops. These technologies make things more efficient by giving farmers data-driven insights that help them run their farms better and get more done (Ray, 2017).

Advanced Machines Used to Advance Agriculture: Manufacturers now sell tractors with automatic drives, which makes them more accurate and efficient. Self-driving tractors reduce overlaps, make accurate turns, and make pesticide application more accurate. There are still improvements being made, even though completely autonomous tractors aren't ready now. Hello Tractor is an economical way to keep an eye on things, and Case IH's Magnum series uses LiDAR and cameras to keep accidents from happening (Khan *et al.* 2021).

Food Safety with Ai and Iot: AI makes food safer and more secure by forecasting outbreaks, keeping an eye on infections, and improving farming. It boosts yields, lowers costs, and makes the world's food supply more secure by integrating supply chains and checking quality (Ahmad *et al.* 2024).

CONCLUSION

Precision Agriculture (PA) uses IoT sensors to collect and send farm data securely for analysis by AI, ML, and big data. This helps meet the world's food needs. These technologies are the basis of Agriculture 5.0 because they help people make smart choices, predict diseases, and set off alarms. The article looks at new technologies like AI, ML, SDN, nanotechnology, blockchain, and UAVs that can help make energy use more efficient and accurate. Edge and fog computing make data processing and reliability better, and blockchain keeps data safe. The suggested Agri Fusion IoT architecture deals with problems and research opportunities in PA.

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