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SMART AGRICULTURE BASED ON WIRELESS SENSOR NETWORKS

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Abstract: India's economy is based largely on agriculture, which supports nearly 70% of the population. To meet the global population's demand for food, agriculture's yield needs to be rapidly increased. The Wireless Sensor Network (WSN) is a modern technology used to address a variety of current issues. In many fields, including transportation, medicine, the military, mobile phones, home appliances, and others, WSN is crucial. All living things rely on agriculture as one of their major food sources.

Agriculture crops, however, are now impacted by numerous environmental changes. WSN plays a significant role in the field of agriculture to combat this. WSN is used in agriculture for monitoring, temperature measurement, irrigation system measurement, water supply measurement, and other tasks. WSN enables the farmer to increase crop production while lowering yield costs. Climate change, environmental change, and natural disasters all have an impact on agriculture. The management of soil and water can be done using WSN. Here, wireless sensors are utilised, resulting in very low implementation costs. In this study, the crops are observed using wireless sensor nodes.

Sensors can be used to measure temperature, humidity, and other theft indicators. Agriculture's productivity is boosted as a result. Automatic processes reduce the need for human effort and encourage farmers to develop their farmland. Using GPS, the location of the farmland can be transmitted. The use of sensors, Wi-Fi, cameras, and other devices helps to make agriculture as smart as possible. All collected data are kept in memory or the cloud. Thus, this system helps the agriculturists, landowners and research experts to monitor these parameters at the base station without going to the field site. The measured data is appropriately archived in the database and displayed using a GUI tool as well. The system's design incorporated the IRIS mote, MDA100 data acquisition board, and MIB520 USB interface board. We use Microsoft Visual Studio to create the GUI tool and the TinyOS operating system to create the wireless node software. For node-to-base station communication, the direct topology and ZigBee IEEE 802.15.4 protocol are utilised. Finally, we also talk about potential future research areas.

I. INTRODUCTION

1.1 Overview of Wireless Sensor Network

Farmers can transition from traditional agriculture to modern agriculture with the aid of wireless sensor networks. WSN supports farmers in a variety of ways. Distributed sensors are used in wireless sensor networks to collect data, which is then transmitted over wireless networks. Global positioning system (GPS)-enabled microsensors are used in WSN to pinpoint a location precisely. It is primarily used to track climatic, temperature, humidity, and soil test changes as well as environmental changes. Sensor networks are incredibly compact, affordable, and are even usable in rural areas.

Three different topologies are used in wireless sensor networks. They are star, cluster tree, and mesh topologies, and connections can be made using them. WSN utilises a variety of components, including a battery, radio, microcontroller, and analogue circuit. The main engine for economic expansion is agriculture. In agriculture, there are many uneducated workers. The traditional methods used by farmers, sadly, result in lower growth yields. However, the use of an automated system in agriculture has historically increased crop yield. The majority of papers employ wireless sensor networks to gather data from sensors placed throughout farmland and transmit it via various wireless protocols to servers. The data that is generated from all the collected information is used to boost crop yield. Insufficient data has been collected and is currently stored on the server to accelerate crop growth. Some additional elements also have an impact on crop growth. The crop is susceptible to the effects of wild animals and birds, which cannot be reduced.

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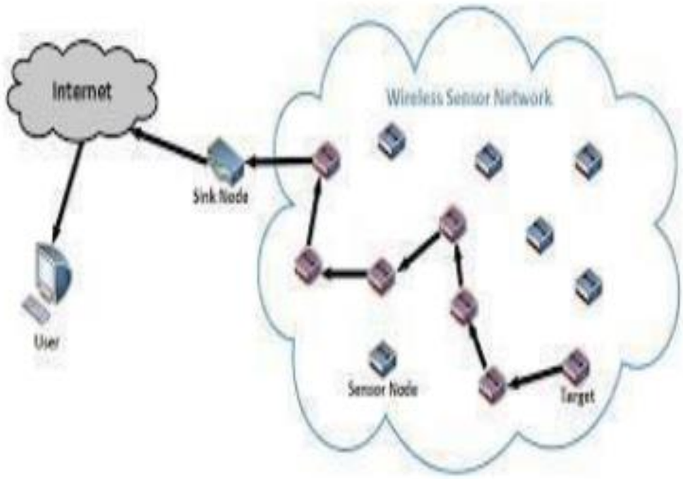

Fig 1 Overview of Wireless Sensor Networks

A measurement is made of the farmland's temperature and humidity.

1.2 Agricultural Sensor classification
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The agricultural industry is where sensing technologies experience explosive creativity, activities, exciting applications, and innovations. Numerous tech companies and business owners demonstrate their diversity and willingness to enter the vast field of agriculture. Here, we talk about some sensing technologies, their wide range of products, and their sensory function in the agricultural industry. A summary of various agricultural sensing technologies is given in Table 1.

Class	Type	Classification
Chemical sensors	pH sensor	Soil and water quality monitoring
	Biosensor	Glucose and acids
	Gas sensor	Pollution and air quality
Physical sensors	Temperature sensor	Soil, plant, crops, and environment
	Humidity sensor	Soil and environment
	Watermark sensor	Soil humidity
	Rain sensor	Environmental monitoring
	Electrical conductivity	Soil monitoring
	Leaf wetness sensor	Tress, crops, and plants
	Terrestrial sensor	Weather and environmental monitoring
	Colour sensor	Nutrient monitoring
	Passive Infra-red	Environmental monitoring
	Underwater sensor	Salinity, solvents, and quality
	Underground sensor	Soil compaction and moisture
	Solar radiation	Crops and plants
Mechanical sensors	Pest detector	Pest and bug detection
	Pressure sensor	Soil compaction
	Vibration sensor	Soil and atmosphere
	Wind sensor	Speed and direction of air
	Motion sensor	Environmental monitoring
	Water flow sensor	Irrigation
	Water level sensor	Ground and underground

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1.3 Deployment Architecture of smart agriculture

The smart agriculture deployment architecture is outfitted with cutting-edge methodologies, paradigms, and tools to offer strong technical support for hastening the transformation and advancement of agriculture. The smart agriculture system uses sensing and communication tools to gather the essential data from the cultivated field. The most important details include the soil's pH, moisture content, humidity, temperature, and water level, among others (more classifications of agricultural sensors are given in figure). Continuous monitoring of these parameters boosts agricultural output. To cover the entire field, the smart agriculture system needs a huge number of sensor nodes of various types. These sensor nodes are tiny and have a meagre amount of battery life. As a result, whenever these nodes' batteries run out, they stop operating as sensing nodes, which reduces the network's lifespan.

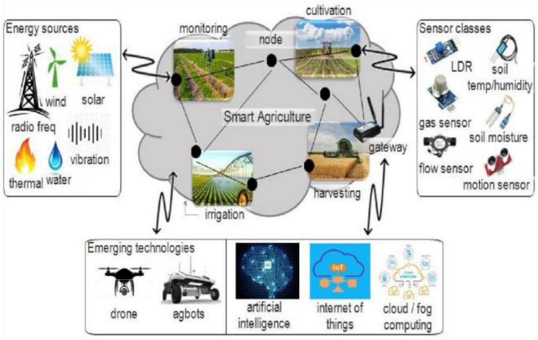

Fig 2 Deployment architecture of smart agriculture

Energy can be harvested using a variety of methods, including solar, wind, thermal, vibrational, radio frequency (RF), water, and more. The biggest problems in agriculture are the collection of field data on-board and the ensuing actions. It takes a lot of time and effort to gather the data from a sizable field or crop monitoring. For instance, conducting soil analysis while monitoring crops and the environment necessitates frequent field trips, or even multiple visits for some crops. This is extremely thorough because it takes a lot of time, effort, and money to gather the sample and field data.

Therefore, we are grateful for the sensing technologies, which gather field data and monitor the crops while giving farmers comfort. There are tens of thousands of different sensing tools and kits that fall under various taxonomies. Among these sensor taxonomies are: i) Measurement, ii) Technology, iii) Material, iv) Operating principle, v) Conversion techniques and vi) Application areas. We classify the agricultural sensors into these groups i) Chemical, ii) Physical, and iii) Mechanical.

II. LITERATURE SURVEY

[1]. Gangurde, P., & Bhende, M. (2020). A Novel Approach for Precision Agriculture Using Wireless Sensor Network
In this study, crops grown on agricultural lands are observed using wireless sensors. Sensor networks are used to measure various things, including the water level, temperature, humidity, and pesticides. Wireless sensors are small and very affordable. A few sensors have been created here to monitor the agricultural lands. By using these sensors, crop production can be increased while crop labour and time requirements are decreased. Different topologies, including bus, star, grid, and ring, are used by WSN. All nodes in a star topology are unable to directly communicate. Ring networks are superior to other topologies because there are only two neighbours available for communication for each node. Both clockwise and anticlockwise directions can be used to send messages.

[2]. J.Infantial Rubala, D. Anitha (2019).Proposed Agriculture Field Monitoring using Wireless Sensor Networks to Improving Crop Production All types of crops use WSN for monitoring, delivering water and fertiliser, as well as other purposes. Since frequent collection does not yield any useful information and places a significant burden on sensors, data from crops are not gathered frequently. Data collection can be done on an hourly basis. This aids the farmer in cultivating the crop and producing a high yield at minimal expense.

[3]. Valente, J., Sanz, D., Barrientos, A., Cerro, J. D., Ribeiro,Á., & Rossi, C. (2020). An air-ground wireless sensor network for crop monitoring. Sensors, 11(6), 6088-6108
The mobile robot sensor is utilised in this paper as node 1. The water pumps are automatically controlled by it. When a land's water content is low, the pump turns on automatically, and when it is high, the pump turns off automatically. Some

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sensors, including a light sensor, motion detector, humidity sensor, space heater, and temperature sensor, are used in node 2. The temperature sensor that is used to gauge the climate in agricultural areas. The soil content of agricultural land is measured in node 3 using a moisture sensor. The data that is being transmitted is sent to the microcontroller and node 2. The water pumps are managed by the data. "Raspberry Pi"

[4]. Verdouw, C. N., Wolfert, S., & Tekinerdogan, B. (2019). Internet of Things in agriculture. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, 11(35).
To produce a crop with a high yield while minimising human effort is the goal of this paper. The crop land is measured using a few sensors in this paper. Farm land uses sensors like temperature sensors, moisture sensors, pressure sensors, and humidity sensors. The amount of nutrients in the form land was decreased by the temperature change. The electrical conductivity principle underlies the operation of moisture sensors. One of the key factors in crop growth is the moisture content. The microcontroller is connected to the pressure sensor to control the water flow. The humidity sensor is used to gauge the air's humidity level.

[5]. Vaibhavraj S. Roham, Ganesh A(2019). Pawar Proposed Smart Farm using Wireless Sensor Network
Zigbee Network is another name for wireless sensor network in this paper. In this context, sensors are referred to as nodes, and those nodes contain additional sensors. It was once used to measure humidity and temperature. Nodes keep an eye on their surroundings and send information to the router. The data is forwarded by the router to the online coordinator

[7]. Finally, all of the data collected for the 2019 Fifth International Conference on Advanced Computing & Communication Systems (ICACCS) 516 is stored in a database for processing. The greenhouse in this instance is monitored by computers and a mobile app [8]. Android applications for smartphones are created and connected to the internet. The application can monitor the crops without a human's assistance because it is connected to a web server.

[6]. Kim, Y., Evans, R. G., & Iversen, W. M. (2018). Remote sensing and control of an irrigation system using a distributed wireless sensor network. IEEE transactions on instrumentation and measurement, 57(7), 1379-1387
In this study, sensors are used to track soil moisture and humidity levels and transmit data over a network. It requires less human effort and increases crop yield at a lower cost. The Raspberry Pi is used in the implementation, and it is connected to a 5V power supply. For measuring soil and humidity, sensors are used: soil moisture sensors and humidity sensors. Data are transmitted using serial communication as 0s and 1s. where 0 means that the motor is on. The user's mobile device is notified when the permissible level is reached. Smartphones can be used to turn a motor. Using a moisture sensor, moisture values are checked every 1 minute. When necessary level is reached, motor automatically shuts off.

III. TECHNOLOGY

Artificial Intelligence: Machines that have been programmed to think and act like people are said to have artificial intelligence (AI), which is the simulation of human intelligence. Any machine that demonstrates characteristics of a human mind, such as learning and problem-solving, may also be considered to be a "machine mind." The ability of artificial intelligence to reason and take actions that have the best chance of achieving a particular goal is its ideal quality. Machine learning (ML), which refers to the idea that computer programmes can automatically learn from and adapt to new data without being helped by humans, is a subset of artificial intelligence. By ingesting vast quantities of unstructured data, including text, images, and video, deep learning techniques make it possible for this automatic learning. The application of AI is ongoing.

IOT (Internet of Things): The term "Internet of things" (IoT) refers to physical things (or groups of such things) equipped with sensors, processing power, software, and other technologies that communicate and exchange data with other systems and devices over the Internet or other communications networks. Devices only need to be connected to a network[6] and be individually addressable; the term "internet of things" has been criticised for implying that they must also be connected to the public internet. Daily "things" are connected to the internet through the Internet of Things. Since the 1990s, sensors and processors have been added to commonplace items by computer engineers. The large size and weight of the chips, however, made progress initially difficult. Inexpensive equipment was first tracked using low power computer chips called RFID tags. Computer hardware became smaller. For example, you can add connectivity with Alexa voice services capabilities to MCUs with less than 1MB embedded RAM, such as for light switches. A whole industry has sprung up with a focus on filling our homes, businesses, and offices with IoT devices. These smart objects can automatically transmit data to and from the Internet. All these “invisible computing devices” and the technology associated with them are collectively referred to as the Internet of Things. The most important features of IoT on which it works are connectivity, analyzing, integrating, active engagement, and many more.

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Fog computing: In a decentralised computing environment known as fog computing, data, compute, storage, and applications are distributed between the data source and the cloud. Fog computing brings the benefits and power of the cloud closer to where data is created and used. This is similar to edge computing. Because both involve bringing processing and intelligence closer to where the data is created, the terms fog computing and edge computing are frequently used interchangeably. Although it might also be done for security and compliance reasons, this is frequently done to increase efficiency. Let's think about the information that a temperature sensor on a production line sent. Every second, a service can push the temperature recording to the cloud while monitoring for changes. But, if there have been any recent temperature changes, that would be a more intelligent approach to store this data. The data is sent to the cloud for archival when a temperature change is detected to ensure the production line is running properly. The temperature may occupy little room, but this kind of situation is very frequent with gadgets like CCTV cameras that generate a lot of video and audio data. Fog computing is the small-scale storing and processing of data before transmitting it to the cloud. With fog computing, some of the workload on the cloud is shared by devices with less powerful processors. Fog computing aims to use the cloud only for long-term solutions.

IV. WORKING PRINCIPLE

The needs of modern agriculture, which demands high yield, high quality, and efficient output, cannot be met by conventional agriculture and its supporting industries. In order to estimate the best possible productivity and crop suitable for the very specific land, it is crucial to modernise existing methods and use information technology and data collected over a period of time. The proliferation of mobile devices, dependable, reasonably priced satellites (for images and positioning), and high-speed internet are a few of the major technologies that define the precision agricultural trend.

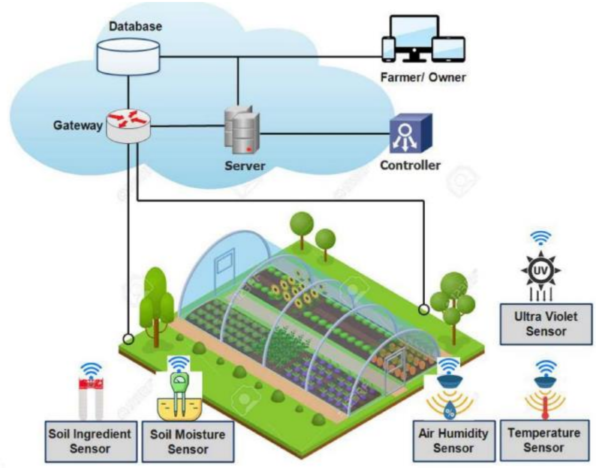

Fig 3 Operational Diagram

One of the most well-known IoT applications in the agricultural industry is precision agriculture, and various businesses all around the world are using this method. Soil moisture probes, virtual optimizer PRO, VRI optimisation, and other items and services are examples of those in use. The optimisation of VRI (Variable Rate Irrigation) on irrigated crop areas with variable topography or soil improves yields and maximises water use effectiveness. Manufacturing, healthcare, and the automotive industries have all seen significant IoT adoption. It provides a range of choices for food production, transportation, and storage that can increase the amount of food per person available in India. sensors that provide data on the quality of the soil's nutrients, the presence of pests, the amount of moisture, and other factors that can be used to increase crop yields

It is now possible to create low-cost solutions and applications for smart farming because to the development of mobile and communication technologies, the Internet of Things, and cloud computing. The design of our proposed SMART AGRICULTURE BASED ON WIRELESS SENSOR NETWORKS system is composed of sensors that gather information on things like temperature, air humidity, and light intensity. The unprocessed data are sent to a cloud platform for analysis via a gateway. The farmer is then advised by email, SMS, or mobile application to take any necessary preventive steps. Figure 3 illustrates the three general architecture levels of the Internet of Things: perception, network, and application. The perception layer, also known as the "sensing layer," is where real-world events are gathered via various sensors, etc. Using gateways, Wi-Fi, Bluetooth, routing, switching, and other methods, the network layer transports data over the Internet. With the end user, the application layer has direct communication. With the help of the services they have been assigned, each of these layers carries out particular duties and tasks.

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Traditional farming relies solely on the knowledge of the farmers and employs little to no technology. There are no data analyses, forecasting tools, or statistics on how the environmental factors affect the development, well-being, and output of the onion crop. Our motivation is to close the gap between the adoption of contemporary technologically based solutions for better onion crop growth, production, and bolting reduction. Furthermore, there is no locally developed technical method for reducing bolting in onion farms. The shortcomings of conventional farming can be eliminated by IoT-based farming. IoT-based solutions can increase output, decrease onion bolting, and enhance the amount and quality of the crop.

V. ADVANTAGES

- Increased Quality of Production.
- Accurate Farm and Field Evaluation.
- Real-Time Data and Production Insight.
- Lowered Operation Costs.
- Reduce Waste, Improve Productivity

VI. APPLICATION

- **Precision farming:** The use of high-speed internet, mobile devices, and dependable, affordable satellites (for images and positioning) by manufacturers is the crucial element of precision farming. One of the most well-known IoT applications in the agricultural industry is precision farming, which is used by numerous organisations across the globe. One illustration is CropMetrics. It is a precision agricultural business that specialises in cutting-edge agronomic approaches. Also, it is an expert in the control of precise irrigation.

- **Monitor Climate Conditions:** Crop output is significantly influenced by the climate. Various crops require varied climate conditions to grow, and any lack of understanding about climate seriously impairs crop output in terms of both quantity and quality. The farmers can now access real-time weather information thanks to IoT technology. Farmers select a crop that can grow in a specific climate using the information gathered by the sensors installed in agricultural fields. Sensors that monitor real-time meteorological factors like humidity, rainfall, and temperature, all of which are essential for agricultural productivity, make up the entire IoT ecosystem. These sensors are able to predict any significant changes in the weather that can have an impact on the production. The server receives notification of the change in weather, which is helpful.

- **Remote Sensing:** IoT-based remote sensing uses sensors installed along farms, like weather stations, to collect data that is then sent on to analytical tools for study. Farmers can use analytical dashboards to monitor their crops and act on the information they gain from doing so.

- **Computer Imaging:** This method of imaging primarily uses sensor cameras that are positioned across the farm to provide photos that are then processed digitally.

- **Smart Greenhouses:** The goal of greenhouse farming is to increase agricultural, fruit, and vegetable production. By using a proportional control system or manual intervention, greenhouses can regulate the environmental conditions. Manual intervention, however, results in lost production, wasted energy, and increased labour expenses. This renders the idea of greenhouses as a whole useless. Thus, intelligent greenhouses are a superior option. The Internet of Things can be used to build a smart greenhouse. Without the need for any kind of personal assistance, these intelligent greenhouses can monitor and manage the climate.

- **Livestock Monitoring:** Large farms' owners use wireless IoT applications to monitor the whereabouts, condition, and welfare of their livestock. This knowledge enables them to recognise sick animals, remove them from the herd, care for them, and prevent the sickness from spreading to other animals. The ability for owners to find their cattle using IoT-based sensors also helps to reduce labour expenditures.

CONCLUSION

In today's world, agriculture can be carried out using a variety of cutting-edge technologies. Here, WSN are utilised to produce a crop at a low cost and with a high yield. Currently, people no longer work in agriculture. Wireless sensor networks are used to lessen the effort required from people. Here, sensor nodes gather data and transmit it to farmers and

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agricultural specialists. Data is sent to smart phones via additional hardware and software. The farmer has access to mobile devices at all times and from any location. This application has the ability to include both specialists and several farmers. This is better suited for nations like India that are heavily dependent on agriculture.

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