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THE IOT FARMING REVOLUTION: ENHANCING EFFICIENCY AND SUSTAINABILITY IN AGRICULTURE

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ABSTRACT

In recent years, several applications in current technologies such as Innovations in IoT, Big Data, the Cloud, and Mobile Computing. Smart cities, home automation, and smartphones are just a few examples of the smart world ideas that are now gaining traction. The agricultural sector is crucial to India's economy. For the most part, rural India still operates this way. Because of improper maintenance, the crop is lost, resulting in a large loss for the farmer, which is why the smart Agriculture concept was established. Smart farming is the practice of using cutting-edge technology to maximize crop yields. It helps with system monitoring and provides information on a wide range of environmental factors. Monitoring environmental conditions is not a complete or adequate strategy for enhancing agricultural yield. There is other more factors that have a significant impact on productivity. One of these issues is an infestation of insects and other vermin, which may be remedied by applying the appropriate chemical pesticides to the crop in question. During the time it takes to harvest the crops, birds and other types of living things end up destroying them. As a direct consequence of this, there are many obstacles that farmers must overcome between planting and picking their crops. In today's world, the Internet is extremely important in all spheres of human endeavor. This research places a strong emphasis on the function that IoT plays in smart farming, which refers to the monitoring and improvement of agricultural areas that are accomplished with the assistance of IoT.

KEYWORDS: *Agriculture, Internet, IOT, Smart Farming*

1. INTRODUCTION

Applications for today's technology, like the Internet of Things, the Big Data cloud, and mobile computing, have proliferated during the past few years. At this time, the globe is moving toward the implementation of smart world concepts including, amongst others, smart cities, home automation, and smartphones. Agriculture has a very important role in India's overall economy. It is still practiced in the great majority of Indian communities and is considered to be a way of life. Productivity is affected by a variety of different factors in addition to those already mentioned. One of these issues is an infestation of insects and other vermin, which may be remedied by applying the appropriate chemical pesticides to the crop in question. During the time it takes to harvest the crops, birds and other types of living things end up destroying them. In the modern world, the Internet plays an important part in a variety of fields. With the assistance of IoT, the proposed approach is utilized in the agricultural domains for the purpose of monitoring the agricultural fields. Based on the technology of wireless sensor networks, sensors are utilized in the agricultural sector for the purpose of performing analyses on a variety of factors [1].
The most recent breakthrough in agricultural technology has been the adoption of "smart agriculture." Processing and analyzing the obtained data in order to give ideas on how harvest may be increased more successfully is essentially what it comes down to in terms of the work involved. The term "precision

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agriculture" is beginning to be used in a more general sense within the agricultural industry. The goal of this strategy is to enhance agricultural preservation, seed technology, and nutrition by putting an emphasis on the collection of data and the application of data analytics. The traditional method for acquiring insight into the land in order to enhance productivity and sustain crops depended on a team of field specialists who physically examined the region and wrote their findings on notepads. This allowed for a more manual approach to gaining insight into the land [2].

2. ISSUES IN FARMING

Farmers are confronted on a daily basis with issues that have an effect on agriculture and involve new challenges and opportunities. These issues include the need to provide food for an expanding population while adhering to stringent new emissions regulations or to increase grain production while simultaneously reducing their ecological footprint [3].

2.1. Significant Challenges Facing the Agriculture Industry

The survey uncovered the following problems that are having an effect on agriculture:

- Meeting the increased worldwide demand for goods caused by rising living standards and expanding economies.
- Cost and affordability of suitable land for development.
- Recent legislative edicts and rules.
- Financial market stability, growth, and volatility across the world.
- The effect of international trade policy on food availability and commodity prices.
- Creation and implementation of biofuels [4].

3. PROBLEMS IN INDIAN AGRICULTURE

Some of the difficulties in Indian agriculture are natural, while others are man-made. The following are some of the most pressing issues and their proposed solutions-

a. Land holdings that are small and fragmented

People live and work in higher concentrations in densely inhabited and extensively agricultural states such as Kerala and West Bengal. It is customary to have a plot of property that measures no more than half an acre or less in these states. Rajasthan, which has a lot of sand and Nagaland, which has a lot of " "Jhoom" (shifting farming) has greater average holdings of 4 and 7.15 hectares. Punjab, Haryana, Maharashtra, Gujarat, Karnataka and Madhya Pradesh have bigger holdings than the national average because of their huge net sown areas. It is believed that subdividing and fracturing farmland is a key contributing element to our low agricultural output and backward position in the world. Transporting seeds, manure, equipment, and animals from one piece of land to another consumes a significant amount of time and work. Between 1990 and 1991, a total of around 45 million assets were consolidated in Punjab, Haryana, and the western Uttar Pradesh region. Cooperative farming is another solution to this problem, which involves farmers pooling their resources and splitting the earning [5].

b. Seeds

In order to boost crop yields and maintain the expansion of agricultural production, quality seed is a necessity. In addition to the manufacturing of high-quality seeds, distributing these seeds is as crucial. Many farmers are unable to afford high-quality seeds, especially small and marginal farms, due to expensive rates for superior seeds. The policy declarations are aimed at making adequate quantities of seed of superior quality available to Indian farmers at a reasonable price, at the right time, and in the right place to achieve national food and nutritional security objective [6].

c. Biocides, Manures and Fertilizers

Indian farmers have been neglecting the soils for thousands of years, cultivating crops without caring about replenishment. Low productivity is a direct outcome of soil depletion and worker fatigue. Many crops are among the lowest-yielding of their kind in the world on average. In order to address this serious problem, more manures and fertilizers should be used. Fertilizers and manure serve the same purpose for soils as a good diet does for the human body [7].

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d. Irrigation

If you reside in India, you are probably aware that the country is the country's second cultivated country, behind China. Irrigation is available on just one-third of the area that has been planted, though. For farmers in a nation like India, where rainfall is erratic, unreliable, and irregular, irrigation is the most critical tool they have available. If you reside in India, you are probably aware that the country is the country's second cultivated country, behind China. Irrigation is available on just one-third of the area that has been planted, though. For farmers in a nation like India, where rainfall is erratic, unreliable, and irregular, irrigation is the most critical tool they have available. India will not be able to have long-term success in farming unless more than half of its cropped land is secured with water [8].

e. Soil erosion

Many parts of agricultural land are eroded by wind and water. This land must be nurtured back to health and fertility [9].

e. Agricultural Marketing

Rural India's agricultural marketing system is still in turmoil. Farmers are losing money by selling their crops to local merchants and middlemen because of a lack of efficient distribution networks. Eighty-five percent of the wheat grown by many farmers in Uttar Pradesh is sold. In West Bengal, they sell a lot of jute. In Punjab, they sell 70 percent of their oilseeds and 35 percent of cotton. This predicament occurs because poor farmers are unable to wait long periods of time after harvesting their crops. There are currently a lot of businesses engaged in warehousing and storage. Among the primary entities tasked with this responsibility are People who work for the Food Corporation of India and the Central Warehousing Corporation to make sure food is safe to eat and that it can be stored (C.W.C.) and the State Warehousing Corporation. Agriculture is a significant industry that, like all others, requires cash. Capital inputs are becoming increasingly crucial as agriculture technology advances. A farmer must borrow money because his money is in his fields and stocks. This forces him to raise agricultural production [10].

4. Empowering Agriculture with IoT and Big Data Analytics: Advantages in Smart Farming

The term "smart agriculture" refers to a broad range of agricultural and food production practices that are made possible by Internet of Things (IoT) technology like big data and advanced analytics. The following are examples of common Internet of Things applications used in "smart farming":

It is possible to use sensor-based systems to keep track of a wide range of important productivity-affecting factors such as crops, soil, fields, animals, and storage facilities.

- Smart farm vehicles include things like drones, robots that can operate independently, and actuators.
- Internet-connected greenhouses and hydroponics systems are two types of smart farm infrastructure.
- This area includes analytics, visualization, and management systems [11].

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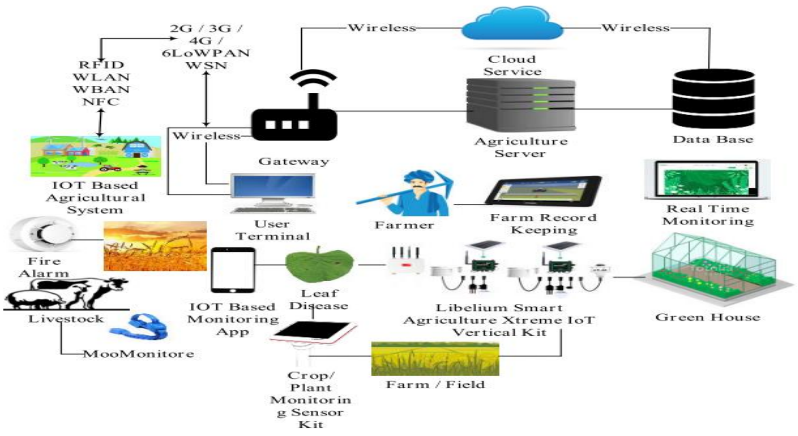

Figure:1. Agriculture Trends Nowadays [12]

4.1 Smart farming has numerous advantages

Agriculture can benefit greatly from new technologies and the Internet of Things. Agriculture, in particular, can benefit from IoT in five ways-

- **Lots of data from smart agriculture sensors** -e.g., Elements such as weather, soil condition, crop development, and animal health are considered. You may use this data to evaluate the health of your company as a whole, as well as the productivity of your employees and the effectiveness of your machinery.
- **Improved monitoring and management of internal processes has led to:** Production hazards have decreased. The distribution of your goods may be planned more efficiently if you can anticipate their production with some degree of precision. Knowing how many crops you will harvest can help you avoid having unsold inventory.
- **Cost-savings and waste reduction -** as a result of improved manufacturing control You can reduce the risk of output loss by spotting any unusual crop or livestock growth.
- **Increased corporate efficiency through automation of processes**- Irrigation, fertilization, and pest control can all be automated through the use of smart devices in your production process [13].

4.2 Enhanced product quality and volumes.

It's possible to improve crop quality and yield potential while also automating the production process. Innovative approaches and new technologies are essential to the farming and agricultural sectors for increasing yields and making more efficient use of available resources. Mechanical innovations like as tractors and harvesters were first used commercially in the late 19th and early 20th century. Developers interested in creating a smart farming solution or IoT agricultural sensor may take advantage of the rising popularity of the IoT. Using livestock sensors, ranchers may be notified as soon as an animal from the herd, allowing them to gather it up.

Having the ability to get early warnings from soil sensors about unusual situations such as excessive acidity gives farmers the opportunity to address the problem and produce better harvests.

Remotely driven tractors can considerably minimize labour expenses [14].

The Food and Agriculture Organization estimates that the world's population will reach 8 billion by 2025, and 9.6 billion by 2050. (FAO). The world's food supply has to increase by 70 percent by 2050.

However, there are a number of challenges in addressing this requirement.

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- The slowing of productivity growth is a major concern.
- Due to a lack of cultivable land.
- Changes in the climate.
- Clean water is increasingly in demand.
- For example, the cost and availability of energy, especially that from fossil fuels.
- Due to a decrease in the number of young people joining the sector, the average age of farmers is rising.

All agricultural sectors should be prepared with new tools and methods, particularly digital ones, to solve these concerns. Using the term "smart farming" as an umbrella term for numerous M2M-based applications, precision agriculture is often referred to as "smart farming." Agricultural precision is an area of expertise all its own. For example, telematics, environmental monitoring and eHealth monitoring are all based on sensor technologies that have been widely used elsewhere [15].

As smart technology and sensors become more commonplace on farms and the volume and variety of agricultural data continue to increase, Agriculture will become increasingly data-driven and data-enabled. A new movement, dubbed "Smart Farming," is gaining traction as a result of the explosion of IoT devices and Cloud computing [16].

Based on facts, context, and situational awareness, but also on location, real-time occurrences activate Smart Farming management activities [17].

Data from sensors on machines are utilized to control their behavior. This reciprocal role of Big Data technologies is crucial and reciprocal in this evolution. This spans from simple feedback systems (such as a thermostat that regulates temperature) to complex algorithms that learn how to do things (for example, execute the best crop protection strategy) [18].

Big data is a combination of approaches and technologies that utilize unique kinds of integration to extract insights from varied, complex, and enormous data sources [19].

Given that Big Data and Smart Farming are both relatively new concepts, it's understandable that understanding their applications and implications for research and development is limited. However, according to Gartner's Hype Cycle, Big Data and associated technologies may have passed the "peak of exaggerated expectations" and are no longer a "technological hoax." [20].

Smart Farming-related Big Data applications and to highlight the most relevant future research and development problems. It is important to include both technical and societal factors while doing a literature review [21].

5. 5. HARDWARE AND TOOLS

IoT in agriculture equips farmers with decision-making tools and automation solutions that connect items effortlessly, knowledge, and services to increase production, quality, and profitability. Large-scale pilots in the agrifood supply chain face numerous challenges, according to recent IoT surveys. Among the key topics explored are new business models, security and privacy, and data governance and ownership [22].

5.1 IOT Ecosystem

It is made up of four main parts

a. The IoT devices embedded systems that require wireless connectivity to interact with sensors and actuators These IoT devices are also referred to as IoT sensors. The sensors track and measure several farm conditions (such as soil nutrients and weather). Sensors include location, optical, mechanical, electrochemical, and airflow sensors. Temperatures, dew points, wind directions and directions of the wind are all measured by these sensors. They also measure atmospheric pressure and relative humidity and gather data on the sun's rays and leaf chlorophyll content.

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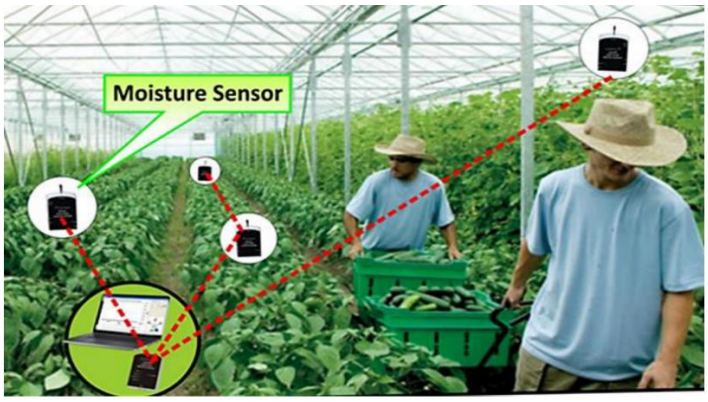

Figure: 2. IoT in agriculture measurement and reporting [23].

b. Technology of Communication: Communication technology is critical to the successful implementation of IoT systems**.** Existing communication technologies can be categorized according to their compliance with standards, their spectrum use, and application scenarios. The communication standard may be divided into two distinct groups, short-distance communication and long-distance communication. The frequency range of the communication spectrum can either be licensed or unlicensed. IoT device application scenarios can make use of sensors or a backhaul network, and deployment scenario implementations can also take place [24].

c. Internet

It is now feasible to connect vast numbers of people to the Internet as a result of developments in wireless communication networks, mobile devices, and pervasive services. Agricultural equipment connected to the internet is expected to rise from 13 million in 2014 to 225 million in 2024, according to research conducted by Machina. Agricultural equipment connected to the internet is expected to rise from 13 million in 2014 to 225 million in 2024, according to research conducted by Machina. Among the network layers, the Internet is the most fundamental, since it provides paths for data and network information to be transmitted and exchanged between numerous subnetworks. The linking of Internet of Things devices to the Internet allows data to be accessed from any location and at any time. Although data transfer via the Internet is relatively safe, it necessitates sufficient security, real-time data support, and ease of access. The Internet laid the groundwork for cloud computing, which collects and stores massive volumes of data for subsequent analysis. The Internet of Things middleware and connectivity protocols are being developed in order to enable the connectivity of heterogeneous systems and devices over the Internet. Examples of IoT middleware that have been used to allow the Internet of Things include service-oriented architecture (SOA), cloud-based IoT middleware, and actor-based IoT middleware. An architecture with multiple layers is used for SOA for IoT [25].

d. Units for Data Storage and Processing: Data driven agriculture entails the collection of huge amounts of data that is dynamic, sophisticated, and spatial in nature, which necessitates the storage and analysis of that data.

Text, photos, audio and video are all acceptable forms of communication. History, sensors, live streaming video, business and market data, and more are all possible sources of information. The utilization of cloud-based Internet of Things platforms enables the storing of significant quantities of data obtained from sensors in the cloud. This includes hosting critical applications for service delivery as well as managing an end-to-end IoT infrastructure from start to finish. Recently, edge or fog computing has been recommended, in which Internet of Things devices and gateways perform computing and analysis in order to minimize latency for key applications, and decrease costs while improving overall performance [26].

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e. Tools and technologies that can be used

In the field of agriculture, the term "Internet of Things" (IoT) refers to sensors, drones, and robots that are connected to the internet and operate automatically or semi-automatically to carry out activities and gather data with the goal of enhancing both predictability and efficiency. Agribots agricultural automation and robots are gaining popularity among farmers as a result of an increase in the number of people throughout the world who require employment but a decrease in the available workforce. As a result of a shortage of personnel, annual crop output in the United States fell by an estimated 213 crores, which is equivalent to around $3.1 billion. Agrobots have gained significance over the course of the past several years due to advancements in sensor and artificial intelligence technologies that enable machines to learn from their environment.

Semi-automatic robots with arms can find weeds and spray pesticides on them, which saves both the plants and the money spent on pesticides. Besides harvesting and lifting, these robots can also be used to do these things.

It is used to map, survey and image the farms with drones that have sensors or cameras that can read the ground. When they aren't being flown by someone else, which works with sensors and GPS. Drone data, among other things, can be utilized to provide insights into crop health, irrigation, spraying, planting, soil and field health, plant counts, and yield prediction [27].

Remote sensing based on the Internet of Things collects data from sensors positioned along farms, such as weather stations, and sends it to a logical tool for analysis. They monitor variations in crop light, humidity, temperature, form, and size. On farms, sensors collect information on humidity, temperature, moisture precipitation, and dew detection in order to develop crops that are suited to the local climate. Measuring soil quality enables the determination of nutrient content and arid regions of fields, soil drainage capacity, and acidity, allowing for the modification of irrigation water demands and the selection of the most advantageous mode of cultivation [28].

f. GPS/GNSS

Without GPS, it's impossible to predict where precision agriculture would be today. There are numerous ways in which operators and manufacturers have used satellite-based position locating systems since the early 1990s, making field operations much more efficient and accurate. According to Trimble Agriculture Marketing Manager T.J. Schulte, "growers can turn on the tractor and go to work virtually instantly" across North America and Europe [29].

g. Mobile Devices

It's hard to overstate how essential mobile devices have been in the past 20 years, after determining how precise agriculture has become. Mobile gadgets such as smartphones and tablets are now commonplace in our daily lives. Precision agriculture companies that have dabbled in the mobile device industry since 2016 have devoted much of their efforts to improving the features that their products can provide to customers [30].

h. Robotics

In agriculture, robots are taking on a wide range of jobs, from planting greenhouse vegetables to pruning vineyards, with various degrees of success. Agricultural crops have also seen a lot of activity. Autonomous devices that can be remotely operated using telematics have received the most attention in recent years. Kinze's engineers designed a self-driving grain cart system to trail a combine from a safe distance with a tractor-compatible attachment.

i. Sensors

Data on soil water availability, soil compaction, soil fertility, leaf temperature, leaf area index, plant hydration status, local climate, insect-disease-weed infestation, and many other issues have been

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gathered using wireless sensors in precision agriculture. Water management is home to some of the most cutting-edge and versatile technology available today. Water shortages and more regulation will continue to push progress in this area across the country [31].

j. Variable Rate Seeding

Seeing variable-rate application (VRA) seeding on this list might surprise some people. There are a lot of new and exciting precision farming technologies on this list. GROWMARK's Precision Farming Manager Sid Parks says the system's design is a big reason why it has remained indispensable [32].

6. APPLICATION OF IOT IN AGRICULTURE

There are several examples of the Internet of Things being used in agricultural settings. The following are some examples of use cases in which this is beneficial: crop and livestock management; machinery; irrigation; weather; soil; disease and pest management; and automation. The Internet of Things is analysed in terms of its use in the following areas: tracking, tracing, and monitoring; farming equipment; pinpoint farming; greenhouse cultivation. There are numerous areas in which the Internet of Things (IoT) could be useful in the present day.

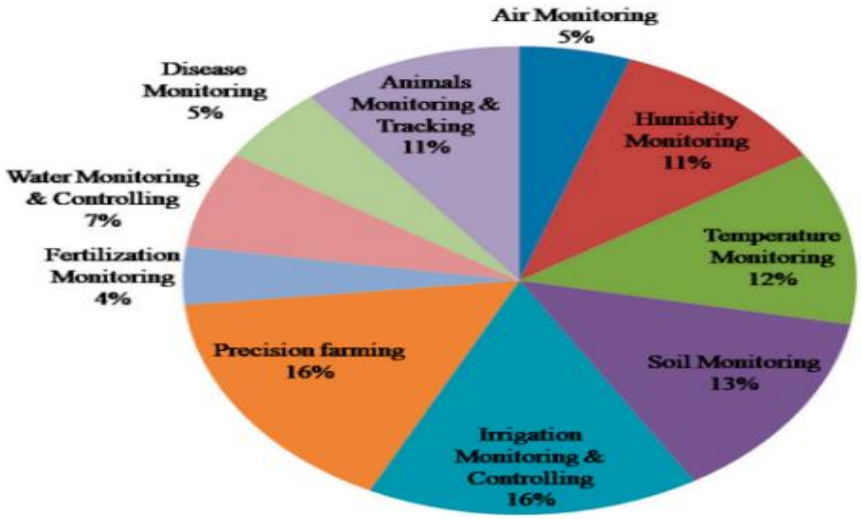

Figure: 3- IoT Agriculture Applications.

a. Crop Farming

In crop farming, there are a lot of things in the environment that can affect how well the crops do. Using such data, one can gain a deeper understanding of a farm's patterns and operations. Such information can include things like rainfall, leaf moisture, temperature, humidity, soil moisture, salinity, climate, dry circle, sun radiation, pest migration, human activities, and so on. Having access to such comprehensive data enables farmers to make more informed decisions, which leads to higher yields, lower costs and more profitability. For example, the data on solar radiation helps farmers determine if their plants are suitably exposed to sunshine or are overexposed [33].

b. Aquaponics

As a result of aquaculture and hydroponics, aquaponics is the practice of feeding fish waste into plant farms in order to provide plants with the nutrients they need. In such farms, it's critical to keep an eye on things like water quality, water level, temperature, fish health, salinity, pH, humidity and even the amount of sunshine hitting the plants and animals. Fish and plant yields can be increased through correct data, which allows nutrients to be transferred between plants and fish. With less human intervention, the data can be exploited for automation.

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c. Forestry

Over two-thirds of the world's known species may be found in forests, making them critical to the carbon cycle. Temperatures and humidity in the soil and air, as well as the concentrations of a variety of gases, the air quality needs to be monitored for dangerous levels of gases such as carbon monoxide, carbon dioxide, toluene, oxygen, hydrogen, methane, isobutane, ammonia, ethanol, hydrogen sulfide, and nitrogen dioxide. Other gases that need to be monitored include toluene, oxygen, hydrogen, and nitrogen dioxide. It is feasible to make use of these elements in order to construct early warning and monitoring systems for forest fires.

d. Livestock Farming

Depending on the type of cattle being studied, there are a number of variables that must be taken into account. The conductivity of milk from buffaloes and cows, for instance, can be used as an indicator of animal health. Temperature, humidity, yield, pest infestation, and water quality are all important considerations. Farmers can use RFID tags to track and query the whereabouts of their livestock, which can assist reduce animal theft [34].

7. CONCLUSION

This comprehensive study delves into the critical role of IoT (Internet of Things) in the realm of agriculture, with a specific focus on smart farming. By leveraging IoT technology, farmers can revolutionize their agricultural practices and achieve increased efficiency and sustainability. The study explores the wide array of tools and applications available in smart farming, such as sensor networks, remote monitoring systems, precision irrigation systems, and livestock tracking devices. These IoT tools enable real-time data collection, analysis, and decision-making, empowering farmers to optimize resource utilization, enhance crop yield, and mitigate risks. Additionally, the study underscores the importance of IoT in addressing key challenges faced by farmers, including environmental monitoring, pest control, and livestock management. By expanding the scope of the study, it is possible to further emphasize the transformative impact of IoT in smart farming and delve deeper into the specific types of IoT tools that offer substantial benefits for modern agricultural practices.

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