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# IoT-Based Smart Agriculture: Advancing Precision Farming and Resource Optimization

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***Abstract***

*One industry or profession that is crucial to modern human existence is agriculture. Food is the most important necessity for human survival, and agriculture supplies it. Similarly, India's economy is centered on agriculture. But in modern Indian agriculture, farmers continue to mainly rely on indigenous or traditional methods. However, if they use smart, advanced, and innovative technologies on their farms or agro-based companies, they may now save more money, time, and energy. Even though the worlds and India's populations are expanding, agricultural productivity is decreasing daily. It should go without saying that humanity would eventually find it difficult to exist with its own inventions.*

**Keywords:** Precision farming, argo-based industry, human survival, ICT, farming and resource

## INTRODUCTION

Every aspect of our lives has been impacted by the growing use of the Internet of Things (IoT), from smart cities and industrial IoT to health and fitness, home automation, automobile, and provision. Farmers have achieved more control over the process of growing crops and developing placental mammals by abusing many useful agricultural tools, making them much more reliable and cost-effective. IoT-enabled smart farming will assist farmers in lowering waste production and increasing output. The amount of fertilizer used and the number of trips the farm trucks have taken might contribute to that. Thus, smart farming is essentially a high-tech method of producing sustainable and clean food for the public. It involves the introduction and use of contemporary ICT (Information and Communication Technologies) in the field of agriculture. The Internet of Things (IoT), which includes smart cities and towns, connected cars, and advanced industries, has the potential to change the world in which we currently live. However, using IoT technology to the agricultural industry may have the greatest impact. By adjusting anything from the quantity of fertilizer used to the number of trips made by farm vehicles, IoT-enabled smart farming can assist farmers and producers in decreasing waste and increasing productivity. One could refer to the high-tech, expensive process of generating clean, plentiful food as "smart farming."

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## APPLICATIONS OF IOT IN AGRICULTURE

Some of the applications used in agricultural fields to efficiently manage and regulate different activities include the following.

### Climate

The climate has a significant impact on farming. Crop productivity, both in terms of quantity and quality, is also severely hampered by inaccurate climate data. However, IoT solutions change how you view the current situation. There are sensors within and outside the agricultural fields. They collect information or data from the atmosphere to

 

select the crops that will flourish in the climate. The entire Internet of Things system is made up of sensors that can detect temperature, precipitation, moisture, and other meteorological factors with extreme precision. To fulfil your practical farming demands, the system can be assembled using a variety of sensors that can detect these factors.

Crop growth, yield, and overall agricultural output are all impacted by climate conditions, which are vital to agriculture. Agriculture is impacted by several climate factors.

- *Temperature:* Various crops need different temperatures to grow at their best. Crops can be harmed by extreme temperatures, either too high or too low. While too much heat might result in heat stress and lower yields, frost can damage delicate plants.
- *Precipitation:* Crop growth depends on timely and sufficient rainfall. Drought can be caused by insufficient rainfall or erratic precipitation patterns, which can impact agricultural growth and productivity. Overwhelming rain can result in waterlogging, which can harm plant roots and cause infections.
- *Humidity:* Plant transpiration rates and disease susceptibility can be influenced by humidity conditions. While low humidity can cause plants to become dehydrated, high humidity can promote the growth of some diseases.
- *Wind:* Crops are susceptible to physical harm from strong winds, particularly in their early stages of growth. The fertility and health of agricultural land are impacted by soil erosion, which is another effect of wind.
- *Sunlight:* Photosynthesis, the process by which plants make food, depends on enough sunlight. On the other hand, excessive sunshine or extended exposure to strong sunlight can harm crops and cause heat stress.
- *Seasonal Variations:* Certain crops require seasons. While some do well in warmer areas, others are better suited to milder seasons. Farmers are better equipped to choose appropriate crops and planting dates when they are aware of the seasonal fluctuations in each area.
- *Climate Change:* As a result of climate change, extreme weather events, such as heatwaves, floods, storms, and droughts, are occurring more frequently and with greater intensity. By altering planting schedules, lowering yields, and escalating pest and disease threats, these changes have the potential to have a substantial effect on agriculture.

In agriculture, farmers frequently use a variety of tactics to adjust to shifting climatic circumstances. To lessen the negative effects of unfavourable climate conditions on agriculture, these tactics include the use of drought-resistant crops, water-saving irrigation techniques, crop rotation, cover crops to prevent soil erosion, conservation tillage techniques, and the application of technology and innovation.

**Accurate Farming**

Precision farming, also known as smart farming or precision agriculture, is one of the most well-known uses of the Internet of Things in agriculture. It combines technology, data analytics, and customized management techniques to maximize crop yields while enhancing sustainability and efficiency. To raise domesticated animals and boost harvests, a technique or training called “exactness cultivating” improves the control and precision of the farming methodology. This methodology’s applicability and components, such as sensors, self-driving cars, computers, control systems, mechanical technologies, and so on, are important. It tightens and improves the cultivation process by identifying clever cultivating applications like stock observation, field perception, vehicle following, and animal checking. Precision agriculture has been one of the most popular IoT applications in the agricultural industry in recent years, and many associations worldwide have begun to employ this method. To gather and evaluate data and enable farmers to make well-informed decisions regarding crop management, it makes use of a variety of technologies and methodologies.

The following are important elements and technology utilized in precision farming:

- *Geographic Information Systems (GIS) and Global Positioning Systems (GPS):* GIS combines

 

spatial data to give comprehensive information about topography, soil changes, and other field characteristics, while GPS technology aids in precisely mapping field borders.
- *Remote sensing:* Information about crop health, soil moisture content, pest infestations, and nutrient deficits is gathered by drones, satellites, and other remote sensing equipment. Finding areas that need attention and intervention is much easier with the use of this information.

Farmers can apply inputs like fertilizers, insecticides, and irrigation water at different rates depending on the spatial variability of a field, thanks to variable rate technology, or VRT. This focused strategy increases crop productivity, minimizes waste, and maximizes resource use.
- *Sensors and IoT (Internet of Things):* Weather stations, soil moisture sensors, and other IoT devices continuously track environmental conditions, giving farmers access to real-time data that enables them to make informed decisions about planting, harvesting, and irrigation.
- *Precision Planting and Seeding:* State-of-the-art planting and seeding tools guarantee accurate seed placement, maximizing depth and spacing for maximum growth. Better crop establishment and uniformity are the outcomes of this.
- *Data analytics and farm management software:* Advanced software tools examine data gathered from several sources, providing analysis and suggestions to enhance crop management, resource allocation, and yield optimization decision-making.

**Agricultural Drones**

Agricultural drones, also known as unmanned aerial vehicles (UAVs) or unmanned aircraft systems (UAS), are aircraft operated remotely by a pilot or autonomously through pre-programmed flight plans. These drones are equipped with various sensors, cameras, and other agricultural tools to assist farmers in managing crops and livestock more efficiently. Agricultural drones have gained popularity due to their versatility and ability to collect valuable data for precision farming practices.

Agricultural drones have the following main characteristics and applications [1]:
- *Data collection and imaging:* Multispectral, hyperspectral, or thermal sensors, as well as high-resolution cameras, are fitted aboard drones. In-depth photos and information regarding crop health, plant stress, disease outbreaks, nutrient deficits, irrigation requirements, and pest infestations are captured by them. Farmers are better able to spot problems early and take focused action thanks to this imagery.
- *Field Mapping and Surveying:* Accurate field maps are produced by drones equipped with mapping capabilities using GPS and imaging technologies. To improve decision-making for planting, irrigation, and land management, these maps help analyze topography, soil changes, and field boundaries.
- *Crop Management and Monitoring:* Throughout the growing season, farmers can keep a close eye on crops thanks to drones. Farmers can make well-informed decisions about fertilizer application, irrigation timing, and pest or disease management by examining aerial imagery and data gathered by drones.

Applying fertilizer, insecticides, or seeds precisely is made possible by certain drones that come with sprayers or seed spreaders. This focused strategy maximizes input utilization, limits chemical exposure, and cuts waste.
- *Livestock Monitoring:* Drones with cameras and sensors help with grazing patterns over wide areas, missing animal detection, herd health checks, and livestock monitoring.
- *Applications in the Environment and Conservation:* Drones are useful for environmental monitoring, including following changes in land usage, evaluating soil erosion, and keeping an eye on conservation initiatives in vulnerable locations.

## IOT-POWERED AGRICULTURE TECHNOLOGIES

**Smart Irrigation System**

By combining many sensors, controls, and Internet of Things (IoT) devices, smart irrigation systems are a cutting-edge technique for effectively watering plants, crops, or landscapes. It seeks to preserve resources, maximize water use, and sustain robust plant development. This is how it usually operates:

 

- *Sensors:* To keep an eye on the soil's moisture content, soil moisture sensors are buried in the ground. Environmental parameters, like temperature, humidity, wind speed, and rainfall, can be monitored by other sensors such as weather sensors [2–4].
- *Data Gathering and Analysis:* The sensors gather information about weather, soil moisture, and occasionally plant health. A cloud-based platform or a central control system receives this data for examination.
- *Decision Making:* Based on variables including soil type, plant type, weather, and evapotranspiration rates, the system employs algorithms and data analysis to pinpoint the precise water requirements of plants. By learning from historical data, machine learning algorithms may be used to gradually increase accuracy.
- *Automated Watering:* The smart system uses the analysis to initiate automated irrigation, which regulates sprinklers or valves to provide the plants with the exact amount of water they require. It can dynamically modify schedules based on current circumstances**.**
- *Remote Control and Monitoring:* Using a web interface or smartphone app, users can frequently monitor and control the system remotely. This makes it possible to modify watering schedules or settings as necessary (Figure 1).
- *Greenhouse Control:* This is the process of controlling and regulating environmental elements in a greenhouse to give plants the best possible growing conditions. This entails managing elements including irrigation, ventilation, light, temperature, humidity, and $CO_2$ levels. To maximize crop yield and plant growth, sophisticated greenhouse management systems automate and monitor key parameters using technology (Figure 2) [5–9].

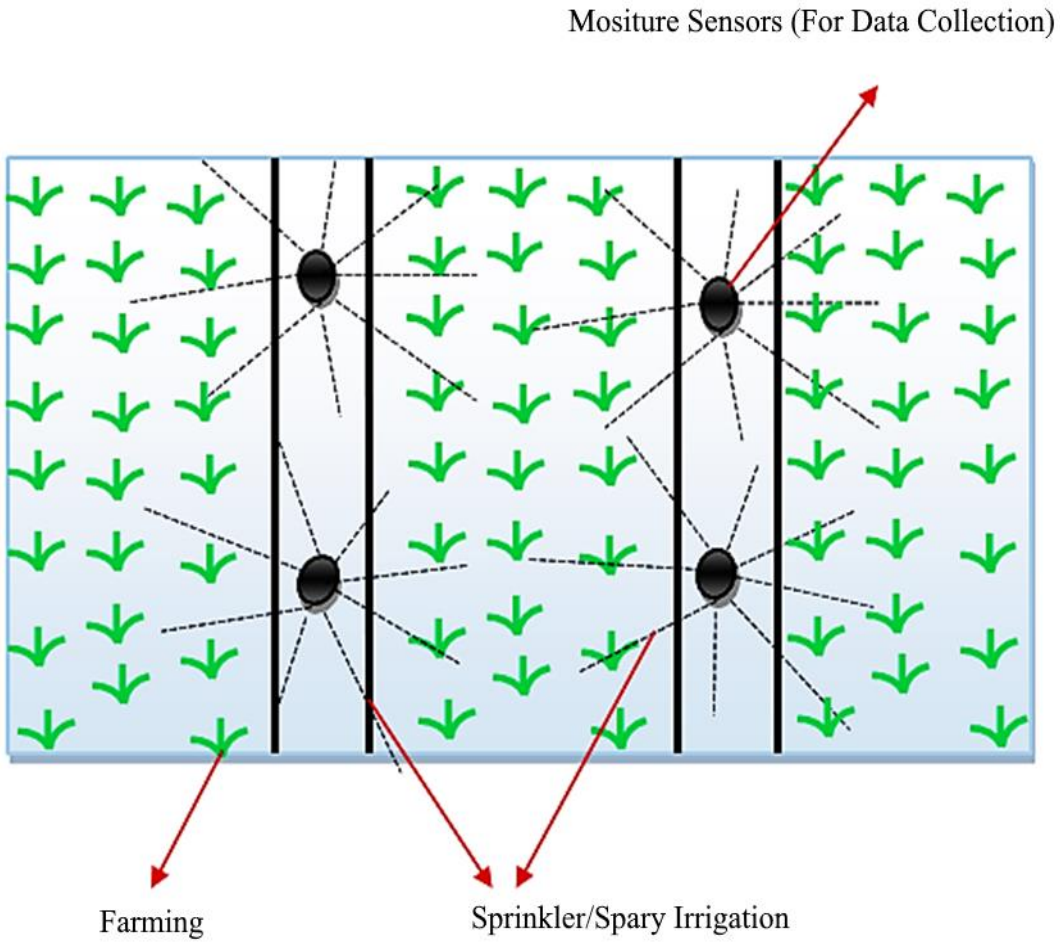


**Figure 1.** Intelligent watering system.

 

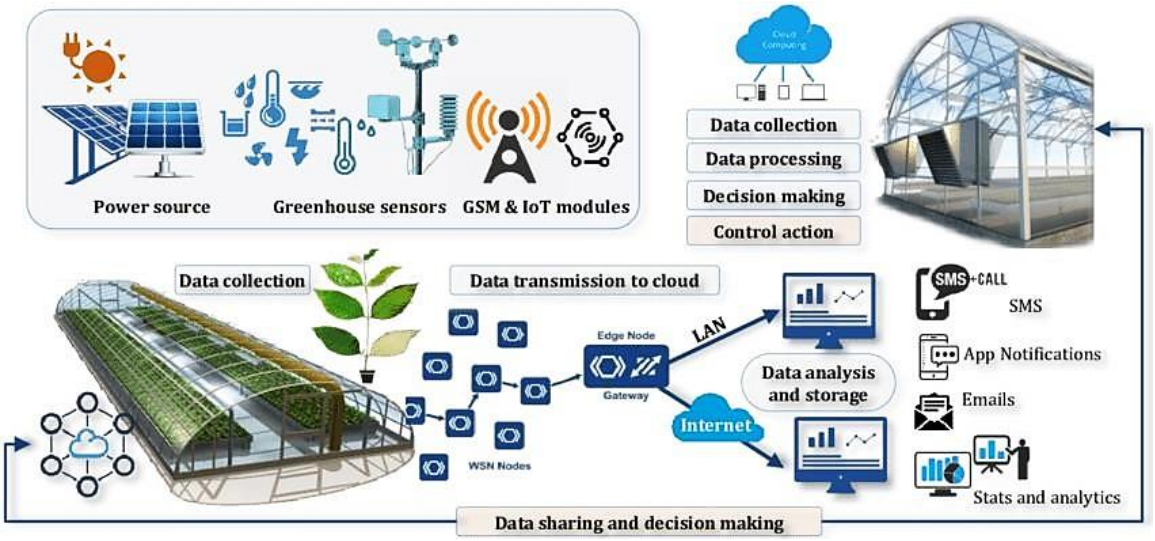


**Figure 2.** Smart greenhouse monitoring system.

### Control Systems for Greenhouses

- *Temperature Control:* Plant growth depends on maintaining the optimal temperature range. Sensors and heating/cooling systems are used in greenhouses to control temperature. While ventilation or cooling systems, like fans or evaporative cooling, assist in bringing temperatures down when they rise too high, heating systems, like boilers or heaters, are turned on when temperatures fall [10].
- *Humidity Control:* Plant development and disease susceptibility are influenced by humidity levels. Depending on sensor readings, humidifiers or dehumidifiers are used to modify humidity levels.
- *Lighting Control:* Although natural sunlight is frequently used in greenhouses, additional artificial lighting may be required, particularly in areas with little sunlight or during the darker seasons. To guarantee ideal growing circumstances, automated devices can control the artificial lighting's duration and intensity.
- *Irrigation Control:* Plants receive water from automated irrigation systems according to their individual requirements. When irrigation is required, sensors in the soil detect the amount of moisture present. This encourages water efficiency and avoids overwatering or underwatering.
- *$CO_2$ and Ventilation Control:* Photosynthesis depends on stable carbon dioxide ($CO_2$) levels. To keep plants in a healthy environment, ventilation systems regulate the greenhouse's $CO_2$ levels and air circulation.
- *Automation and Monitoring:* Sensors, actuators, and a central control unit that gathers information and adjusts automatically are frequently included in greenhouse control systems. This enables remote monitoring and control and can be linked to a central computer or controlled via a smartphone app.

### Current Situations and Prospects for IoT and Agriculture

The increase of IoT-based adoption in the agriculture sector between 2000 and 2050 is displayed in the following (Table 1).

**Table 1.** Evolution of IoT adoption in agriculture from 2000 to 2050 [1].

| S.N. | Year | Data Analysis |
|---|---|---|
| 1 | 2000 | 525 million Farms connected to IoT. |
| 2 | 2016 | 540 million Farms till Date are connected to IoT. |
| 3 | 2035 | 780 million Farms would be connected to IoT. |
| 4 | 2050 | 2 billion Farms are likely to be connected to IoT. |

 

## IOT IN AGRICULTURE IS IMPROVED FOR INTELLIGENT FARMING

The IT strategy at the opposite end of the supply chain, the back-office decision support system, is what sets precision agriculture apart. The idea of "the linked farm" is becoming increasingly tangible, even though technology is still in its infancy. Numerous historical data points, such as weather occurrences, climate, economics, product specifics and specifications, system settings, etc., are linked to farming activities. Connecting processes to provide a more thorough picture of how the entire ecosystem functions and to interpret agricultural operations in a complex, interconnected manner is the essence of the Internet of Things. "Smart agriculture" or "decision-making" will replace precision farming.

## CONCLUSIONS

Here, an attempt has been made to evaluate the impact of integrating advanced technologies into conventional agriculture. The numerous IoT applications in agriculture, their usage, and the advantages that IOT systems provide to agricultural fields are all explained in this study paper. IoT-enabled agriculture has made it easier to apply state-of-the-art technical solutions to well-established knowledge. Data absorbed through the collection and importation of information from the various sensors for use in real time or storage in a database ensures quick response and less damage to the crops. This guide will increase agricultural output and assist farmers in better managing food production.

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