

# Potential and Trends of IoT Application in Agriculture in Vietnam

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## Abstract

Vietnam is a country with a lot of potential and strengths in agriculture, but in the current period, along with the narrowing of arable land, the quality of soil and the increasingly harsh climate have caused difficulties for activities. Along with the strong development of the industrial revolution 4.0, the application of Internet of Things (IoT) technology in agriculture is increasingly popular. However, for the application to be synchronized and to effectively exploit IoT technology resources in the agricultural sector, it is necessary to have a policy orientation on science and application from the government. This article will address the outstanding issues of IoT application in Vietnamese agriculture and point out some potential applications.

## Keywords

Industry 4.0, IoT Technology, Agriculture 4.0, IoT Application in Agriculture

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## 1. IoT Technology

### The Concept and Characteristics of IoT

The Internet of Things or the network of Internet-connected devices (IoT), when each object and person is provided with its identifier, and all are capable of transmitting and exchanging information and data through a single network without the need for direct human-to-human or human-to-computer interaction. IoT has evolved from the convergence of wireless technology, micro-electro-mechanical technology, and the Internet. Many experts suggest that “Things” should be seen as “an integral whole of hardware, software, data and network services”. Put simply, it is a collection of connected devices that can connect to the Internet, and to the outside world to do a particular job (Gillis, 2021).

An essential point of IoT is that objects must be recognized and identified. If

every object, including humans, is “tagged” to distinguish that object from the things around it, we can completely manage it through computers. Tagging can be done through many technologies, such as RFID, NFC, barcode, QR code, digital watermark. Put simply, IoT is all connected devices and the connection can be made via Wi-Fi, broadband telecommunications networks (3G, 4G, 5G), Bluetooth, ZigBee, infrared, etc. With more than 7 billion connected IoT devices today, experts expect this number to grow to 22 billion by 2025.

In the past ten years, the world has made many advances in technology such as manufacturing sensors, Internet protocols to connect many devices, wireless data transmission technology and data processing and analysis technology, etc. These advancements give us many opportunities to collect and process large volumes of data efficiently.

IoT is a set of technologies that allow us to collect large volumes of data organized through intelligent devices connected via the Internet and wireless networks and process that data effectively to serve the management, administration, and business activities.

The world is entering an era when people are searching for new resources, and IoT allows us to exploit available resources, that is, information resources, to create a competitive advantage. IoT is considered a potential technology trend that can bring significant benefits. IoT has several characteristics that can be seen as follows (Gillis, 2021; *What Is the Internet of Things? Configuring IoT Technology and Applications in Implementation, 2021, April 28*):

- **Intelligence:** In recent times, the combination of IoT with autonomous control creates a network of intelligent entities capable of acting individually depending on specific situations. At the same time, they can exchange information with each other. The inclusion of AI technology in data processing analysis will make IoT systems more and more intelligent;

- **Complex systems:** In an open world, IoT will be complex because it includes a large number of links between devices, machines, and services and the ability to scale with new elements;

- **Size:** An IoT network can contain up to 50 to 100 trillion connected objects, and the network can track the movement of each object;

- **Data:** The collected IoT data is extensive; besides important data information, there is also data about time, place, space, etc. Therefore, it is necessary to consider what types of data to collect and how often to sample data as well as collecting event-based data to optimize network resources;

- **Enormous potential:** Currently, IoT has reached a stage, and the cost of deployment is getting cheaper. Many ARM embedded devices can collect and transmit data on the network but cost less than 40 USD per product. Currently, we can see 32-bit ARM-based microcontrollers for less than 1 USD. With this microcontroller, it is possible to do many things on it, such as collecting and transmitting data much cheaper: only about 50 cents for a 32-bit ARM microcontroller. In the next 5 years, products will become more abundant and affordable. Ongoing challenges are data management and migration to IPv6 (IPv6 is

now available and running with allocated addresses). With IPv6, we will have an abundance of addresses, and this will open up the possibility of assigning addresses to each device (gadget) and chip. Solutions will be easier and more straightforward, clearer, recoverable to individual address entries, and the scope for growth is immense;

In Vietnam, according to the policy of integration into the international economy of the Party and the State, the Vietnamese IT industry cannot stand aside from this trend. In the coming time, at the state level, the exploitation of data as a resource for forecasting and management will be promoted more strongly. On the part of information technology, businesses need to take advantage of this opportunity to launch a new application layer that allows exploiting the business's hidden potential through the analysis of relevant data. IoT has the potential to be applied in a variety of fields that are of interest to society, such as transportation, health care, agriculture, education, etc., to help lower costs and improve service quality. In particular, agriculture is one of the fields attached to the country for thousands of years, but its potential has not been effectively exploited.

## **2. IoT Application in High-Tech Agricultural Development**

A report by the McKinsey global economic research institute (USA) estimates that by 2025, the Internet of Things could bring in more than 11 trillion USD per year. The report summarizes that the potential of IoT is being underestimated because IoT is not only present in all areas of life, but it also creates many new concepts and areas in Life and Business.

The world population will reach 9.8 billion people by 2050. Therefore, to serve this population well, agriculture must accept IoT. To combat challenges such as extreme weather conditions, increased climate change, and the impact on the environment caused by intensive farming practices, more food needs to be met. Applications of IoT-based smart agriculture target large-scale livestock operations and provide new levers to enhance other development trends in agriculture such as organic farming, family livestock, and intensification of agriculture (Ayaz, Ammad-Uddin, Sharif, Mansour, & Aggoune, 2019).

### **2.1. The Concept of IoT Application in High-Tech Agriculture**

High-tech agriculture is a system that relies heavily on investment capital and high-tech techniques to grow crops. In high-tech (smart) agriculture, we have successfully applied IoT to create a system built to monitor crop fields. The purpose of most agricultural IoT models is to allow businesses and farmers to pre-plan operations around planting, watering, harvesting, etc. Specifically, the application of IoT in agriculture will be (What Is the Internet of Things? Configuring IoT Technology and Applications in Implementation, 2021, April 28):

- **Applying science and technology** to the whole process in agriculture (the closed process): Particularly, applying information technology, electronics, and

telecommunications to processes from seed preparation, soil, etc. -> cultivation - breeding -> harvesting -> processing -> preservation -> distribution -> to the table;

- **Apply new technologies** such as artificial intelligence (AI) to process the collected big data. Collected data must form a large-scale database to automate the whole process gradually (i.e., eliminate progressively human “experience” proactively recognizing problems and proposing solutions);

- **Application of new and modern equipment** such as drones in planting, health monitoring, crop care, pesticide spraying, irrigation, etc.;

- **Greenhouses:** Greenhouses are now commonly used in our country, especially in Da Lat—where has the advantage of climate and weather. Greenhouses were initially born to help isolate plants from outside weather conditions. Gradually, additional climate control systems inside greenhouses (temperature, humidity, light, etc.) and irrigation control systems were added. Greenhouses contain two central systems as follows:

- + **Irrigation control systems:** The system includes devices: A drip irrigation head or a mist/rain sprinkler, a fertilizer injector, an irrigation controller, etc. The systems help to water/fertilize in an economical, efficient, and high-yield way, helping farmers reduce production costs;

- + **Microclimate control systems:** The system includes sensors to detect temperature and humidity inside and outside the greenhouses, the ventilation fan system for the air convection, the lighting system to be able to increase the light when needed; the weather station measures the following parameters: solar radiation intensity, rain warning, wind speed, rain volume, etc. The goal is to help the greenhouses stay in the desired conditions.

All these applications of IoT technology in agriculture contribute to reducing labour costs, input costs through the rational use of fertilizers, water sources, etc. and improving the quality of the plants; bringing the country’s agriculture to a new height, gaining a position in the international agricultural product market.

## 2.2. Benefits of IoT Application in Agriculture

IoT applications in agriculture play a vital role in the current technology era. We need more support to promote IoT technology adoption in agriculture and bring about greater efficiency. The above is considered a successful step for many major agricultural brands with benefits such as:

- **Agricultural coverage:** Combining many types of farming including greenhouse growing methods, hydroponics, some farm models can be located in cities;

- **Resources reduction:** Optimizing the use of resources such as water, land, energy, etc. This resource-saving is significant, and productivity is improved;

- **Clean processes:** Applying IoT to the production process helps to minimize the use of pesticides, chemical fertilizers, etc. Therefore, agricultural products will ensure better quality and can be exported to many more countries;

- **Fast:** With the support from the IoT system, the living and growing environment of the plants are at ideal levels. Plants are monitored and cared for right from the time of sowing to harvesting, helping the plants to grow very quickly and soon to harvest;

- **Improving the quality of agricultural products:** With the 24/7 continuous operation of the IoT system in particular and smart agriculture in general, agricultural products will be developed in quality (and quantity), thereby increasing the value of products;

- **Risk control:** Estimating production in advance when businesses, farmers plan product distribution and accurately predict how many crops you will harvest; as a result, ensuring to have products that will make sales more convenient.

The application of IoT in high-tech agriculture in Vietnam will create great opportunities for farmers to become businesses with outstanding productivity and value and an increasingly better quality of life. Thereby helping farmers save resources, operating costs, improve production, crop quality, labor optimization, management time, etc. Currently, IoT applications are widely applied by farmers to reduce labour and accelerate the development of crops, helping farmers increase their income.

Agricultural IoT applications are helping farmers collect meaningful data. Small landowners and farmers must understand the potential of the IoT market for agriculture by installing innovative technologies to increase the competitiveness and sustainability of their production. Increasing population demand can be achieved if ranchers and smallholder farmers implement IoT agricultural solutions successfully.

### **3. Advantages, Disadvantages, and Directions of IoT Applications for Agriculture in Vietnam**

#### **3.1. Advantages and Disadvantages**

Vietnam is a country with a long history of agriculture through which farmers have gained a lot of experience in farming and animal husbandry. Farmers have been used to farming for generations; since then, they are willing to stick with the land where they were born and pursue this work for the rest of their lives. In recent years, the policies of the Communist Party and the Vietnamese State on land accumulation have facilitated the implementation of IoT application for agriculture more favorable.

Vietnam has many advantages when it comes to emerging as a dynamic country, with many tech startups and this community being supported by the Government. Technological human resources in Vietnam are huge, young, intelligent, passionate, and hard-working to learn new things.

Besides the advantages, Vietnam also faces difficulties and challenges to promote IoT development:

- Firstly, we lack businesses that provide technologies, solutions, and data analysis and processing services. To have strong companies in data analysis and

create competitive advantages, Vietnam needs to have policies to attract talent, develop appropriate training and research programs in this field;

- Secondly, there is a gap between the research sectors and enterprises, which leads to the low application of research results into practice;

- Thirdly, the issue of funding, when applying new technology, the first difficulty often mentioned is the issue of the financing. The actual cost is not high, but the price is mainly on the design stage. Therefore, farmers can connect to their farms through smartphones. And since then, farmers have been communicating with the farm through intelligent devices, unfamiliar with changing traditional farming methods;

- Fourthly, the issue of farmers' awareness: The main factor in Vietnamese agriculture is farmers and cooperatives, but the reality shows that they are still confused with the application of technology in agriculture. Therefore, it is necessary to have a companion, buy agricultural products, apply flexible processes and technologies to make agricultural products effective, valuable, and of high quality;

- Fifthly, there is a lack of ideas when applying IoT in agriculture in Vietnam; currently, mainly uses sensors, programming for irrigation, automatic indoor hydroponics and is only applied to large-scale enterprises.

Vietnam's agriculture has many advantages, but mainly small-scale production based on household economy, labour productivity is still low. Therefore, the application of IoT in agriculture will create significant opportunities for farmers to become businesses with outstanding productivity and value that bring a better quality of life.

### **3.2. Some Directions for IoT Application in Agricultural Development in Vietnam**

One of that premises is resolution No. 36-NQ/TW of the Politburo (XI term) on promoting IT application and development to meet the requirements of sustainable development and international integration, issued on 1<sup>st</sup> July 2014. The resolution mentioned building industry and IT services ecosystem to meet export and domestic markets, supporting the development of Vietnamese brand technology products and services with high intellectual content, investing in software products research, etc.

It is necessary to propagate to businesses and cooperatives that understand the importance and trends of IoT application in agriculture in the long run. Promote the trend of IoT and innovation (DDI) for businesses to develop in this direction. The development of the IoT ecosystem is necessary to create a community of companies to participate, promote creativity and competition. IoT applications can only be effectively deployed if the right infrastructure is in place. The IoT infrastructure has many layers: the transport layer, the underlying IT service layer, the data providers and data analytics service providers, and finally, the community of businesses that develop data mining tools to service agencies, or-

ganizations, and companies.

In this model, the State plays the role of providing supportive policies and developing primary infrastructure layers. The State makes appropriate policies to encourage businesses and agricultural households to apply IoT technology in agriculture. It is expected that the State will support the infrastructure and initial promotion. In addition, there should also be solutions for new ideas to be kept to express; demonstrate novelty, creativity, and feasibility. Another important issue is that it is necessary to have a mechanism to ensure the rights of inventors in the future, especially a strict management mechanism for intellectual property.

On the side of businesses, farmers with dynamism will play an active role in promoting IoT development. Moreover, startups and innovative companies must prove that their ideas are good, realistic, technologically advanced, and highly feasible to receive support from the community according to the market economy model. IoT allows us to collect a lot of data, but this will become meaningless if we cannot exploit the data to make decisions that serve a specific purpose. Therefore, we need new technology to analyze and process data according to creating innovation based on data potential (Data-Driven Innovation or DDI). Thus, in the coming time and focusing on hardware and software information technology services, it is necessary to invest in data analysis technology, turning data into a resource to create a competitive advantage.

In recent times, policies to support IoT applications in agriculture have been increasingly encouraged and developed by agencies and ministries, including the Ministry of Information and Communications, which has enabled businesses to propose IoT initiatives proactively and discuss with functional units of the Ministry to be able to come up with specific and reasonable policies. The connection between government agencies, businesses, and scientific research is an essential factor in promoting the development of information technology. The application of IoT in agriculture is more and more widespread.

## **4. Potential IoT Applications Applied to Agriculture in Vietnam**

### **4.1. Using IoT for Precision Farming**

Precision farming is a process that makes the farming process more controlled and precise for raising livestock and growing crops. The key components are the use of IT and feature such as sensors, autonomous vehicles, autonomous hardware, control systems, robots, etc., in this approach (**Figure 1**).

Precision agriculture in recent years has become one of the most well-known applications of IoT in the agricultural sector, and a lot of organizations have started using this technique around the world.

The products and services provided by the IoT system include soil moisture sensors, VRI optimization (Variable Rate Irrigation), PRO virtual optimizer, etc. VRI optimization is a process of maximizing profits in crop fields irrigated with soil change, thus improving yield and increasing water use efficiency.



**Figure 1.** The precision agriculture model (Image: Internet).

Variable Rate Technology (VRT)—VRT refers to technologies that allow input changes and help farmers control the number of inputs in a particular area. The essential components of this technology include a computer, software, a controller, and a differential global positioning system (DGPS). There are three basic approaches to using VRT—map-based, sensor-based, and manual-based (The Future of Manufacturing Is Digital—Predictive Maintenance, 2021, December 9).

GPS Soil Sampling—Check the soil properties of an area to determine available nutrients, pH, and many other types of data necessary for making informed decisions and profitability. In essence, soil sampling allows farmers to look at yield differences in a field and develop a plan to consider these differences. Sampling and analysis services are essential, allowing data to be used for input with variable factors to optimize seeding and fertilization.

Computer applications—Computer applications can be used to create farm plans, farming area maps, and yield maps. This allows for more precise use of inputs such as pesticides, herbicides, and fertilizers, reducing costs, giving high yields, and being environmentally friendly. The challenge with these software systems is that they sometimes provide only modest value, not allowing the data to be used to make large-scale agricultural decisions. Another concern with many software applications is their poor user interface and inability to integrate the information they provide with other data sources to give farmers more valuable information.

It uses remote sensing technology to monitor and manage land, water, and other resources. It can help identify everything from factors that can strongly affect a crop at a particular point to estimate soil moisture. This data supports decision-making on the farm and can come from various sources, including aircraft and satellites.



The primary goal of precision agriculture and precision agronomy is to ensure profitability, efficiency, and sustainability while protecting the environment. This is achieved by using the big data gathered from this technology to help make immediate or future decisions on everything from different rates for different areas until the best results are achieved: chemicals, fertilizers, or seeds.

Today, with the strong development of technology, artificial intelligence in data analysis will effectively support farmers in making decisions. Farmers now have access to a lot of data. There's so much data they don't know what to do with it. AI is capable of analyzing large amounts of data in a short time and using it to recommend the best course of action. This information can then be used to predict the best time to plant, predict pest and disease outbreaks before they happen, and make yield predictions before harvest. While AI will never be able to replace the kinds of complex decisions farmers have to make regularly, it can be used to make those decisions easier.

Vietnam is a country with long-standing agriculture but farming in individual households. In recent years, the State has had policies on land accumulation; there have been large cooperatives and companies engaged in high-tech agriculture such as Hoa Phat, Hoang Anh Gia Lai, Vinamilk, and TH group, etc. With traditional farming, the efficiency decreases due to climate change, bad soil, and many diseases. Since then, the above-listed IoT technologies have been applied more and more and have proven their effectiveness.

#### **4.2. Smart Greenhouses (DroneLife, 2020)**

Greenhouse farming is a technique to improve the yield of crops, vegetables, tubers, and fruits (**Figure 2**). Greenhouses control environmental parameters in two ways: through manual intervention or a rate control mechanism. However, because manual intervention methods have disadvantages such as production costs, energy consumption, and labour costs, these methods are less effective. An intelligent greenhouse through IoT embedded systems intelligently monitors and controls the climate eliminating all need for human intervention.

Various sensors that measure the environmental parameters required by the plant are used to control the environment in the innovative greenhouse. A cloud server is then created for remote access to the system when it connects using IoT. Inside the greenhouse, a cloud server helps process data and apply control actions. This design provides optimal and cost-effective solutions for farmers with minimal manual intervention.

An example of this is Illumin Greenhouses, an Agriculture Technology greenhouse organization that uses technology and IoT to provide services. It builds modern and affordable greenhouses using solar-powered IoT sensors. Greenhouse status and water consumption can be monitored with these sensors by sending SMS alerts to farmers using an online portal.

Sensors in the IoT system in the greenhouse provide information about temperature, pressure, humidity, and light levels.



**Figure 2.** Greenhouse covered with glass material (Image: internet).

Covering material is one of the essential components that cannot be missed when constructing and installing agricultural greenhouses, whether you are just making a small home rooftop model or a large-scale production model. Currently, we can use many different types of covering materials: plastic film, polycarbonate, glass or fiberglass. The choice of material depends on the investment budget, climate zone, and what kind of crops you plan to grow in the greenhouse. Each material has different advantages and disadvantages.

- **Greenhouses covered with plastic film:** Plastic film is usually produced from PE plastic (polyethylene), which is considered the most commonly used material globally because of its relatively low investment cost. Another advantage of this material is its high light diffusion ability, allowing more sunlight to pass through, helping to promote photosynthesis and increase crop yields. This material also casts less shade because of the limited use of reinforcing materials (Agricultural Weight IoT Application—4 Best Benefits of Agriculture IoT White IoT, 2020, November 30). The disadvantage is that the life cycle is short, usually about 4 to 5 years.

- **Greenhouses covered with Polycarbonate:** Polycarbonate is the newest greenhouse material on the market with the characteristic of flat, 2 layers or a corrugated layer. It is a stronger material than nylon, the 2-layer type has quite good insulation properties, suitable for temperature-sensitive crops. Polycarbonate has high durability, can withstand adverse weather conditions such as hail better than glass materials. And this material is not affected by UV, air pollution or agricultural chemicals like PE plastic film can be used for up to 10 years without needing to be replaced. The disadvantage is that the cost for this type is often higher than glass or polyethylene, and over time this type of greenhouse can turn yellow or grow moss affecting the illumination of the plants.

- **Greenhouses covered with glass materials:** Glass is the most ideal material for covering greenhouses due to its significantly better light transmission prop-

erties than other materials. Glass is also highly durable, fire resistant and unaffected by air pollution, UV rays or agrochemicals. The disadvantage of greenhouses is the high cost of construction and materials and often broken due to substantial impacts such as hail, complex objects falling.

- **Greenhouses covered with glass fibres:** glass fibres are also another material frequently used to build agricultural greenhouses. This material is cheaper than glass and polycarbonate, and often more expensive than polyethylene. Thanks to its hard nature, this material does not need a strong supporting structure like glass, which helps to reduce construction costs significantly. The disadvantage of using glass fibre is that this material is easily damaged by sunlight, reducing light transmission; the material is also flammable and has a short life cycle of about five years.

### 4.3. Application of Drones in Agriculture

Agricultural drones are an excellent example of IoT applications in agriculture (**Figure 3**). The application of drones in agriculture is increasingly popular thanks to its relatively low cost and ease of application. Today, precision agriculture allows farmers to use drones to measure and observe the variety of crops. Sowing seeds, automated crop care, and close monitoring of crop health also help increase yield and profitability (*DroneLife, 2020*).

The benefits of using drones include ease of use, time savings, crop health imaging, integrated GIS mapping, and increased productivity. Drone technology will bring high-tech change to the agriculture industry using strategy and planning based on real-time data collection and processing.

Farmers using drones can enter details of the fields they want to survey. Select elevation or ground resolution to get data on the areas. From the data collected by the drones, it is possible to derive valuable and detailed information about various factors such as plant counting, yield prediction, plant health index, height trees measurement, coverage mapping, nitrogen content in wheat, drainage mapping, etc. The areas where drones are used are detailed below:



**Figure 3.** Using drones in agriculture (Image: Internet).

- **Planting and Irrigation:** Today's modern planting systems can perform simultaneous seeding and fertilization. The speed and efficiency of this method are assessed to bring absorption rates up to 75% and cost reductions up to 85%.

Thanks to the types of sensors on drones such as heat, spectrum, etc., helping farmers quickly identify crops that lack water. Moreover, thanks to other technology, it can calculate the density and health of plants provide heat charts, alert farmers when crops need more or less water. This efficient water use is a huge cost-saving measure as water costs rise and drought hits many areas. Careful irrigation also reduces other risks such as fertilizers flowing into rivers and streams, preventing affecting plant life, etc.

- **Monitoring and assessing crop health:** Frequent weather conditions combined with large cultivated areas make it difficult to monitor crops. Using satellite images gives us low quality and limited use. Today, drones can provide low-cost time-series videos, helping us realize production inefficiencies and the real-time growth of crops. Using multi-spectral images captured from the drone system, it is possible to monitor the changes of crops and make specific recommendations. This allows farmers to take timely handling measures, especially to warn of disease abnormalities that may affect crop yields, etc.

- **Soil analysis and weed removal:** Thanks to drones, it is possible to build 3D maps to help farmers analyze the soil. Once the seeding model is complete, the drones can monitor soil quality and provide data on nitrogen levels and irrigation requirements. Thanks to intelligent AI cameras that can detect weeds to adjust the appropriate amount of spray, the effect will be better, and the cost of use will be reduced.

- **Spraying:** Using drones to spray drugs is increasingly popular thanks to its superior effects on safety, fast and evenly spreading impact. A new study shows that drones spray pesticides five times faster than traditional methods. Thanks to laser distance measurement technology that helps them adjust their altitude on all terrains, prevent accidents while spraying, etc. Most pesticides are harmful to human and animal health, leaving a severe, even irreversible impact on the environment, eventually causing significant pollution to the entire ecosystem. Therefore, the use of drones helps significantly reduce the number of pesticides, thereby reducing the impact on the environment.

## 5. Conclusion

The article presents the concept, characteristics, need, and trends of IoT applications for high-tech agriculture today. We offer the remaining problems and difficulties for IoT applications in agriculture in Vietnam and suggest solutions to promote the development of IoT applications to be more popular and effective.

The research has also presented several specific and practical IoT applications in agriculture in the current period, thereby helping managers better orient agricultural enterprises and cooperatives to use more effectively and complete the proposed solutions.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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