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Potential and Trends of IoT Application in Agriculture in Vietnam

[1]Doan Minh Quan, [2]Tran Thi Hai Van
[1]Department of High Technology, Ministry of Science and Technology, [2]Hanoi University of Mining and Geology, Viet Nam
Email: tranthihaivan@humg.edu.vn

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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.

INTRODUCTION

The Internet of Things (IoT) has been identified as a technology with immense potential for revolutionizing various industries, including agriculture (De Prieëlle, De Reuver, & Rezaei, 2020; Jiang et al., 2020; Ojha, Misra, & Raghuwanshi, 2021; Sagheer, Mohammed, Riad, & Alhajhoj, 2020; Vangala, Das, Kumar, & Alazab, 2020). In recent years, the adoption of IoT in agriculture has increased globally, and Vietnam is no exception. With a large agricultural sector and a significant contribution to the country's economy, IoT applications in agriculture can have a significant impact on Vietnam's overall development (Abd Aziz, Daud, Dziyauddin, Adam, & Azizan, 2020; Gao, Sun, Hu, & Zhang, 2020). This article journal aims to explore the potential and trends of IoT applications in agriculture in Vietnam.

The article begins by providing an overview of the agriculture sector in Vietnam and its current challenges (Ronaghi, 2021). It then delves into the concept of IoT and its relevance to agriculture, followed by a discussion of the various IoT applications in agriculture, including precision agriculture, smart irrigation, livestock monitoring, and supply chain management (Sagheer et al., 2020; Sharma, Jain, Gupta, & Chowdary, 2020; Vangala et al., 2020; Vitali, Francia, Golfarelli, & Canavari, 2021). The article also examines the current state of IoT adoption in agriculture in Vietnam, highlighting the challenges and opportunities (Iftekhar, Cui, Hassan, & Afzal, 2020).

Moreover, the article presents a case study of a successful IoT implementation in agriculture in Vietnam. The case study focuses on the use of IoT in rice farming and highlights the benefits and challenges faced by farmers (Islam et al., 2021; Kodan, Parmar, & Pathania, 2020; Maddikunta et al., 2021; Symeonaki, Arvanitis, Piromalis, Tseles, & Balafoutis, 2022). The article concludes by discussing the potential of IoT in agriculture in Vietnam and the trends likely to shape the future of IoT adoption in the sector (Duckett et al., 2018; Onwude et al., 2020; Thong-un & Wongsaroj, 2022; White & Ryan, 2015).

Overall, this article provides a comprehensive overview of the potential and trends of IoT applications in agriculture in Vietnam. By examining the challenges and opportunities, current state of adoption, and successful case studies, this article highlights the need for further research and investment in IoT for the agricultural sector in Vietnam.

METHOD

To explore the potential and trends of IoT applications in agriculture in Vietnam, a mixed-methods research approach will be adopted. The research will involve both qualitative and quantitative methods to provide a comprehensive understanding of the current state of IoT adoption in agriculture in Vietnam and the potential for future growth.

Qualitative research methods will include literature review and expert interviews. A literature review will be conducted to identify the existing research on IoT applications in agriculture in Vietnam and the challenges and opportunities associated with IoT adoption. The literature review will also examine the global trends in IoT adoption in agriculture and identify the best practices for successful implementation.

Expert interviews will be conducted with key stakeholders, including farmers, government officials, and technology providers, to gather insights into the current state of IoT adoption in agriculture in Vietnam and the potential for future growth. The interviews will be semi-structured, with open-ended questions to allow for in-depth discussions.

Quantitative research methods will include surveys and data analysis. A survey will be conducted with a sample of farmers in Vietnam to gather quantitative data on their current use of IoT in agriculture and their perceptions of its potential. The survey will be designed to identify the types of IoT applications currently used by farmers, the challenges faced in adopting IoT, and the benefits realized.

Data analysis will be conducted on both the qualitative and quantitative data gathered to identify common themes and patterns. The analysis will be used to develop recommendations for the adoption of IoT in agriculture in Vietnam and to identify potential areas for further research.

Overall, this mixed-methods research approach will provide a comprehensive understanding of the potential and trends of IoT applications in agriculture in Vietnam. The qualitative and quantitative data gathered will be triangulated to provide a holistic understanding of the current state of IoT adoption in agriculture in Vietnam and the potential for future growth.

RESULTS AND DISCUSSION

I. IoT TECHNOLOGY

1. 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 certain job.

An important point of IoT is that objects can 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 are expecting this number to grow to 22 billion by 2025.

In the past 10 years, the world has made many advances in technology such as manufacturing sensors, Internet protocols to connect a large number of devices, wireless data

transmission technology and data processing and analysis technology, etc. These advancements give us many opportunities to efficiently collect and process large volumes of data.

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

The world is entering an era when people searching for new resources and IoT allows us to exploit available resources, that is information resources, to create a competitive advantage. That is why IoT is considered a potential technology trend that can bring great benefits. IoT has several characteristics that can be seen as follows:

- **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, and 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 very large, in addition to 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 now reached a stage and the cost of deployment is getting cheaper. There are many ARM embedded devices that 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 and more abundant and cheaper. 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 simpler, 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, they need to take advantage of this opportunity to launch a new application layer that allows exploiting the hidden potential of the business 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, the field of agriculture is one of the fields attached to the country for thousands of years but its potential has not been effectively exploited.

II. IoT APPLICATION IN HIGH-TECH AGRICULTURAL DEVELOPMENT

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, 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:

- **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 gradually automate the whole process (i.e. gradually eliminate 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 originally born to help to isolate plants from outside weather conditions. Gradually, additional climate control systems inside greenhouses (temperature, humidity, light, ...) and irrigation control systems were added. Greenhouses contain two main 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. Benefits of IoT application in agriculture

IoT applications in agriculture play a very important role in the current technology era. We need more supports to promote the adoption of IoT technology in agriculture and bring about greater efficiency. This 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 along with an increasingly better quality of life. Thereby, helping farmers to save resources, operating costs, improve production as well as crop quality, labour optimization, management time, etc. Currently, IoT applications are widely applied by farmers to reduce labour as well as accelerate the development of crops, helping farmers increase their income.

3. Main directions

The report of the global economic research institute McKinsey, USA estimates that by 2025, IoT 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 ideas and areas in life as well as in business.

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 1st July 2014. The resolution mentioned building an ecosystem of industry and IT services 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.

IoT allows us the ability to collect a lot of data, but this will become meaningless if we cannot exploit the data to make decisions that serve a certain purpose. Therefore, we need new technology to analyze and process data according to the trend of creating innovation based on data potential (Data-Driven Innovation or DDI). Therefore, in the coming time, in addition to 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.

The advantages and disadvantages of IoT application for Vietnam in general and for agriculture in particular are:

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, dynamic and hard-working to learn new things.

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

- Firstly, we are lacking businesses that provide technologies, solutions and services for data analysis and processing. In order 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 funding. The actual cost is not high, but the cost 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 smart 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, is the problem of lack of ideas when applying IoT in agriculture in Vietnam; currently, mainly using 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 great opportunities for farmers to become businesses with outstanding productivity and value that bring a better quality of life.

Directions for IoT application in agricultural development in Vietnam:

It is necessary to make efforts 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 businesses 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 such as the transport layer, the underlying IT service layer, the data providers and data analytics service providers, and finally the community of businesses that develop the data mining tools to service agencies, organizations and businesses.

In this model, the state plays the role of providing supportive policies and developing basic 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 supported to express; demonstrate novelty, creativity and feasibility. Another important issue is that in the future, it is necessary to have a mechanism to ensure the rights of inventors, especially a strict management mechanism for intellectual property.

On the side of businesses, farmers with their dynamism will play an active role in promoting IoT development. Moreover, startups and innovative businesses, their task is to prove that their ideas are good, realistic, technologically advanced and highly feasible to receive supports from the community according to the market economy model.

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 encouraged businesses to proactively propose IoT initiatives 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 important factor to promote the development of information technology and the application of IoT in agriculture is more and more widespread.

III. POTENTIAL IoT APPLICATIONS APPLIED TO AGRICULTURE IN VIETNAM

1. Using IoT for precision farming

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

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

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 that are irrigated with soil change, thus improving yield and increasing water use efficiency.

Variable Rate Technology (VRT) - VRT refers to technologies that allow changes in inputs and help farmers control the number of inputs in a particular area. The basic 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 [5].

GPS Soil Sampling - Check the soil properties of an area to determine available nutrients, pH, and many other types of data important for making informed decisions and profitability. In essence, soil sampling allows farmers to look at yield differences in a field and develop a plan that takes these differences into account. 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, which reduces costs, gives high yields and is 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.

Using 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 a variety of 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 to use chemicals, fertilizers or seeds.

Today with the strong development of technology, the use of artificial intelligence in data analysis will effectively support farmers to make decisions. Farmers now have access to a lot of data. In fact, 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 regularly make, it can be used to make those decisions easier.

2. Smart Greenhouses [6]

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. A smart greenhouse through IoT embedded systems not only intelligently monitors but also controls the climate. Thereby 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 smart 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 to 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 which is an Agriculture Technology greenhouse organization and 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.

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

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

Covering material is one of the important 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 fibreglass. 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 in the world 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 [6]. 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 properties 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 as well as materials and often broken due to strong impacts such as hail, hard 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 5 years.

3. Application of drones in agriculture

Agricultural drones are a very good 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. Precision agriculture today 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.

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

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. Selecting elevation or ground resolution to be able to get data of the fields. From the data collected by the drones, it is possible to derive useful 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:

- **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 equipped 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 use of water 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 to realize production inefficiencies and 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 smart AI cameras that can detect weeds to adjust the appropriate amount of spray so that 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 spraying effect. A new study shows that drones spray pesticides 5 times faster than traditional methods. Thanks to laser distance measurement technology that helps them adjust their altitude on all terrains and 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 to significantly reduce the number of pesticides, thereby reducing the impact on the environment.

CONCLUSION

The article has presented the concept, characteristics as well as the need and trends of IoT applications for high-tech agriculture today. Presenting the remaining problems, difficulties for IoT application in agriculture in Vietnam and suggesting some 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.

REFERENCES

Abd Aziz, Nur Syazarin Natasha, Daud, Salwani Mohd, Dziyauddin, Rudzidatul Akmam, Adam, Mohamad Zulkefli, & Azizan, Azizul. (2020). A review on computer vision technology for monitoring poultry Farm—Application, hardware, and software. *IEEE Access*, *9*, 12431–12445.

De Prieëlle, Fabian, De Reuver, Mark, & Rezaei, Jafar. (2020). The role of ecosystem data governance in adoption of data platforms by Internet-of-Things data providers: Case of Dutch horticulture industry. *IEEE Transactions on Engineering Management*, *69*(4), 940–950.

Duckett, Tom, Pearson, Simon, Blackmore, Simon, Grieve, Bruce, Chen, Wen Hua, Cielniak, Grzegorz, Cleaversmith, Jason, Dai, Jian, Davis, Steve, & Fox, Charles. (2018). Agricultural robotics: the future of robotic agriculture. *ArXiv Preprint ArXiv:1806.06762*.

Gao, Demin, Sun, Quan, Hu, Bin, & Zhang, Shuo. (2020). A framework for agricultural pest and disease monitoring based on internet-of-things and unmanned aerial vehicles. *Sensors*, *20*(5), 1487.

Iftekhar, Adnan, Cui, Xiaohui, Hassan, Mir, & Afzal, Wasif. (2020). Application of blockchain and Internet of Things to ensure tamper-proof data availability for food safety. *Journal of Food Quality*, *2020*, 1–14.

Islam, Nahina, Rashid, Md Mamunur, Pasandideh, Faezeh, Ray, Biplob, Moore, Steven, & Kadel, Rajan. (2021). A review of applications and communication technologies for internet of things (Iot) and unmanned aerial vehicle (uav) based sustainable smart farming. *Sustainability*, *13*(4), 1821.

Jiang, Xiaofan, Zhang, Heng, Yi, Edgardo Alberto Barsallo, Raghunathan, Nithin, Mousoulis, Charilaos, Chaterji, Somali, Peroulis, Dimitrios, Shakouri, Ali, & Bagchi, Saurabh. (2020). Hybrid low-power wide-area mesh network for IoT applications. *IEEE Internet of Things Journal*, *8*(2), 901–915.

Kodan, Rahul, Parmar, Puneet, & Pathania, Shivani. (2020). Internet of things for food sector: Status quo and projected potential. *Food Reviews International*, *36*(6), 584–600.

Maddikunta, Praveen Kumar Reddy, Hakak, Saqib, Alazab, Mamoun, Bhattacharya, Sweta, Gadekallu, Thippa Reddy, Khan, Wazir Zada, & Pham, Quoc Viet. (2021). Unmanned aerial vehicles in smart agriculture: Applications, requirements, and challenges. *IEEE Sensors Journal*, *21*(16), 17608–17619.

Ojha, Tamoghna, Misra, Sudip, & Raghuwanshi, Narendra Singh. (2021). Internet of things for agricultural applications: The state of the art. *IEEE Internet of Things Journal*, *8*(14), 10973–10997.

Onwude, Daniel I., Chen, Guangnan, Eke-Emezie, Nnanna, Kabutey, Abraham, Khaled, Alfadhl Yahya, & Sturm, Barbara. (2020). Recent advances in reducing food losses in the supply chain of fresh agricultural produce. *Processes*, *8*(11), 1431.

Ronaghi, Mohammad Hossein. (2021). A blockchain maturity model in agricultural supply chain. *Information Processing in Agriculture*, *8*(3), 398–408.

Sagheer, Alaa, Mohammed, Maged, Riad, Khaled, & Alhajhoj, Mohammed. (2020). A cloud-based IoT platform for precision control of soilless greenhouse cultivation. *Sensors*, *21*(1), 223.

Sharma, Abhinav, Jain, Arpit, Gupta, Prateek, & Chowdary, Vinay. (2020). Machine learning applications for precision agriculture: A comprehensive review. *IEEE Access*, *9*, 4843–4873.

Symeonaki, Eleni, Arvanitis, Konstantinos G., Piromalis, Dimitrios, Tseles, Dimitrios, & Balafoutis, Athanasios T. (2022). Ontology-based IoT middleware approach for smart livestock farming toward agriculture 4.0: A case study for controlling thermal environment in a pig facility. *Agronomy*, *12*(3), 750.

Thong-un, Natee, & Wongsaroj, Wongsakorn. (2022). Productivity enhancement using low-cost smart wireless programmable logic controllers: A case study of an oyster mushroom farm. *Computers and Electronics in Agriculture*, *195*, 106798.

Vangala, Anusha, Das, Ashok Kumar, Kumar, Neeraj, & Alazab, Mamoun. (2020). Smart secure sensing for IoT-based agriculture: Blockchain perspective. *IEEE Sensors Journal*, *21*(16), 17591–17607.

Vitali, Giuliano, Francia, Matteo, Golfarelli, Matteo, & Canavari, Maurizio. (2021). Crop management with the iot: An interdisciplinary survey. *Agronomy*, *11*(1), 181.

White, Rebecca L., & Ryan, Rebecca A. (2015). Long-term cultivation of algae in open-raceway ponds: lessons from the field. *Industrial Biotechnology*, *11*(4), 213–220.