The FFTC Journal of Agricultural Policy
http:/ap.fftc.org.tw/e-journal

Smart Agriculture for Small Farms in Vietnam: Opportunities, Challenges and Policy Solutions

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Received March 10, 2022; Accepted June 14, 2022

ABSTRACT

Vietnam's agriculture has gained outstanding achievements such as having a foothold on its food and nutrition security, solving the jobs in the rural areas, its contribution to GDP, etc., but it has also been facing challenges in the context of climate change and disasters. Smart agriculture is a solution for Vietnam and its small farmers to overcome the above difficulties. Smart agriculture helps farmers gain access to complete and timely information, skills, techniques to make better decisions in their production and trading. This will lead to farmers' increases in productivity, outputs, income and profits. The application of smart agriculture in Vietnam still has some basic limitations such as small household size, high cost in technology investments, difficulties in accessing capital, land and suitable technologies, etc. To develop smart agriculture in Vietnam, the State needs to innovate policies on digital transformation in line with smart agricultural technology so that small households and cooperatives can have convenient access.

Keywords: smart agriculture, digital transformation, small farms, policy solution

INTRODUCTION

Vietnam's agriculture has achieved many considerable achievements in recent years, even in the volatile situation of COVID-19. It deserves to be the backbone of the economy by ensuring both food and nutrition security and exports having achieved the title of the 15th exporting country in the world. Although accounting for just over 14% of Vietnam's GDP, the agriculture sector occupies nearly 40% of the labor force. Therefore, the agricultural sector and rural areas can't separate themselves from the Government's chapter on digital transformation. On the contrary, the experts claimed that the digital transformation in the agriculture and rural areas holds Vietnam as a country with so much potential. The digital transformation in agriculture in Vietnam is mostly observed through the development of its smart agriculture.

Vietnam's agriculture is characterized by its wide distribution over the entire territory, fragmented by 8.6 million small farming households participating, and highly depending on the fluctuating external factors such as climate change, impacts of epidemics, market fluctuations and degradation of productive resources like land, water, and biodiversity. These are the main challenges for the sustainable development of agriculture and farmers' income in the coming decade. However, with the emergence of smart agriculture, the above-mentioned difficulties could be the solutions that can bring obvious results.

OPPORTUNITIES OF SMART AGRICULTURE IN VIETNAM

For farmers and rural people, the biggest limitation is the lack of information in the areas of production and other areas of life. Smart agriculture will bring opportunities for them to enhance their connectivity with information, better production management, partially erase the geographical distance, and reduce the

complexity of many-level administrative procedures in order to directly use the State's public services for agriculture.

Regarding the opportunity of smart agricultural activities, the first specific benefit is that farmers can have access to more information to make more accurate production decisions, reduce production costs, increase labor productivity and production efficiency, and reduce environmental pollution through digital platforms provided by enterprises or the State to connect with production input services such as seeds, fertilizers, pesticides, mechanization services, credit loans, access to digital agricultural extension, weather forecast services, plant protection services, storage, transportation, harvesting services, access to information about buyers' needs, market standards and updated prices, etc. These information sources are collected, accumulated gradually and gathered in the form of an open database and jointly managed and provided by the Ministry of Agriculture and Rural Development and enterprises so that everyone can connect and use them. Farm households, farms, cooperatives, or production enterprises can also apply the production technologies of precision agriculture, apply automation technology to optimize each part of the production process of fertilizing, watering, pesticide treatment, etc., to ensure food safety and reduce environmental pollution with the support of digital platforms.

The next opportunity is at the post-harvest stage, value chain management, traceability from farm to table, information and sales retrieval through e-commerce with digital platforms provided by enterprises. These platforms can also undertake logistics and transportation. With advanced digital technologies such as blockchain, IoT, AI, etc. developed by Vietnamese enterprises, it is possible for farmers to have access to a suitable cost.

CURRENT STATUS OF SMART AGRICULTURE IN VIETNAM: SOME SMALLHOLDER MODELS

According to the concept of the European Smart Farming Thematic Network, smart farming is the application of modern information and communication technologies (ICT) into agriculture (the Third Green Revolution). This revolution combines ICT such as precision devices, Internet of things (IoT), sensors, global positioning, big data management, drones, robots, etc. to enable farmers to add value through making more effective exploitation and management decisions, which are: (1) Information management system to meet the needs of collecting, processing, storing and providing the necessary data to perform the functions of the farm; (2) Precision agriculture through systems that can manage spatial and temporal variability to improve investment efficiency and reduce environmental harm.

Vietnam hasn't had an integrated model of smart agriculture yet which is in accordance with the concept of Agriculture 4.0. Currently we can only meet some components of smart agriculture due to the out of synchronous infrastructure to be able to apply IoT connectivity. With the diversified terrain and types of crops and livestock, small farmers and the unequal educational level between regions, there have been only a few trials of smart agriculture in Vietnam that stem from the demand of small farms to reduce labor in production. Some typical models with the participation of small farm households are presented below.

SMART HYDROPONIC VEGETABLE GROWING MODEL

This model has started to be popular in Vietnam across all regions and there are many models with different sizes from a few hundred m^2 to several tens of hectares. Therefore, it can be suitable for small farm households or large-scale enterprises and cooperatives with a partner network of small farm households supplying products under contracts. We present some typical cases of the application of smart vegetable growing technology below.

Hachi company

Hachi is a start-up enterprise of a group of young people from Hanoi University of Science and Technology and Vietnam National University of Agriculture with an initial capital of only US$4,350. Hachi has conducted a test of IoT technology application solution on smart hydroponic system for growing vegetables. Hachi's system consists of 3 components: (1) Conventional hydroponic system; (2) Controller via IoT application to control through Smartphone; and (3) The LED artificial light system that can illuminate the plants without sunlight.

Hachi's hydroponic growing system using IoT technology has the outstanding advantage. Thanks to a sensor on the system that records changes in temperature and humidity in the air where the system is located and will send it to Hachi's server. Each plant will be planted in a separate compartment and will continuously

be watered by an automatic watering system according to environmental conditions. Each plant will be grown through pre-mixed water with nutrients which will continuously pump through the pipe below the plants. When the planting system is placed in the apartments, the addition of light is solved by the LED system to generate sunlight.

All data will be sent to Hachi's server and updated in the user's Hachi mobile application. From that, users can easily monitor the environmental status and offer effective solutions such as setting watering time, lighting time and alert levels through a smartphone. Unlike conventional planting, users only need to add water twice a week and replace the seeds after harvesting the previous plants. In the case of the parameters change, the server will resend the request for irrigation or additional lighting to the system to perform. The interface on the user's application displays detailed parameters about environmental conditions, nutrients in the water and diary of changes over time. This planting solution will give a higher yield and will help to increase the growth rate of plants from 30 to 50%, ensure safe vegetables and fruits, completely isolated from the external pest and disease environment and grow off-season crops that are difficult to grow in natural conditions. High-tech solutions applied by Hachi to the farms help increase productivity by 50-300% compared to traditional farming.

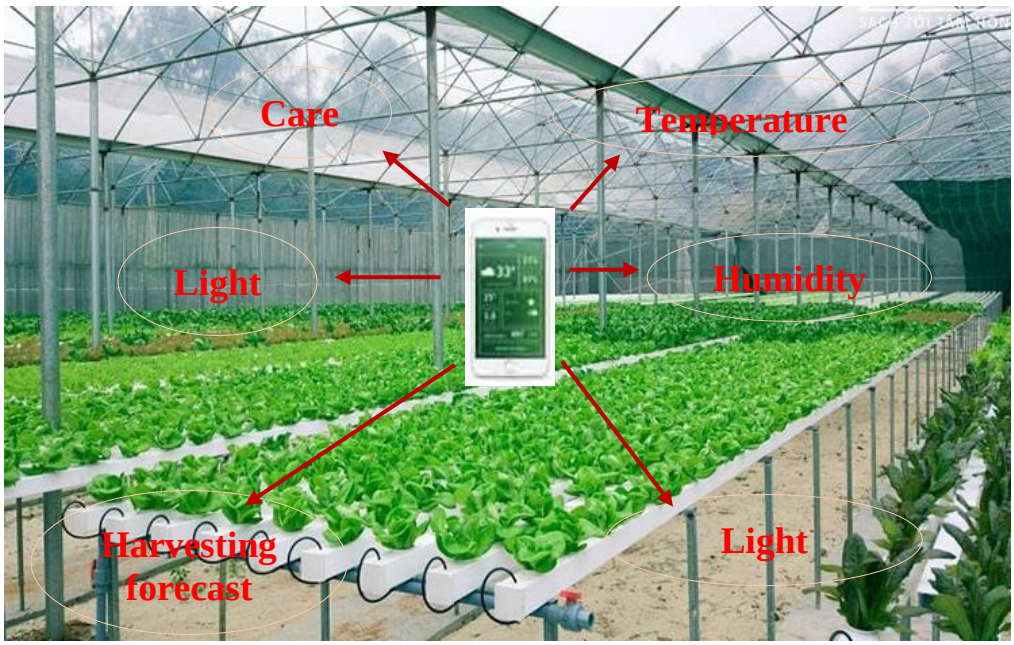

Figure 1. Smart hydroponic vegetable growing technology

In terms of economic efficiency, with family size, each set of products costs from VND 3 to 5 million (US$132 to US$219) depending on the size of the planting truss. Hachi's system with a 46-hole two-floor standard truss can provide about 5-6 kg of vegetables per harvest for a family. To ensure a stable volume of vegetables, users should grow an overlapping crop or buy seedlings to reduce the harvest time by 30% to only 10-15 days. As for the farm model, the cost can range from US$2,200-4,400 for small-scale farms (500-1,000 m^2), but it can also be up to US$300,000 for large-scale models.

Up to now, Hachi has nearly 100 Smart agriculture application projects that have been implemented in areas such as Lam Dong, Hanoi, Bac Ninh, Hue, etc. In which, examples are TEKY educational hydroponic farm project with 30 m^2 in Hanoi, NFT Delco Eco Hydroponic Farm with 1,000 m^2 in Bac Ninh, etc. In addition, Hachi also implemented a project in Melbourne, Australia. Besides, Hachi's farms also self-produces and supplies 200 tons of clean vegetables per month to the market, create jobs for more than 500 local workers. Hachi's technology can be applied to orchids, in urban agriculture.

Truong Phuc Farm

Lam Dong province has many successful family farm models that uses the application of smart agriculture in Vietnam. The hydroponic lettuce farm of Mr. To Quang Dung, CEO of Truong Phuc Farm Limited

Company, is located in Da Sar commune, Lac Duong district, Lam Dong province. In mid-2015, Mr. Dung decided to invest in building a greenhouse and a hydroponic system to grow vegetables. Initially, the cost of the hydroponic vegetable growing system was quite high, about US$34,800/1,000 m^2, but the market was a main difficulty. In the first harvest, the farm could only sell about 100 kg of vegetables per day. Up to 2016, the farm signed a contract to export the first containers of hydroponic vegetables to a partner in Korea. Until now, the farm has maintained and developed this market, the product quality is increasing to meet the demands of customers.

Currently, at the hydroponic vegetable growing farm of more than 3 hectares, Mr. Dung is gradually perfecting the specialization of key products in which, lettuce is specialized to supply the Korean market and are continuously being rotated with an area of 1.5 hectares. With a high-tech hydroponic vegetable growing method, the growing time is shorter, the vegetables are completely isolated from the ground and so heavy metal contamination and bacteria below the ground are minimized. The type of vegetable preservation film is nano film. When preserving vegetables, it will absorb O_2, push CO_2 and H_2O out, so the cells inside the vegetables will be protected, the quality of vegetables will still be maintained and remain for a long time especially since the farm is using radial cooling technology. This is a way to help preserve the vegetables for a long time, keep them green, and ensure quality during transportation from 10 to 12 days. A lettuce crop is about 35 days, each year, on average, 11-12 crops can be grown, the output is 2.5-4.0 tons/1,000 m^2. Especially, in seasons with favorable climate, the output has reached more than 4.0 tons/1,000 m^2. The farm has not only exported hundreds of tons to foreign countries every year but also provided a large number of vegetables and fruits into domestic supermarkets. Every day, Truong Phuc Company supplies the domestic market more than 2 tons of green vegetables. Despite the complicated development of the COVID-19 pandemic, the company's export orders to foreign countries still grew by 40%-50%. Currently, the company is associated with 20 households with an area of over 20 hectares to produce 30 other types of green vegetables, tubers and fruits: baby carrots, baby broccoli, leafy green vegetables, etc. to supply the domestic and export markets.

Benefits of smart hydroponic vegetable growing models

The models provide farmers with an advanced, efficient, and reliable monitoring and control solution. The solution increases crop productivity and plant quality with the following outstanding benefits:

- ✓ Increase the productivity of hydroponic crops by optimizing the control process of plant nutrient solution supply.
- ✓ Ensure a stable hydroponic environment based on the continuous monitoring system and timely warning function.
- ✓ Enhance the plant quality because the system meets fully, automatically, and optimally the nutritional needs of plants.
- ✓ Optimize resources in plant care, crop management, nutrient solution control, and environment monitoring.

Usefulness of the models

When the farmer applies an intelligent hydroponic system, the plants grow quickly with uniform product quality and yield from 20 to 50% higher than conventional cultivation. The application of the automated hydroponics system helps to overcome the following difficulties of traditional farming:

- ✓ Traditional farming requires specialized knowledge and farming experiences.
- ✓ Manual environmental monitoring and irrigation control should be intermittent and human dependent.
- ✓ Traditional farming wastes valuable resources for management and plant care.

PESTICIDE SPRAYING DRONES REMOTELY CONTROLLED AT THOAI SON, AN GIANG

Thoai Son district of An Giang province is a rice-growing specialization area with 10 cooperatives. With the support of Dai Thanh Company, each cooperative has been equipped with a remote-control drone (GlobalCheck) to spray pesticides for cooperative members. In 2021, all cooperatives have agreed to establish the Thoai Son Cooperative Union to better coordinate the provision of mechanization services in the region for farmers. The use of drones to spray pesticides on rice fields saves time and labor, protects the health of producers, reduces costs, avoids damage to rice, avoids disease spreading, etc. and could provide agricultural services to farmers in other places in the near future. Formerly, each hectare of rice required 250 liters of

pesticides and took 3 hours to spray by hand but now using a sprayer, it only takes 10 liters of pesticide per ha and only about 10 minutes for ha. Currently, there is a shortage of local laborers to grow rice. The cost for worker rent to spray pesticides is from US$10 to 15 /ha. To hire a GlobalCheck drone to spray, farmers only need to spend US$9 /ha.

Figure 2. Drone technology to spray pesticides for rice paddy

Table 1. Economic efficiency of paddy production by drone and conventional production

Order	Items	Paddy production by drone (1)	Conventional paddy production (2)	Changing between (1) – (2)
I	**Cost (US$/ha)**	**750**	**887**	**- 137**
	Seed (US$/ha)	172	172	0
	Fertilizer (US$/ha)	280	310	- 30
	Pesticides (US$/ha)	181	280	- 99
	Labor (US$/ha)	52	73	- 21
	Others (US$/ha)	65	52	13
II	**Revenue (US$/ha)**	1,495	1,408	87
	Productivity (kg/ha)	6,800	6,400	400
	Price (US$/kg)	0.22	0.22	0
III	**Benefit (US$/ha)**	745	520	225

Table 1 shows that the economic efficiency of using drones to spray pesticides for paddy is higher than it when spraying by hand. The profit of paddy production by drone is higher than that of conventional paddy production at US$225/ha (increasing by about 43%). This additional benefit is mainly due to increased productivity by 6.3%, reducing the cost of fertilizers, pesticides and labor because using drones will save fertilizers, spray accurately and so less pests.

Benefits of pesticide spraying drones remotely controlled

- ✓ The drone technology leads to a future with less pesticide usage and fewer pesticide impacts. Farmers are using drones to spray pesticides more purposefully over smaller areas as drones can spray with higher accuracy than most boom sprayers, tractors or piloted aircraft.

- ✓ Reduce the labor in agriculture production: One of the advantages of drone use is replacing the labor intensiveness.
- ✓ It helps in achieving more yields by using resources effectively.

Usefulness of drone technology for farmers

Drones don't merely enhance overall performance but also encourage farmers to solve other assorted barriers and receive plenty of benefits through precision agriculture. Drone empowers the farmer to adapt to specific environments and make mindful choices accordingly.

PADDY PRODUCTION APPLIES SMART WATER MANAGEMENT SOLUTIONS IN THE MEKONG DELTA

With the support of the World Bank, Tra Vinh University piloted IoT applications to manage and control water by alternating wet and dry irrigation (AWD) to reduce methane emissions. MimosaTEK, a Vietnamese startup, developed this technology. A sensor measures the water level in the paddy field and sends the information to cloud-based management software. Farmers can track actual and recommended water levels on a smartphone app to help determine the best time to water their paddies and the optimal amount of water to fertilize. They can operate the water pump through a mobile app or manually. In addition to the uncompromising requirements for AWD mentioned above, IoT AWD requires a mobile or internet connection, electricity, and access to a connected smartphone. The test showed that IoT technology was technically feasible for smallholder farmers. The system ran reliably whole time, accuracy in water level measurement and solves minor problems, loss of power or maintenance. The IoT system is user-friendly for farmers and they appreciate its accuracy and convenience. Farmers applying IoT use 13 to 20% less water than conventional AWD farmers.

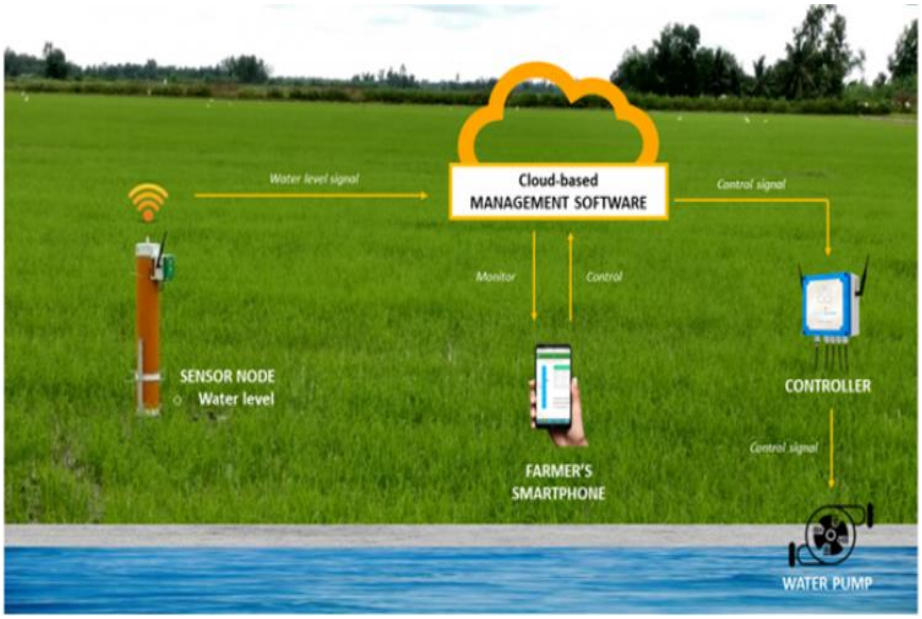

Figure 3. AWD water management technology for paddy

Benefits of smart water management solution

This solution gives many benefits to farmers: reduced water consumption and expenditure, decreased maintenance and repair costs, reduced leakage and wastage, and allows for remote control of water infrastructure.

Usefulness of the solution for farmers

This irrigation technology helps small farmers improve their livelihoods and efficiency. It will be a low cost and scalable solution to enable a more efficient use of inputs, such as water, fertilizers, energy & labor, resulting in increased yields and enhanced quality of crops.

Comparing the economic efficiency of AWD paddy production and conventional paddy production we can see that the benefit of AWD paddy production is US$655/ha, 25% more than it in conventional paddy

production (the benefit of conventional paddy production is US$526/ha) (see Figure 4). This additional benefit is due to the cost reduction and the increase in the productivity. Many researches indicated that AWD technology reduced pests and disease in the paddy fields and this will decrease the production cost and also raise the yield.

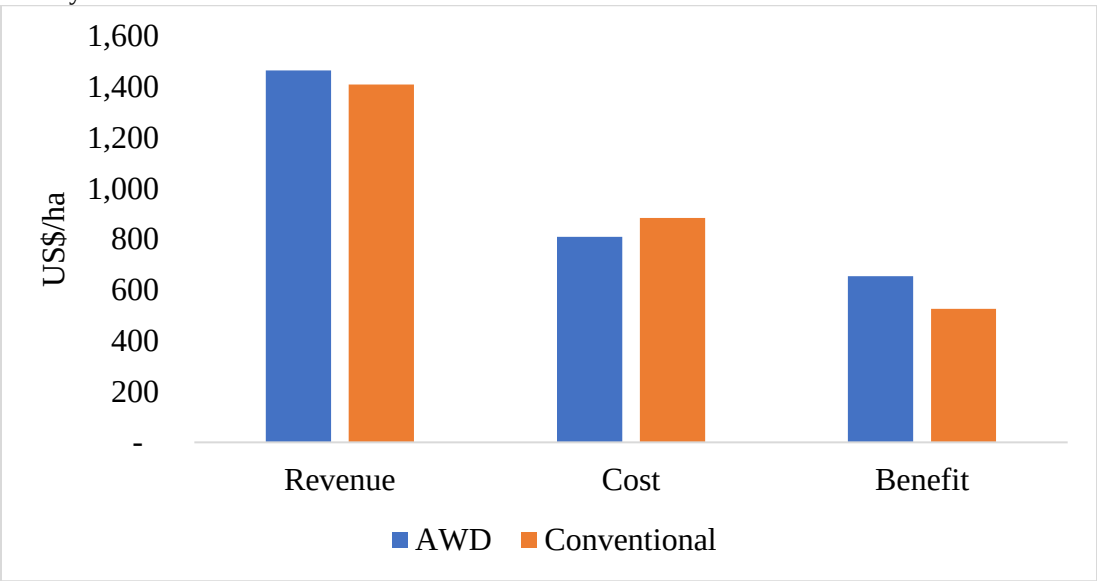

Figure 4. Revenue, cost and benefit of AWD paddy production and conventional paddy production (US$/ha)

TRACEABILITY FROM FARM TO TABLE WITH BLOCKCHAIN TECHNOLOGY

Recently, in order to develop digital technology platforms that are suitable for agriculture, we need the cooperation between the IT industry and agricultural sciences in the form of public-private partnership. The model of cooperation between 100% Vietnamese enterprises - VNCheck, a traceability platform applying IoT and Blockchain technology for traceability of agricultural products and medicinal products with the Vietnam Academy of Agricultural Sciences is a remarkable model of research and development.

Since 2018, VNCheck has officially and successfully tested the technology towards perfecting the B2B business model. VNCheck's customers are agricultural products and foods supply, production and export enterprises directly relating to human life and health. VNCheck applies IoT (Internet of Things) technology to collect data in real time by electronic diaries, process by consensus algorithms on smart contract for encryption data accordingly through a closed, logistical and very tight process. VNCheck's data collection process ensures three factors (security, transparency and objectivity) and is according to the Organics, VietGAP, GMP and GS1 standards which are being managed by the General Department for Standards, Metrology and Quality.

In the process of product traceability to serve the domestic and export demands, in accordance with international rules on data standardization, the system uses QR code (quick response code) in combination with Barcode to manage customers' products according to global GS1 standards. VN Check can be fully integrated into automated processes (manufacturing practices, processing, etc.), semi-automatic or manual but still ensuring the integrity of data in real time, transparency and full security. VN Check's initiative has been supported by technology from large corporations such as Google, FPT, Vietnam Academy of Agricultural Sciences, Univer Farm Organics and SotaNext to complete the test target by May 2021. With a Vietnamese technology platform using leading scientific advances from IBM, Microsoft, Linux and Google, VN Check will become a national brand of Vietnam's digital agricultural platform.

In Vietnam, QR code is being used widely as traceability for food safety control by farmers and their organizations because of low cost and easy management. The farmers can buy QR code system and manage it themselves. The traceability method using QR code sometime cannot convince the consumer trust. So the blockchain traceability using QR code can bring the solution.

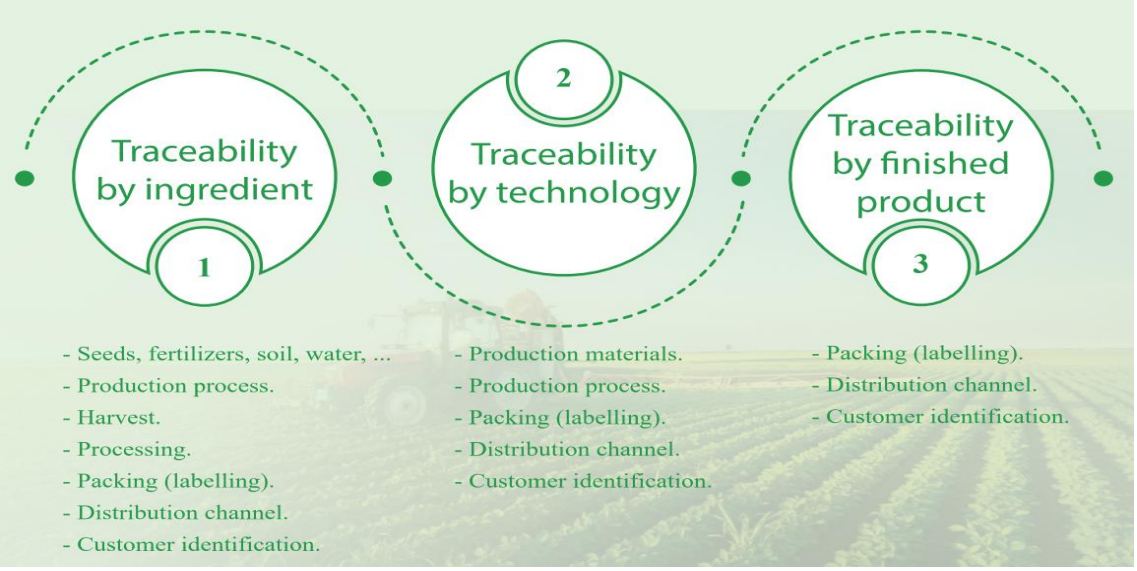

Figure 5. Blockchain technology traceability from farm to table

Benefits of traceability in food value chain with Blockchain technology

- Building a competitive advantage by creating trust with consumers: By providing complete information about the production process, the manufacturer can give consumers a comprehensive view of the origin of the product, helping to ensure product safety. Blockchain can track and trace the origin of the input process, which helps to eliminate almost the possibility of counterfeit products, better control product quality and contributes to improving the overall value of the whole supply chain.
- Reduce the pressure of proving food safety: Blockchain also saves costs and reduces pressure on manufacturers to prove product's origin.
- Real-time better management of production processes: For manufacturers, blockchain helps to manage the entire process from farm to shelf in real time. All information from farmers, the care process, transportation, storage, processing are recorded and closely monitored by the system. This helps manufacturers have better control over activities in the chain, reducing the risk of unsafe food.

CHALLENGES IN APPLYING SMART AGRICULTURE FOR SMALLHOLDER FARMERS IN VIETNAM

The first challenge is the large number of farming households with a small-scale, low investment capital, old and outdated equipment, while the role of cooperatives is not yet strong. Due to the complex terrains, fragmented production land, many areas do not have water sources for production and therefore, it is so difficult to invest and develop high-tech agricultural production and smart agriculture.

The common weakness is the lack of cooperation and association among farmers, who are fragmented and operate on a small-scale production, and are dependent on middlemen. Therefore, to successfully apply smart agriculture, first farmers must change their production and business thought and participate in cooperation and association with cooperatives along the value chain.

Besides, the challenge of information technology infrastructure in the rural areas is still poor compared to the requirements. The next challenge is the lack of research on digital governance models in order to design suitable software platforms which are in accordance with the needs of value chains, and diverse agricultural products of different ecological regions across the country.

The digital database serving agriculture is still scattered. It hasn't been designed and digitized synchronously.

The ability to supply technology for smart agriculture is still limited. Currently, Vietnam has about 15 companies providing smart agricultural solutions to farmers and small farms. Small and medium-sized companies often use individual solutions that don't connect to each other. Meanwhile, the market for agricultural machineries and equipment is still underdeveloped, the automation rate in agriculture is not high. Products for smart agriculture on the market are not synchronized or can't communicate with each other because each enterprise supplies products from a different supplier.

The investment cost for high technology agriculture, smart agriculture is much higher than traditional agriculture, so most farmers are not eligible for such investments. On the other hand, the planning and implementation are slow and this has affected the organization of production development.

Although the research, application and transfer of science and technology have been intensively invested, it still hasn't kept up with the actual production requirements. Criteria on high technology agriculture, smart agriculture along with regulations, standards and production processes for each animal and plant creature have not been promulgated by the State.

Budget from the State and credit capital in investment and development of high technology agriculture and smart agriculture are still limited.

The progress of implementing a number of high technology agriculture and smart agriculture projects is still slow; Supporting mechanisms and policies haven't been timely built and promulgated and there isn't preferential mechanism about credit and land for smart agriculture development.

RECOMMEND NECESSARY SOLUTIONS TO PROMOTE SMART AGRICULTURE IN VIETNAM

In order to overcome significant challenges to achieve great benefits brought by digital transformation and smart agriculture, we propose a number of specific policy solutions as follows:

First, the Government needs to continue to issue policies that are suitable to production practices and are highly feasible in order to mobilize resources to implement the smart agricultural revolution, thereby actively investing in technologies that are suitable for each ecological region and production scale to create a new vitality with large-scale smart agricultural models and unique, safe and highly competitive agricultural products.

Second, the Ministry of Agriculture and Rural Development in collaboration with the Ministry of Information and Communications should focus on building the overall architecture of the digital Government and the digital economy of the agricultural sector. There is a need to clearly research on and identify functional service needs of small farmers, farms, cooperatives, agricultural enterprises to design a centralized digital platform and digital database framework for agriculture, synchronize occupation groups according to organizational structure from central to local. It is necessary to have a focal point at the ministerial level to design the structure of the information technology system, to avoid spontaneous phenomena when there aren't common connection standards, which later becomes difficult to integrate into a common system and cause wastes.

Third, strengthen the training of human resources, especially high-quality human resources to take the initiative in the process of the approaching smart agriculture. Agricultural extension work focuses on training skills to change digital business models for cooperatives and enterprises, build experimental digital transformation models at grassroots level based on a common foundation.

Fourth, public-private partnerships (PPPs) should universalize rural digital infrastructure to the commune, cooperative and farmer household levels.

Fifth, build and collect agricultural online database that is integrated and synchronous.

Sixth, encourage and attract digital technology enterprises to invest in agriculture and rural areas to accompany farmers because this has a very huge potential for customers. The automation technologies in agricultural production that are suitable for small-scale farmers, associated with the traceability platform are the prioritized areas for research so that they can be applied in a short time.

Seventh, promote research and innovation in the field of smart agriculture and simultaneously expand international cooperation to acquire smart agricultural technologies, the world's appropriate digital governance method, and in order to save time, increase labor productivity, and bring high efficiency.

Eighth, encourage small farmers to join cooperatives and link along the value chain to be able to apply smart agricultural technology. The cost for the application of smart agricultural technology is high and small farmers need have knowledge and skills to use technology meanwhile the farmer's cooperatives will be a solution to share the cost, knowledge and skills between farmers.

Ninth, smart agriculture should be encouraged in urban farming development because people in the urban have knowledge and finance to apply smart agricultural technology and the production area there is small.

CONCLUSIONS

The current situation shows that in Vietnam small agricultural farms, cooperatives and enterprises have initially approached technological solutions and smart agricultural administration, but it is still at the beginning stage. Although there are many opportunities but the application of smart agriculture in Vietnam still has some basic limitations such as small household size, high cost in technology investments, and difficulties in accessing capital, land and suitable technologies. To develop smart agriculture in Vietnam, the State needs to innovate policies on digital transformation in line with smart agricultural technology so that small households and cooperatives can have convenient access. This is an important basis for Vietnam to become one of the successful countries to develop smart agriculture in the coming years.

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ACKNOWLEDGMENT

The authors would like to express their thanks to VNCheck for sharing information and data relating to this article.

AUTHORS' CONTRIBUTIONS

Dr. Dao The Anh and Dr. Pham Cong Nghiep jointly took part in writing the article and besides, the first manuscript was written by Dr. Dao The Anh.

COMPETING INTEREST

It is declared that both of us have no competing interest in developing smart agriculture in Vietnam. We are working as research officers at VAAS and CASRAD.