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Application of Artificial Intelligence in Vietnam's Agriculture Supply Chain

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Abstract

Agriculture has always been the foundation of Vietnam's economy, accounting for a significant portion of GDP. However, like many traditional industries, Vietnamese agriculture faces many challenges, from inefficient supply chains to unpredictable weather developments. In recent years, Vietnam's agricultural sector has been looking for ways to improve productivity and efficiency by applying modern technology. Among these technologies, artificial intelligence (AI) has emerged as a potential solution to address the challenges farmers and other stakeholders face in the agricultural supply chain. AI can analyze large amounts of data, optimize resource allocation, and predict market trends, which can significantly improve decision-making in agriculture. However, despite the promising prospects of AI in agriculture, there are still challenges to the widespread application of AI in Vietnam. These include the need for more awareness, technical expertise, and Infrastructure to support AI implementation. In this study, we analyze the current state of AI applications in Vietnam's agricultural supply chain, identify key challenges, and propose strategies to facilitate the integration of AI technology in agriculture supply chains in Vietnam in the digital age.

Keywords: *AI, Agriculture, Roadmap, Ecosystem, Supply chain*

1. Introduction

In recent years, with the advantage of being an agricultural country, Vietnam's agricultural sector has increasingly promoted its role in fostering innovation in the economy, contributing to national Gross domestic product (GDP) growth and ensuring food safety and affirm its position in the global supply chain. Supply chain management in agriculture is essential to ensure the efficiency and sustainability of food production and distribution. Recently, the Vietnamese Government has had many policies to promote and improve the safe agricultural supply chain. For example, Decree No. 98/2018/ND-CP [1] dated July 05 2018 of the Government on policies to encourage the development of collaboration and linkage in the production and consumption of

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agricultural goods, linking along the price chain. The supply chain needs to be more cohesive, leading to significant post-harvest losses, inconsistent product quality, and inefficient markets. Smallholder farmers often need more access to market information, credit facilities and modern resources, hindering their ability to compete in domestic and international markets. One of the primary challenges facing Vietnam's agriculture supply chain is the need for efficient logistics and transportation infrastructure. This hinders the timely and cost-effective distribution of agricultural products from farms to markets, leading to significant post-harvest losses. Additionally, the fragmentation of the supply chain, with several intermediaries between producers and consumers, results in increased complexity and reduced transparency. This limits farmers' ability to negotiate fair prices for their products and makes traceability and quality control more difficult. Farmers often lack timely information about market prices, leading to suboptimal decision making about what and when to grow, harvest or sell.

Artificial Intelligence (AI) has many applications in today's society. It is becoming essential today because it can solve many problems efficiently in various industries, such as entertainment, finance, healthcare, and education [2, 3]. The advent of AI has the potential to revolutionize traditional supply chain processes by increasing transparency, optimizing resource usage, and enhancing decision-making capabilities. By leveraging AI technologies such as machine learning and data analytics, stakeholders in the agricultural supply chain can gain valuable insights into production, storage, and transportation operations and distribution. In Vietnam, AI application in agriculture is still relatively new but is attracting the attention of the Government, the Ministry of Agriculture and Rural Development, and businesses and farmers because of the advantages and benefits it brings compared to traditional agriculture. The government has established policies to enhance the development of AI adoptions, including a national strategy for researching, and applying AI by 2030, with Decision No. 127/QD-TTg dated January 26, approving the National Strategy for research, development and application of AI until 2030 [4]. Under the strategy, the country will enhance AI R&D and transform the sector into a key technology field in Vietnam's Industry 4.0 revolution [5]. Report on the current status and prospects of Agriculture 4.0 in developing countries, especially in Vietnam, was presented by [6]. The impact of smart technologies and digital supply chains on the operational performance in the manufacturing industry was investigated by [7]. The level of readiness for digital transformation in agriculture of economic entities in agricultural production and limitations on the level of readiness for digital transformation in agriculture are presented by [8]. However, the application of AI in agricultural supply chain management still has many difficulties and shortcomings, such as management, administration, and digital application issues of the industry are not comprehensive. The agricultural industry data architecture, large database on traceability, planting area codes, farming area codes, and commodity chain data have not yet been built. At the same time, the equipment infrastructure is old, lacking synchronization, scattered and not centralized. The software serving management and direction does not have data sharing links. In addition, investment resources are fragmented and not focused on the right focus of the industry, leading to low efficiency. This research aims to explore the current state of AI adoption in Vietnam's agriculture sector and identify solutions for improving supply chain management practices to achieve greater efficiency and sustainability.

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2. Research Methods

2.1 Theoretical Background

2.1.1 Artificial Intelligence

Artificial intelligence (AI) refers to technology that enables computers and machines to simulate human intelligence and problem-solving capabilities. It permits them to execute tasks that would otherwise require

human intervention. AI can be combined with other technologies, such as sensors, geolocation, and robotics, to achieve various functions [9]. Machine learning (ML) is a subset of AI that focuses on the development of algorithms and statistical models that permit computers to perform tasks without explicit instructions. Instead, machines learn from and make predictions or decisions based on data [10]. On the other hand, Deep learning (DL) is a specialized subfield of ML that focuses on neural networks with many layers, which are often referred to as deep neural networks. These networks are designed to automatically learn hierarchical representations of data, allowing them to handle complex tasks and large datasets effectively [11]. A neural network (NN) is a computational model that mimics the way the human brain makes decisions. It consists of interconnected units called neurons, which send signals to one another. These neurons can be either biological cells or mathematical models. And individual neurons are simple, when many of them work together in a network, they can perform complex tasks [12]. The relationship between AI, ML, DL and NN is shown in Fig. 1.

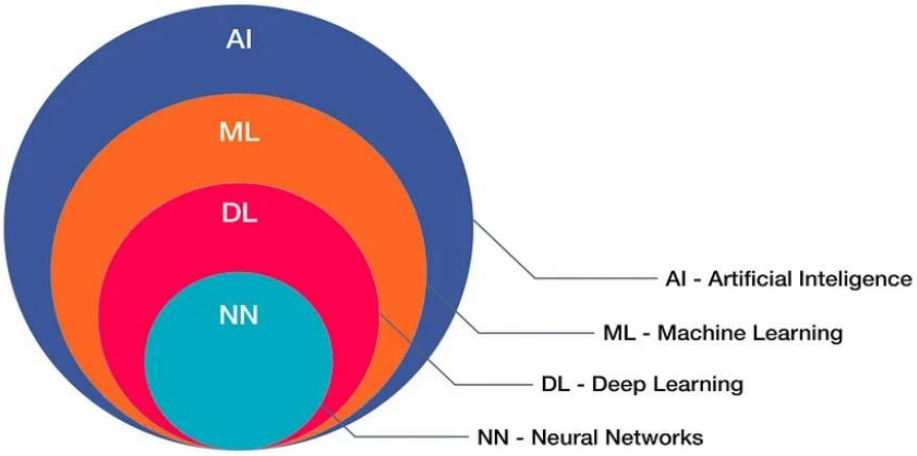

Figure. 1. Relationship between AI, ML, DL and NN

2.1.2 Agricultural Supply Chain (ASC)

The agricultural supply chain includes the entire process of production, processing, and distribution agricultural products from farm to consumer. It involves a chain of activities of stakeholders, including farmers, processors, distributors, logistics providers, retailers, consumer and customer, as shown in Fig. 2 [13].

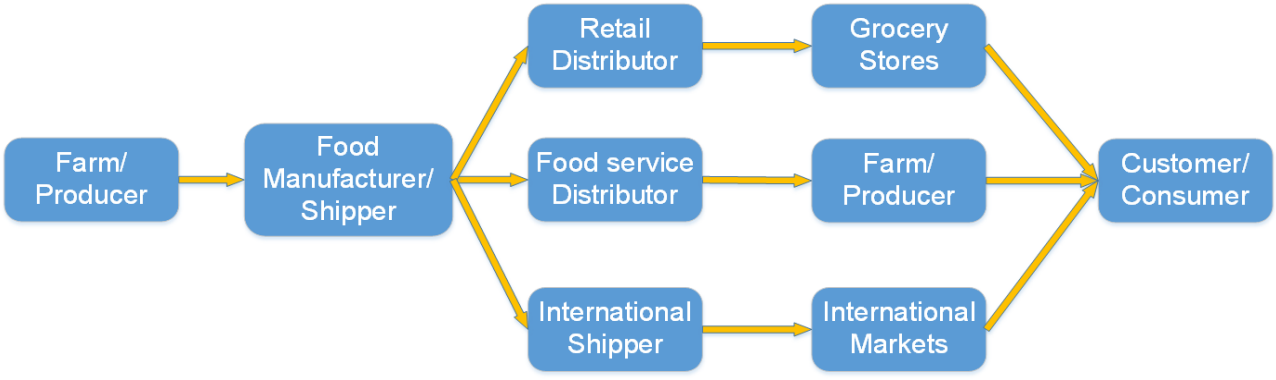

Figure 2. A typical model of the agricultural supply chain begins from the farmer to the customer or the consumer.

This chain starts from the production stage (including: growing and harvesting crops or livestock) followed by various stages such as processing, packaging and quality control. Many farmers do not have good knowledge about the chain of agricultural product supply. They manufacture products, own agriculture, and sell to people intermediaries, where they can only earn profits very small. Today, farmers can learn basic supply chain knowledge to improve their finances by offering competitive advantage and serviceability to reach consumers and keep customers loyal to their brand.

2.2. Research Methods

The study uses qualitative methods to collect data from foreign and domestic papers, magazines, and reports. Besides, in the study, the author used keywords to find domestic and foreign documents such as "Application of AI in agricultural supply chains"; "Roadmap for implementing agricultural supply chains". The method is based on standard systematic review procedures that combine search strategies, record extraction, and results reporting [14]. On the other hand, previous research review is also a method of implementing research and giving an overview of different kinds of reviews as some guidelines on how to implement and review the literature [15].

3. Results and discussion

3.1 Role of AI for agriculture supply chains in Vietnam

+Precision Agriculture

AI-driven precision agriculture can revolutionize how Vietnamese farmers manage their operations. Utilizing AI algorithms, farmers can benefit from predictive analytics to optimize crop selection, planting schedules, and irrigation needs. Drones and satellite imagery powered by AI can monitor crop health and identify problems such as pests or nutrient deficiencies early, allowing for timely intervention. This precision approach not only enhances yield but also minimizes resource wastage, fostering sustainability. For instance, the Nextfarm Data Platform provides consultation for farmers on how they can control the nutritional dosage at the optimal level that considers the external environment (light intensity, temperature), type of crops, and soil quality [16].

+ Enhanced Supply Chain Visibility

AI can provide real-time visibility across the entire supply chain, from farm to fork. Predictive analytics can forecast demand, helping farmers plan production to match market needs accurately. Blockchain technology, augmented by AI, can ensure traceability, enhancing food safety and authenticity. This transparency can build greater trust among consumers and reduce intermediaries, ensuring fairer prices for farmers. For instance, ONE Farm is the smart agriculture solution developed on VNPT Technology that brings to customers a smart agricultural chain management system that includes supply chain management, planting, inventory management, and logistics. By offering real-time insights and facilitating direct transactions, these platforms help farmers secure better prices and reduce dependency on intermediaries, as shown in Fig.3 [17].

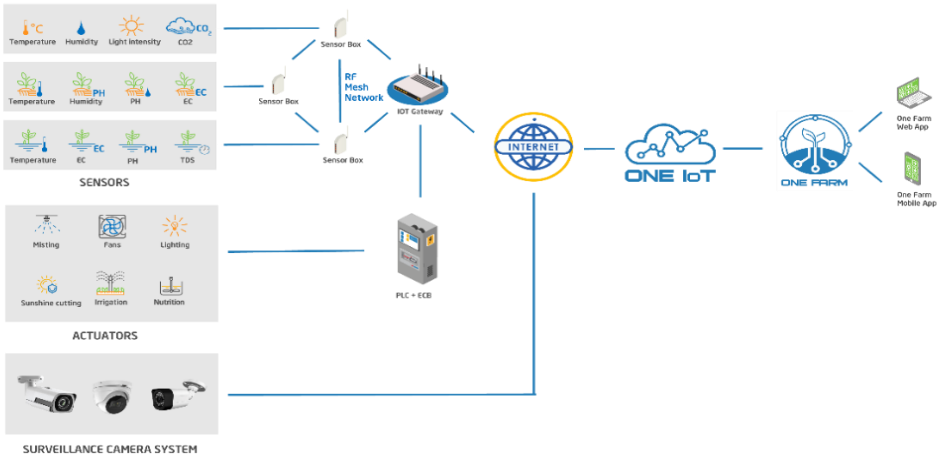

Figure 3. A Diagram of the ONE Farm platform of VNPT Technology, used in ASC

+ Inventory and Warehouse Management

AI-driven inventory management systems can forecast demand patterns and optimize stock levels, reducing surplus and shortages. Automated warehousing solutions can ensure optimal storage conditions, especially critical for perishables. Machine learning algorithms can enhance these systems by continuously learning from data to improve accuracy over time.

+ Logistics Optimization

AI can streamline logistics, reducing transportation costs and delivery times. Vehicle routing algorithms can determine the most efficient paths for distribution, considering real-time traffic and weather conditions. AI can also predict potential disruptions in the supply chain, such as delays or demand spikes, allowing preemptive actions to mitigate their impact.

3.2 Challenges to AI Adoption

While the potential of AI in agricultural supply chain management is immense, several challenges must be addressed to ensure successful implementation:

+ Technological Infrastructure

Adopting AI requires strong technological infrastructure, including reliable power supply, high-speed internet and advanced farming equipment, which are not uniformly available across Vietnam's rural areas. Investments in this Infrastructure are crucial for widespread AI adoption.

+ Skill Development and Education

The use of AI in agriculture necessitates a workforce skilled in both farming and technology. Training programs and educational initiatives are essential to equip farmers and agribusiness professionals with the knowledge and skills to leverage AI tools effectively.

+ Data Availability and Quality

AI thrives on high-quality data. However, data collection in agriculture can be challenging. Ensuring accurate and comprehensive data collection and addressing issues related to data privacy and security is vital

for AI applications to deliver their full potential.

+ Cost Considerations

The initial investment in AI technologies can be a barrier for smallholder farmers. Government policies, subsidies, and financial models that mitigate these costs and make AI accessible to all levels of farmers are necessary to ensure equitable adoption.

3.3 Proposal of the Roadmap for applying AI in ASC

The roadmap for applying AI in ASC in Vietnam is shown in Fig.4.

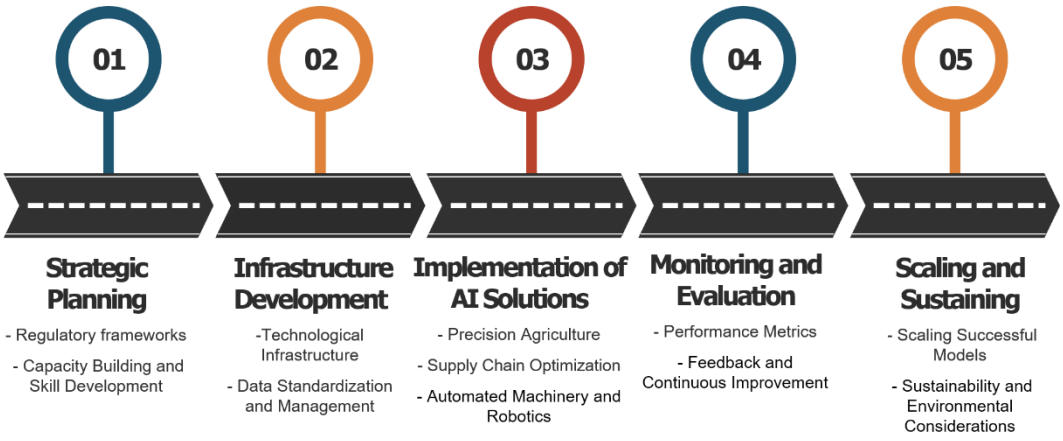

Figure 4. Proposing the roadmap for the development AI adoption in ASC with the following steps

Stage 1: Strategic Planning and Policy Building

Government Policies and Regulations Supportive government policies are critical for fostering AI application in agriculture. This includes regulatory frameworks that encourage innovation while safeguarding stakeholder interests. Policies that facilitate access to technology, financial subsidies, and grants for AI projects can significantly accelerate adoption. Understanding Needs and Opportunities The inception stage requires a meticulous assessment of Vietnam's current agricultural landscape, including identifying challenges, opportunities, and needs. This assessment can be guided by extensive data collection and stakeholder engagement, including farmers, agronomists, supply chain experts, and policy makers. Capacity Building and Skill Development For effective AI integration, there is a need to develop a robust skillset in AI and data science among stakeholders. Governmental and educational institutions should collaborate to design training programs and workshops for farmers, technicians, and agribusiness professionals. International partnerships can be leveraged to bring in expertise and best practices.

Stage 2: Infrastructure Development

Technological Infrastructure Building the technological Infrastructure is crucial for AI adoption. This includes enhanced internet connectivity in rural areas, installing sensors and IoT devices for data collection, and establishing data centers for storage and processing. Advances in 5G technology can significantly contribute to seamless data transmission and real-time analytics. Data Standardization and Management A robust data management system is essential for AI function. This involves creating standardized protocols for data collection, ensuring data quality, and integrating disparate data sources. The development of national

agriculture databases can facilitate the accumulation and utilization of large datasets needed for training AI models. Data privacy and security measures must also be considered to protect sensitive information.

Stage 3: Implementation of AI Solutions

Precision Agriculture Precision agriculture utilizes AI algorithms to a variety of sources, such as satellite images, weather forecasts, and soil sensors. These insights enable farmers to make informed decisions regarding crop selection, planting schedules, and resource management. Examples include machine learning models that predict crop diseases, guide irrigation practices, and advise on optimal harvesting times.

Supply Chain Optimization AI can streamline the agriculture supply chain from farm to market. Predictive analytics can forecast market demand, helping farmers avoid overproduction or shortages, thus stabilizing prices. AI can also optimize logistics and transportation, reduce post-harvest losses and ensure timely delivery of goods. Blockchain technology, combined with AI, can enhance transparency and traceability, thereby boosting consumer trust. Automated Machinery and Robotics The introduction of AI-powered machinery, such as autonomous tractors, drones, and robotic harvesters, can reduce labor dependency and increase efficiency. These technologies can perform tasks ranging from planting and spraying to harvesting and sorting with greater precision, reducing human error and physical strain on workers.

Stage 4: Monitoring and Evaluation

Performance Metrics Establishing key performance indicators (KPIs) is crucial to measure the effectiveness of AI implementations. Metrics such as yield improvement, cost savings, resource efficiency, and market resilience should be regularly monitored. Data analytics platforms can be used to generate reports and supply actionable insights for continuous improvement. Feedback and Continuous Improvement Continuous monitoring and feedback mechanisms ensure that AI solutions remain relevant and effective. Engaging with end-users, particularly farmers, to gather feedback can help in refining AI models and technologies. This iterative process of monitoring, evaluation, and adjustment is vital for long-term success.

Stage 5: Scaling and Sustaining

Scaling Successful Models Once pilot projects demonstrate success, scaling these models across wider geographical areas is necessary. This scaling should be supported by adequate training, infrastructure expansion, and financial investment. The creation of regional AI innovation hubs can facilitate widespread adoption and adaptation to local conditions. Sustainability and Environmental Considerations AI applications in agriculture should prioritize sustainability, minimizing environmental impact while maximizing productivity. The focus should be on practices that conserve water, reduce chemical usage, and enhance soil health. The use of renewable energy in AI solutions should also be explored to further environmental goals.

Furthermore, based on some challenges of applying AI for ASC, some solutions to overcome challenges can include the following:

Establishing an ecosystem for AI integration in ASC

The AI integration ASC ecosystem requires interaction and collaboration between different components, as shown in Fig. 5.

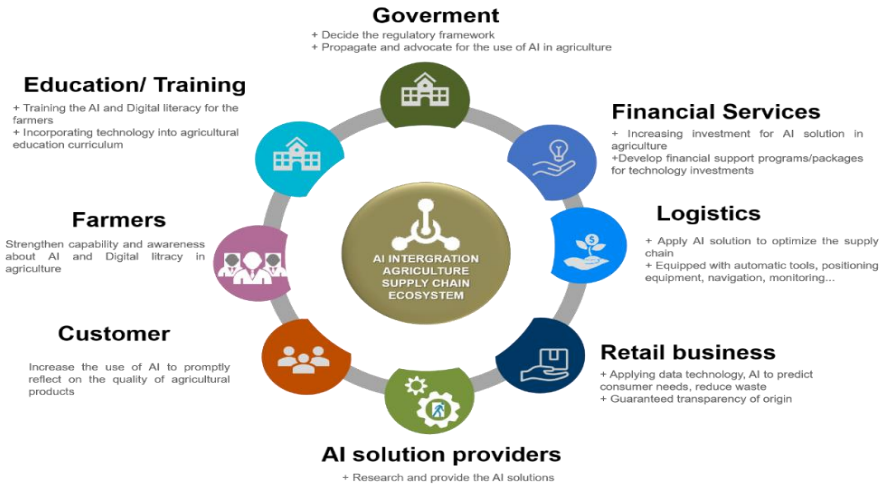

Figure 5. Proposal of an AI integration ASC ecosystem for the agricultural supply chain ecosystem in Vietnam

The main factors in the ecosystem include the Government, AI solution providers, financial organizations, consumers, retail businesses and logistics enterprises, The government develops a clear regulatory framework for AI in agriculture, addressing issues of data privacy, security, and ethical considerations. In addition, the government also invests in digital infrastructure in rural areas to support AI implementation. Farmers are provided with the AI and digital literacy training programs to enhance their knowledge of AI. AI solution providers develop practical applications of AI in the agricultural industry. Financial organizations support and invest funds for agricultural technology suppliers and retail businesses to forecast consumer food demand and enhance safe food consumption habits. Logistics businesses need to improve technology to improve the efficiency of warehouse and distribution management. Educational and training organizations supplement research and education programs that drive AI knowledge in the agricultural sector. Finally, the customer is necessary for the habit of consuming clean, safe and quality food from agricultural farms that apply high technology.

4. Conclusions

Integrating AI into agricultural supply chain management brings great potential for change in Vietnam. With the increasing application of AI technology in various aspects of the agricultural sector, from smart farming techniques to data analytics and predictive modeling, Vietnam will benefit greatly from the efficiency, productivity and sustainability that these innovations bring. By integrating AI into the supply chain, farmers can make more informed decisions, optimize resources and minimize risk. Furthermore, AI can help bridge the gap between smallholder farmers and the market, facilitating better access to information, finance and markets. In this study, we have analyzed the advantages and disadvantages of applying AI, thereby proposing solutions and a roadmap to apply AI to the agricultural supply chain. By following this roadmap, Vietnam can lead a new era of agricultural efficiency and sustainability, improving the livelihoods of farmers and fortifying the nation’s food security and global competitiveness in the digital age.

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