ARTIFICIAL INTELLIGENCE IN SUSTAINABLE AGRO-PROCESSING IN VIETNAM: CHALLENGES AND PROSPECTS

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ABSTRACT

Artificial Intelligence (AI) is gradually reshaping Vietnam's agricultural and food processing sectors by improving productivity, product consistency, and overall sustainability. Although Vietnam is a major agricultural exporter, the country continues to face persistent challenges, including high postharvest losses, inconsistent product quality, and limited value-added processing capacity. This paper reviews the application of AI in areas such as sorting, quality inspection, preservation, food safety monitoring, and traceability. When integrated with technologies such as IoT, smart sensors, and blockchain, AI has the potential to reduce energy consumption, extend shelf life, and help producers comply with international standards. However, several constraints remain, notably the absence of standardized datasets, substantial investment requirements, a shortage of trained personnel, and limited regulatory guidance. The article closes with a set of recommendations designed to encourage AI adoption and strengthen the long-term sustainability of Vietnam's agro-processing sector.

1. INTRODUCTION

Agriculture remains a central pillar in Vietnam's economy, with rural regions accounting for 63% of the population and more than 60% of the national workforce, contributing approximately 17% to GDP (Nguyen, 2022). Despite its importance, the sector is constrained by fragmented small-scale production, weak value chain linkages, and increasing pressure on freshwater and arable land resources (Nguyen, 2022). The export value of agricultural goods also remains modest, largely because many products are still processed using outdated technologies and exported in raw form, leaving higher-value processing to foreign enterprises (Ha, 2025).

Artificial Intelligence (AI), a core component of the Fourth Industrial Revolution, offers promising opportunities to help overcome limitations in infrastructure, capital, and skilled labor while supporting the shift toward more sustainable agricultural practices (Adão et al., 2025; Pham et al., 2024). Vietnam's National AI Strategy to 2030 identifies agriculture and food

supply chains as priority areas for development (Pham et al., 2024). Internationally, AI has already shown significant impact in areas such as precision agriculture, weather prediction, pest and disease management, and value-chain optimization, helping reduce production costs, conserve resources, and enhance product quality.

However, Vietnam's AI ecosystem is still in an early stage, with limited investment, a developing regulatory environment, and relatively modest research capacity. This paper examines the role of AI in transforming agricultural processing and promoting sustainable supply chains, outlines the key obstacles to adoption, and proposes strategic directions to enable Vietnam to better harness the potential of AI in the coming years.

2. APPLICATION OF AI IN SUSTAINABLE AGRICULTURAL PROCESSING

The use of Artificial Intelligence (AI) in Vietnam's agricultural processing sector is emerging as a strategic approach to increase product value and strengthen the country's position in global markets. In practice, AI-based solutions are being explored to improve operational efficiency, reduce postharvest losses, and support more sustainable and resilient supply chains (Adão et al., 2025; Nguyen, 2022).

Figure 1. Application of artificial intelligence in agriculture

2.1. Improving Quality and Reducing Postharvest Losses

AI is increasingly transforming quality control and processing activities in agriculture, offering practical solutions to the long-standing issue whereby many Vietnamese agricultural exports remain minimally processed and low in value (Ha, 2025). Computer vision and deep learning (DL) technologies enable automated grading and defect detection across a wide range of agricultural products (Lu et al., 2021). In Vietnam, several studies have explored these applications, such as AI-assisted mango grading systems using image processing techniques

(Pham et al., 2024; Thong et al., 2019). In seed inspection, a MobileNetV2-based Convolutional Neural Network (CNN) achieved 98% accuracy in identifying defects in soybean seeds and processed up to 222 seeds per minute, demonstrating the strong potential of lightweight AI models in practical settings (Castillo-Girones et al., 2025).

When integrated with hyperspectral imaging (HSI), AI enables more comprehensive assessments of product attributes. Recent work has shown that machine learning models can accurately predict crude protein levels in maize-based animal feed, achieving a coefficient of determination of $R^2 = 0.89$ (Liang et al., 2024). AI has also been shown to be effective in early disease detection: a Multilayer Perceptron (MLP) model reached an overall accuracy of 95.9% ± 0.26% in diagnosing early-stage fungal infections in Chinese cabbage, with 99% accuracy in distinguishing healthy from infected plants just one day after infection (Pham et al., 2024).

AI contributes further to process optimization. Modeling the drying behavior of quince slices using an MLP-ANN produced highly accurate predictions of moisture content ($R^2 > 0.99$) (Chasiotis et al., 2020). Similarly, essential oil yield from orange peels was predicted with strong precision using an MLP-ANN model, achieving $R^2 = 97.6\%$ (Fajardo Muñoz et al., 2023).

AI applications in Vietnam include fruit sorting systems using image processing. The article also highlights the use of YOLOv3 combined with image processing to identify tomatoes based on color, size, shape, and surface condition (ripe, green, rotten, moldy, scratched). AI helps eliminate reliance on the naked eye of workers, who are prone to errors due to fatigue or subjective judgment. Experimental results showed an accuracy rate of 94%, demonstrating that AI can replace or strongly support the process of inspecting agricultural product quality (Thien et al., 2022).

2.2. Smart Supply Chain and Traceability

Beyond advancements in processing and quality control, AI also plays a significant role in optimizing agricultural supply chains and improving system transparency. Incorporating AI into logistics and supply chain management helps address longstanding challenges related to coordination and traceability, both of which are essential for ensuring sustainability and food safety. Machine learning models, for instance, have been used to support the design of cross-border logistics networks for agricultural commodities (Pitakaso et al., 2022). In cold-chain operations, AI assists in monitoring and managing energy consumption, helping firms operate more efficiently (Wang & Du, 2025).

Blockchain technology is also gaining traction in Vietnam as a tool for enhancing traceability in agricultural production (Ha, 2025). Several clean-vegetable cooperatives in Hanoi have been successfully piloted blockchain-based traceability systems, which have been recognized by Japanese importers and contributed to strengthening consumer confidence (Tran & Dao, 2023).

AI applications also extend to on-farm production. At Can Tho University, a study on dragon fruit farming reported that deploying AI-based disease detection tools reduced pesticide use by 30% and improved crop quality by 10%, demonstrating the practical value of AI for generating high-quality raw materials for downstream processing (Can Tho University, 2024, as cited in Nguyen et al., 2025).

3. CHALLENGES AND LIMITATIONS IN AI APPLICATIONS IN VIETNAM

3.1. Challenges in Investment and Development Strategy

Although Vietnam has issued a National Strategy on Artificial Intelligence, the AI remains underdeveloped and is still in the early stages of development in terms of investment and regulatory frameworks (Pham et al., 2024). Investment in AI remains modest, reaching approximately USD 31 million in 2021, which is significantly lower than neighboring countries in Southeast Asia, where investment levels can be 10 to 100 times higher (Figure 2; Pham et al., 2024)

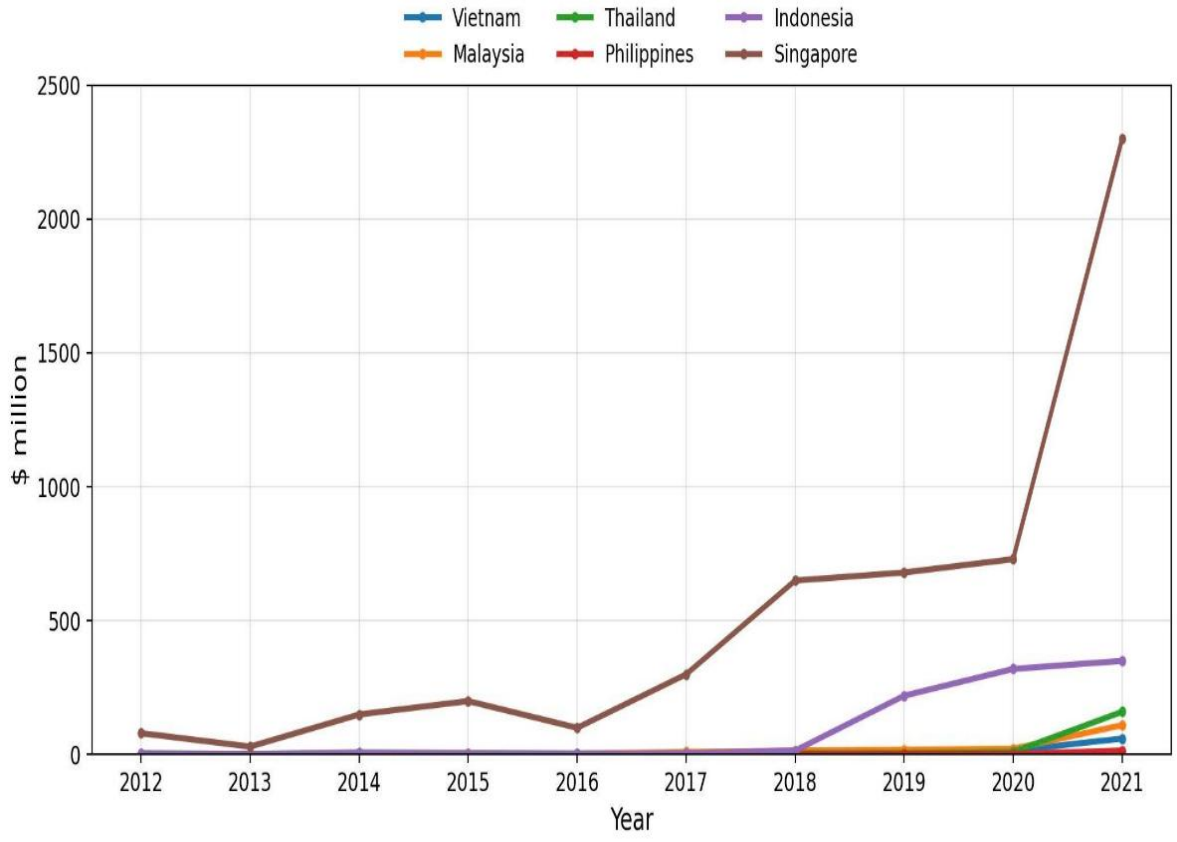

Figure 2. Value of AI Investment in Southeast Asia during the period 2012–2021. Source: OECD.AI.

This low level of investment hinders Vietnam's strategic goal of becoming one of the top five ASEAN countries in AI development by 2025 (Pham et al., 2024). In addition, the limited AI investment that does exist is dispersed across multiple sectors, leaving agriculture with only a very small portion—USD 0.1 million in 2020, USD 0.3 million in 2021, and a slight decrease to USD 0.2 million in 2022, equivalent to less than 1% of total national AI funding (Table 1; Pham et al., 2024). This pattern suggests that government priorities remain diffuse and that resources have not been strategically directed toward core industries where AI could create meaningful competitive advantages (Pham et al., 2024).

Table 1. Value of AI Investment in Vietnam by Sector (2012-2022) (million USD). Source: OECD.AI.

Year	Media, social platforms & marketing	Consumer services	Education & Training	Business processes & support services	Agriculture	Total investment value (Million USD)
2012	0.5	–	–	0.3	–	0.8
2013	1.6	0.8	–	0.7	–	3.1
2014	2.5	1.2	0.7	2.3	–	6.7
2015	0.4	0.3	–	0.3	–	1
2016	–	–	–	–	–	0
2017	0.2	0.1	–	0.2	–	0.5
2018	0.4	0.3	0.2	0.4	–	1.3
2019	1.2	0.5	0.6	0.9	–	3.2
2020	4	2	2.5	2.5	0.1	11.1
2021	9.5	6	7	6.5	0.3	29.3
2022	8.2	5.1	6.3	5.8	0.2	25.6

3.2. Limitations in Infrastructure and Technology

A major obstacle to AI adoption in agriculture is the lack of reliable digital infrastructure, especially in rural and mountainous regions where most agricultural production occurs (Ha, 2025; Loi, 2022). Research shows that approximately 40% of farms in the Northern mountainous areas still lack stable internet access (Ha, 2025; Tran & Nguyen, 2021), creating significant challenges for implementing Internet of Things (IoT) systems and real-time data analytics (Ha, 2025).

Another challenge lies in the limited scalability of existing AI and information technology (IT) initiatives. Many solutions remain at the pilot stage and are mainly deployed by large enterprises, while adoption among small and medium farms is still very modest (Ha, 2025; Loi, 2022; Ngoc et al., 2021). High upfront costs for sensors and imported technologies, along with compatibility issues and the need for specialized maintenance, pose significant financial barriers for most smallholder farmers (Ha, 2025). As shown in Table 1, overall investment in AI for agriculture in Vietnam remains extremely low.

3.3. Challenges in Human Resources and Research

Vietnam also faces a significant shortage of digital skills within the agricultural workforce (Loi, 2022). Approximately 15% of agricultural cooperatives and enterprises have technical teams capable of independently deploying

Information Technology (IT) solutions (Ha, 2025). Over 70% of workers in the sector have not received formal training in digital technologies, which limits the effective use of advanced AI tools in day-to-day operations (Le & Nguyen, 2022; Ha, 2025).

The country's research capacity in AI remains relatively limited as well. Vietnam produces far fewer AI-related publications in top-tier journals (top 5%) than regional peers such as Indonesia, Malaysia, and Singapore (Pham et al., 2024). OECD.AI data show that Vietnam generated roughly 2,000 AI publications in 2021, but fewer than 50 of these were classified as high-quality each year. In contrast, Singapore produced about 4,800 publications and achieved a research productivity index of 800. This disparity highlights significant gaps in expertise, investment levels, and research infrastructure, and suggests that much of Vietnam's AI research remains limited in scope, with insufficient attention to broader economic, social, and environmental dimensions (Pham et al., 2024).

Table 2. AI Publications by Country in Southeast Asia during the period 2014-2021. Source: OECD.AI.

Index	Singapore	Indonesia	Malaysia	Vietnam
Total number of AI publications	~4.800 (2021)	12.200 (2020)	~6.000 (2015)	~2.000 (2021)
High-quality publications	~250 (2021)	Less than 50 (annually)	~50 (2021)	Less than 50 (annually)
Research productivity	800 (2021)	Less than 50 (annually)	~180 (maintained since 2014)	Lowest

4. PROSPECTS AND RECOMMENDATIONS

4.1. Strategic Investment Orientation and Resource Concentration

Vietnam must accelerate its investment in Artificial Intelligence (AI) in the coming years to position itself among the leading AI adopters in Southeast Asia. With resources still limited, a focused approach is essential. Priority should be given to strategic AI technologies that can strengthen national competitiveness, particularly in areas such as decarbonization and applications for agriculture and food systems. These sectors remain especially important, not only for food security but also because agriculture remains one of Vietnam's key comparative advantages, with farmland making up roughly 40% of the national territory. To advance these priorities, the government should develop mechanisms that attract and channel both public and private investment—as well as international assistance—toward industries where AI can create the greatest long-term impact. Prioritize AI investment in agriculture and food systems; establish a National Agricultural Data Center to standardize and share data; and enhance research capacity through international cooperation and ministerial-level coordination mechanisms between universities and research institutes. The role of AI in agriculture and food systems, as well as a proposal to establish a National

Agricultural Data Center under the National AI Strategy to 2030. National AI Investment Incentives: Introduce targeted tax breaks and subsidies for AI adoption in agriculture and food systems. Digital Infrastructure Mandates: Enact regulations requiring minimum internet and data standards in rural farming zones. Data Governance Frameworks: Establish legal protocols for agricultural data collection, sharing, and protection through a centralized National Agricultural Data Center.

4.2. Development of Data Infrastructure and Ecosystem

Strengthening Vietnam's infrastructure for AI research and innovation requires clearer planning, particularly with regard to funding sources, scale, geographic placement, and the types of facilities needed. In line with the National Strategy on Artificial Intelligence to 2030, which calls for the establishment of one national center for big data storage and supercomputing by 2025 and three centers by 2030, greater emphasis should be placed on the agricultural sector. Establishing a National Agricultural Data Center would provide the foundational digital infrastructure needed to collect, standardize, and share agricultural data across the country. Such a facility would not only support AI-driven innovation in agricultural processing and supply-chain management but also help Vietnam progress toward its goal of ranking among the top four ASEAN countries in AI development by 2030. Clear and coordinated infrastructure planning will further allow Vietnam to allocate resources more effectively and determine where international partnerships and technical assistance are most needed to address existing gaps. Another critical aspect of digital transformation in agriculture is the emergence of intelligent problem-solving systems. According to (Nguyen et al., 2020), AI-based tutoring tools and sample-based reasoning can support farmers in making decisions under complex conditions. These systems enable the analysis of multi-source data, providing optimal recommendations for crop and resource management. This strengthens and expands the theoretical foundation of AI applications in sustainable agriculture.

4.3. Enhancing Research Capacity and International Collaboration

To make meaningful progress toward its target of becoming one of the top four AI leaders in ASEAN by 2030, Vietnam must strengthen its human-resource base and expand its national research capacity.

A ministerial-level coordination mechanism would facilitate collaboration among universities and research institutes, not only in engineering and technical fields, but also in economics, social sciences, and environmental studies. Broadening participation in this way would allow AI research to cover a more complete range of economic, social, and ecological issues.

Vietnam should also increase funding for universities conducting AI-related research and promote the exchange of experts with leading international institutions. Building partnerships with countries such as the United States, China, Iran, and Australia can help expand research networks and improve publication quality in top-tier journals.

5. CONCLUSION

Artificial Intelligence (AI) offers significant potential to support the modernization of Vietnam's agricultural sector and support its transition toward a more intelligent and sustainable development model. Current applications already show clear benefits,

particularly in non-destructive quality assessment using HSI-based AI methods and in enhancing traceability through blockchain systems, which have been successfully piloted in clean-vegetable cooperatives in Hanoi.

Despite these advancements, digital transformation in Vietnam's agriculture is still at an early stage. Adoption remains limited, concentrated mainly in pilot initiatives and larger enterprises. Several structural challenges persist, including low national investment in AI (only USD 31 million in 2021), uneven digital infrastructure in rural regions, where nearly 40% of mountainous farms still lack stable internet access, and a significant shortage of digitally trained workers, with more than 70% of the agricultural labor force lacking formal digital skills.

To advance toward its goal of becoming one of the top four AI leaders in ASEAN by 2030, Vietnam requires a more focused and long-term AI development strategy, with priority given to targeted investment across the agri-food system. Equally important is the accelerated establishment of a National Agricultural Data Center and the strengthening of both domestic and international research partnerships. These efforts are essential for fostering innovation, improving data-driven decision-making, and enabling Vietnam to capitalize on emerging opportunities within the global AI value chain.

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TRÍ TUỆ NHÂN TẠO TRONG CHẾ BIẾN NÔNG SẢN BỀN VỮNG TẠI VIỆT NAM: THÁCH THỨC VÀ TRIỂN VỌNG

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TỪ KHOÁ

Trí tuệ nhân tạo;

Nông nghiệp;

Tính bền vững;

Sau thu hoạch;

Cảm biến thông minh.

TÓM TẮT

Trí tuệ nhân tạo (AI) đóng vai trò quan trọng trong việc chuyển đổi ngành nông nghiệp và chế biến thực phẩm của Việt Nam thông qua việc nâng cao năng suất, chất lượng và tính bền vững. Mặc dù là một quốc gia xuất khẩu nông sản lớn, Việt Nam vẫn đối mặt với tình trạng tổn thất sau thu hoạch, chất lượng sản phẩm không đồng đều và hạn chế trong hoạt động chế biến gia tăng giá trị. Bài báo này phân tích tiềm năng ứng dụng AI trong các lĩnh vực như phân loại, giám sát chất lượng, bảo quản, an toàn thực phẩm và truy xuất nguồn gốc. Việc tích hợp AI với các công nghệ như IoT, cảm biến thông minh và blockchain có thể giúp giảm tiêu thụ năng lượng, kéo dài thời gian bảo quản và đáp ứng các tiêu chuẩn quốc tế. Tuy nhiên, nhiều thách thức vẫn tồn tại, bao gồm thiếu dữ liệu chuẩn hóa, chi phí đầu tư cao, sự thiếu hụt nhân lực có trình độ và hệ thống chính sách quản lý chưa hoàn thiện. Bài viết kết luận bằng các khuyến nghị trọng tâm nhằm thúc đẩy việc ứng dụng AI và hỗ trợ phát triển một ngành chế biến nông sản của Việt Nam theo hướng bền vững và nâng cao khả năng thích ứng trước những rủi ro và thách thức trong chuỗi giá trị nông sản.