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ADOPTING TECHNOLOGY IN THE GREEN ECONOMY: PROMOTING SUSTAINABLE AGRICULTURE DEVELOPMENT – BARRIERS & SOLUTIONS

Thi Thuy Hanh Nguyen[1], Tuan Anh Tran[2*]

[1]*University of Economics and Law, Vietnam National University Ho Chi Minh City, Vietnam*

[2]*Ho Chi Minh City University of Industry and Trade, Ho Chi Minh City, Vietnam*

Email: anhtt@huit.edu.vn*

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ABSTRACT

Agriculture is vital in national and global social and economic development because it provides crucial nutrition for people's health and existence. Developing and managing sustainable agricultural supply chains is essential to ensuring alimentary quality and quantity. However, this process has gotten more challenges due to increasing global food demand and climate change. Artificial intelligence (AI) has contributed to revolutionizing agricultural supply chains. Much research has demonstrated the effectiveness of various AI-powered solutions, such as agricultural forecasting, automated irrigation, crop monitoring, and quality control. Besides, numerous developing nations have encountered significant barriers to using such AI technologies. This research explores the main challenges to adopting AI applications in agriculture. This study uses qualitative methodology by conducting in-depth interviews with agricultural businesses. As a result, this study will provide practical recommendations to assist government officials, scientists, and businesses in developing countries in establishing efficient strategies for applying AI-driven solutions, leading to more sustainable agricultural supply chains and fostering a green economy.

Keywords: AI applications, agriculture, green economy, sustainable agricultural supply chains.

1. INTRODUCTION

The remarkable development of today's technologies, such as the Internet of Things (IoT), Big Data and Analytics, Machine Learning (ML), and especially Artificial Intelligence (AI), has increasingly transformed and revolutionized industries, improved efficiency, supported the decision-making process, and promoted continuous improvement [1]. Since AI has been applied in the agricultural sector, its related research, innovation, and development bring outstanding results in enhancing both the quality and yield of crops by making farming management and practices more "connected" and "intelligent" [2], which is often referred to as "smart farming."

The empirical result of Javaid et al. [1] points out that Integrating Artificial Intelligence (AI) technologies presents a valuable opportunity to address existing challenges in agriculture, improve resource allocation, boost productivity, and strengthen the resilience and sustainability of farming systems [3]. According to Javaid et al. [1], AI tools can generate actionable insights that help farmers determine optimal planting times, nutrient application schedules, irrigation planning, and pest or disease control strategies. These data-driven

interventions contribute to maximizing crop yields while minimizing input waste, enhancing both efficiency and environmental sustainability [4].

Although the growing recognition of Artificial Intelligence (AI) as a supportive tool in modern agriculture—offering capabilities in precision farming, crop disease prediction, yield forecasting, and resource optimization—the adoption of AI technologies remains limited and uneven across the sector. The main cause comes from barriers, including restricted access to cost, a lack of quality data, data privacy and security, standardization, and interoperability, or might derive from groups of barriers, such as technological, organizational, and external barriers. As a result, the potential benefits of AI in enhancing productivity, sustainability, and resilience in agriculture are not being fully realized. This research aims to deeply explore and analyze barriers in adopting AI in agricultural sector, suggesting solutions to overcome these key barriers and identifying enabling conditions for more effective AI adoption in the agricultural supply chains to promote sustainability and the green economy.

2. RELATED WORKS

2.1. Introduction of Agricultural supply chain (ASC)

According to [5], they conducted a comprehensive review of Agricultural Supply Chain (ASC) operations and pointed out the critical role of uncertainty in shaping supply chain performance (Figure 1). Their study categorized key sources of uncertainty—including demand fluctuations, supply disruptions, price volatility, and environmental variability—and examined how these factors impact decision-making processes within ASCs. This work provides a vital foundation for advancing resilient and adaptive agricultural supply chain operations in increasingly volatile environments. Based on the ASC operations developed by [5], [6] examined the operational vulnerabilities of ASC during the COVID-19 pandemic, and their empirical results underscore the importance of leveraging digital tools and cooperative mechanisms to strengthen ASC resilience and sustainability in the face of key sources of uncertainty and systemic disruptions.

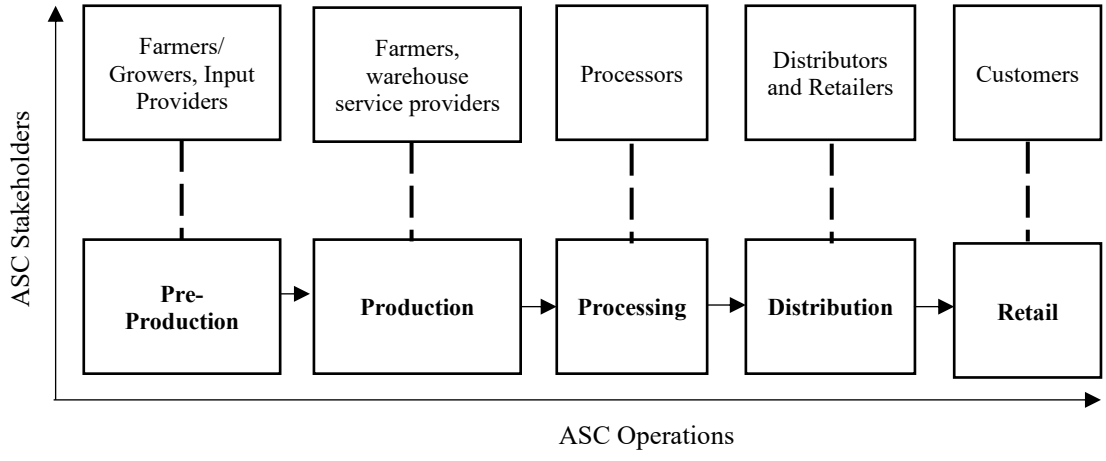

Figure 1. Agriculrual Supply Chain (ASC) operations [5]

2.2. The important role of Agriculture in supporting green economic development

Agriculture significantly contributes to advancing the green economy by promoting sustainable practices that contribute to environmental preservation, resource efficiency, and

carbon footprint reduction [1]. The green economy in agriculture focuses on improving agricultural productivity while ensuring minimal environmental impact, fostering biodiversity, and enhancing the sustainable use of natural resources. Studies have highlighted how sustainable agricultural practices, such as precision farming, organic agriculture, and agroforestry, contribute to the green economy by reducing greenhouse gas emissions, improving soil health, and conserving water resources [1], [7].

Moreover, the integration of technologies like Artificial Intelligence (AI) and Internet of Things (IoT) in agriculture offers the potential to enhance resource management, optimize yields, and mitigate the negative environmental impacts of traditional farming practices [1], [7], [8]. By embracing these innovations, agriculture can significantly achieve green economy goals, ensuring long-term ecological sustainability and economic resilience.

2.3. Role of AI applications in sustainable agricultural supply chains

According to [9], they conducted a study examining the relationship between Artificial Intelligence (AI) and green economic efficiency in China's marine fisheries. Their research, utilizing panel data from 11 coastal provinces from 2009 to 2020, revealed that AI significantly enhances green economic efficiency in this sector. Additionally, the study conducted by [10] examined the dual influence of Artificial Intelligence (AI) and natural resource markets on Green Total Factor Productivity (GTFP) in China. Their results pointed out that AI significantly reduces carbon intensity, with varying effects across industries and developmental phases. These findings underscore the need to strategically develop AI tailored to specific industrial sectors to boost green economic development effectively.

In agriculture, the integration of Artificial Intelligence (AI) presents a transformative opportunity to advance the goals of the green economy by enhancing sustainability, resource efficiency, and environmental stewardship [8]. Related to [11], the application of AI tools has also transformed supply chain management in agriculture and the broader food industry. Predictive models are created to support demand forecasting, which helps optimize distribution, increase market access, and minimize food waste throughout the value chain.

Moreover, AI contributes significantly to sustainable resource use. Systems that analyze real-time data on soil moisture, weather patterns, and plant health enable precise irrigation control and water conservation. This not only improves productivity but also supports environmentally responsible farming. Through such multifaceted applications, AI stands as a transformative force in agriculture—enhancing yields, improving resource efficiency, and promoting a more sustainable and resilient food system [4]. In addition, [4] also empasizes that the transition to a green economy necessitates sustainable, resource-efficient, and low-carbon agricultural practices that could meet growing food demands while minimizing environmental impact (Figure 2). Artificial Intelligence (AI) plays a significant role in this transformation by offering data-driven solutions that enhance decision-making, optimize resource use, reduce waste, and improve agricultural productivity.

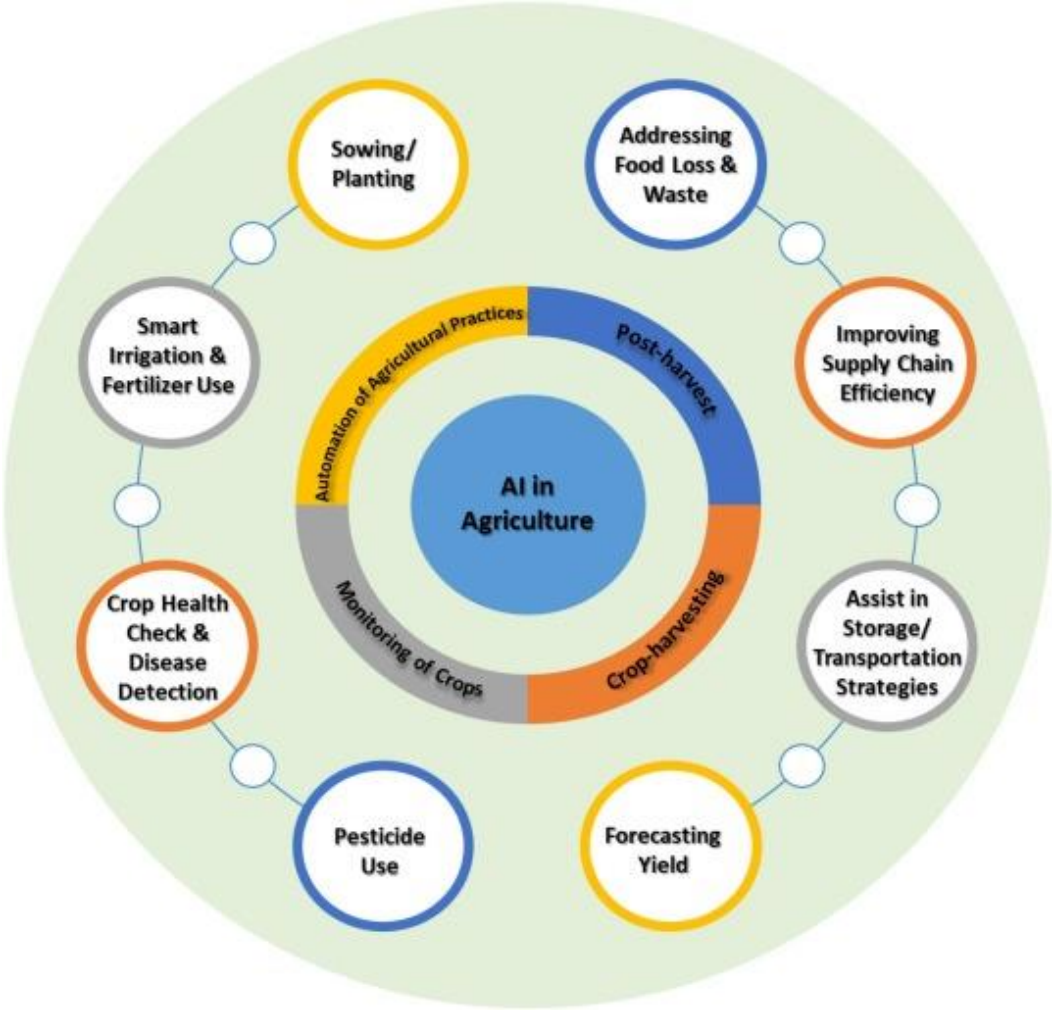

Figure 2. Importance of AI in Agriculture [10]

2.4. Barriers to adopting AI applications

According to Table 1, the primary technological barriers are cost, a lack of quality data, data privacy and security, standardization, and interoperability. Organizational impediments include a lack of clarity in vision and strategy, a lack of leadership support, resource and organizational limitations, knowledge and skill gaps, reluctance, and technical demands. Environmental constraints include lack of laws and regulations, infrastructure and accessibility, environmental and market uncertainty, a lack of technical businesses, and ethics and social readiness.

Table 1. Barriers to adopting AI applications

Authors	Methodology	Concentration	Barriers		
			Technology	Organization	Environment
Ghag et al., [12]	**DEMATEL-NK**	Food supply chain	Lack of Technology readiness Lack of sufficient privacy and security Lack of compatible facilities and trial ability	Lack of clear linkage between vision and strategy Lack of top management support and ownership Lack of establish sufficient resource and competiveness Proper training for staff and end user Lack of clarity about relative advancement/ perceived benefit	Peer/ competitor Lack of regulatory compliance requirement Demand volatility Lack of institutional Lack of ethics in data collection
Sharma et al., [13]	systematic literature review	machine learning (ML) applications in agricultural supply chains	Data security Insfrastructure Standardization of data Device interoperability	Human resources with analytical skills	lack of policy regulations on the use of data, the involvement of different stakeholders, and in-formation sharing practices.
Davis & Deif, [14]	literature review	use of artificial intelligence (AI) in the agricultural supply chain (AgSC) and	Cost, Data, Security		
Javaid et al., [1]	literature review	AI in agriculture	Lack of simple solutions that seamlessly incorporate and embed AI in agriculture, require a large amount of data, takes significant time	Lack technical knowledge	
Hasteer et al., [15]	literature review	AI in agriculture	'High Cost incurred', 'Difficulty in handling data, Lack of infrastructure	Lack of computa- tional resource, Reluctance in imple mentation of advanced technology, High precision and accuracy required'	Lack of skilled workforce, Extreme climatic conditions, Government policy'
Pandey & Mishra, [4]			Data volume, Cost		Accessibility of AI solutions, internet connectivity and robust digital infrastructure

Source: authors

3. METHODOLOGY

This study uses qualitative methodology to achieve its goals. Figure 3 depicts the main research steps, which include defining study goals, conducting literature reviews, interviewing experts, analyzing results, and proposing suggestions.

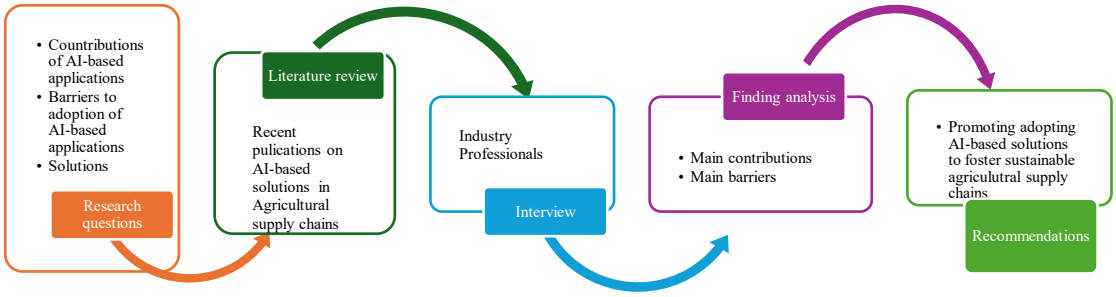

Figure 3. Main research stage

Source: authors

Every stage will be explained in the detail below, it also shows the process of research

Stage 1: Develop research questions.

This project will answer three research questions.

RQ1: What are the primary contributions of AI-powered apps in agricultural supply chains?

RQ2: What are the key challenges to using AI-based technologies in agricultural supply chains?

RQ3: What solutions should be offered to alleviate these barriers and boost the usage of AI?

Stage 2: Review recent studies

This step will review previous studies on AI applications in sustainable agricultural supply chains to explore contributions and challenges.

Stage 3: Conduct Industry Interview

This phase will involve in-depth interviews with industry to gather their views and practical experiences. This study will focus on businesses in the agricultural sector. The convenience sampling technique will be utilized since it allows for the easy selection and access of respondents. The goal is to analyze contributions and existing difficulties and propose possible solutions. Therefore, this study will use open-ended questions. The foundation questions will be built from Stage 2.

Stage 4: Analyze results.

This stage will analyze and discuss the interview findings.

Stage 5: Make Recommendations

This stage will suggest solutions to the main difficulties while supporting the use of AI applications in agricultural supply chains to promote sustainability and the green economy.

4. RESULTS AND DISCUSSION

4.1. Descriptive statistics

This survey gathered representatives from 16 businesses located in Ho Chi Minh City, Vietnam. Table 2 details the characteristics of the respondents. Most businesses are small and medium-sized, accounting for 63% and 25%, respectively. Only 13% of businesses are large, having 200 or more employees (Table 2). Besides, they play essential functions in agricultural supply chains, including purchasing, production, retail, import, and distribution. Half of the companies are in the procurement and distribution sectors, including chemical trading, fertilizers, product additives, veterinary medicine, aquatic medicine, and animal feed ingredients. The remaining companies primarily manufacture and retail, particularly agricultural chemical products.

Furthermore, nearly 80% of the questioned firms reported being aware of AI, with more than 56% having a solid grasp. As a result, more than 85% of businesses have already implemented AI, with 44% integrating it into almost all of their processes. However, several businesses have yet to integrate AI, accounting for 13%. This is due to a lack of understanding and expertise in AI.

Table 2. Company Information

	Number of companies	Percentage %
Size		
Small (less than 50 employees)	10	63%
Medium (50–200 employees)	4	25%
Large (over 200 employees)	2	13%
Main roles of enterprises in the supply chain		
Purchasing & distribution	8	50%
Production	4	25%
Retail	2	13%
Import	1	6%
Distributor	1	6%
Level of understanding of AI in your business		
Good	9	56%
Average	4	25%
Limited	3	19%
Level of deployment and application of AI technology in enterprises		
Mostly implemented	7	44%
Partially implemented	5	31%
Rarely implemented	2	13%
Not implemented at all	2	13%
Total	16	100%

Source: authors

4.2. Primary contributions of AI applications

According to the interview, all respondents agreed that AI plays a significant part in increasing the efficiency of the agricultural supply chain. Over 70% of organizations stated that AI is critical to supply chain efficiency. Figure 4 illustrates the primary operations of businesses that apply AI. AI has been used in various processes, including logistics, inventory management, demand forecasting, weather and seasonal data analysis, and product controls. AI is primarily employed for logistics optimization, inventory management, and demand forecasting.

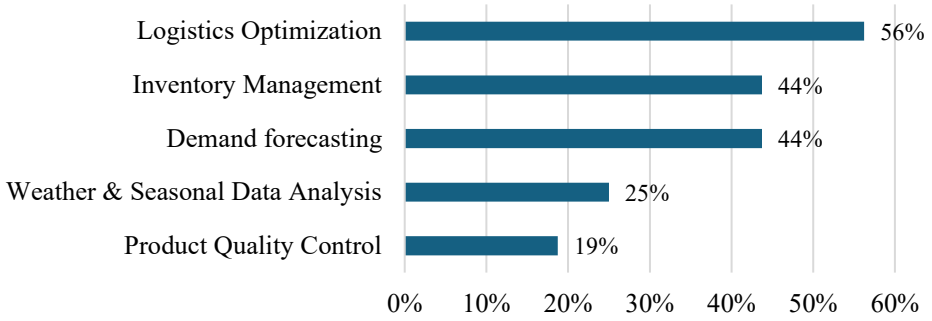

Figure 4. Primary activities implementing AI

Source: authors

Furthermore, respondents agreed that AI helps improve various activities (illustrated in Figure 5). They pointed out that AI increases labor efficiency and reduces staff workload by automating numerous operations. AI also helps search and analyze information on new raw resources. Thus, they can discover suitable providers. Besides, AI can help analyze client behaviors to improve the customer experience.

Figure 5. The primary advantages that AI provides

Source: authors

4.3. Main barriers to the deploying AI applications

Although AI provides numerous benefits to businesses, its implementation faces many obstacles, including technological, organizational, and external.

4.3.1. Technological barriers

Figure 6 depicts the key technological barriers. Many problems businesses encounter when implementing AI include personnel preparation, security and privacy concerns, a lack of high-quality data, data standardization, device compatibility, and cost. Cost is the most

significant obstacle, followed by a lack of high-quality data, data standardization, and device compatibility. Thus, businesses should develop strategies for investing in AI applications and generating solid data. In Vietnam, the technological barrier is also found that one of the most difficult ones that prevent people from applying AI applications in agriculture [16], for example, lack of reliable Internet, data center, and IoT infrastructure.

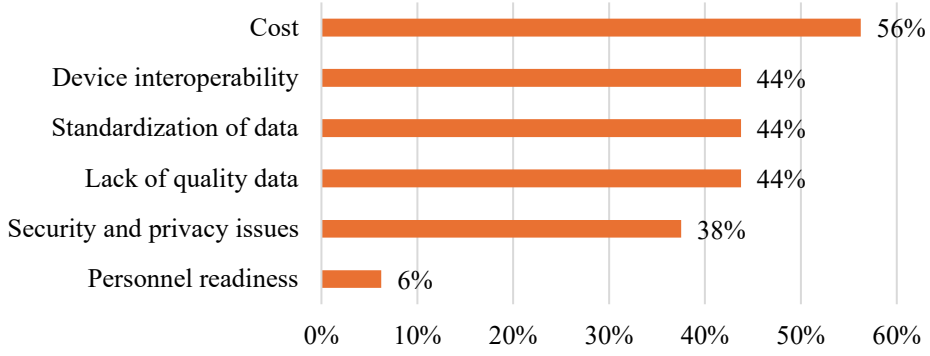

Figure 6. Technological barriers

Source: authors

4.3.2. Organizational barriers

Figure 7 depicts the primary organizational challenges. They include a lack of strategy and vision, a lack of budget, hesitancy and high implementation requirements, a lack of commitment from senior leadership, insufficient resources and organizational capacity, and a lack of knowledge, skills, and training. Most businesses, 75%, said they lack skills, knowledge, and training. Thus, it is vital to provide AI training to employers and managers so that they may gain a better grasp of AI applications. Besides, half of the respondents stated that they lacked resources and organizational capabilities, particularly digital infrastructure. This is because they are small-scale businesses. Furthermore, 44% of businesses claimed a lack of commitment from senior leaders. As a result, enhancing senior leadership's awareness of AI capabilities is critical to helping them realize that AI contributes considerably to business success. In the study of FAO Vietnam and MARD [17], it shows that many Vietnamese farmers and local argridultural workers have limited knowledge of AI technologies and they do not know how to use it.

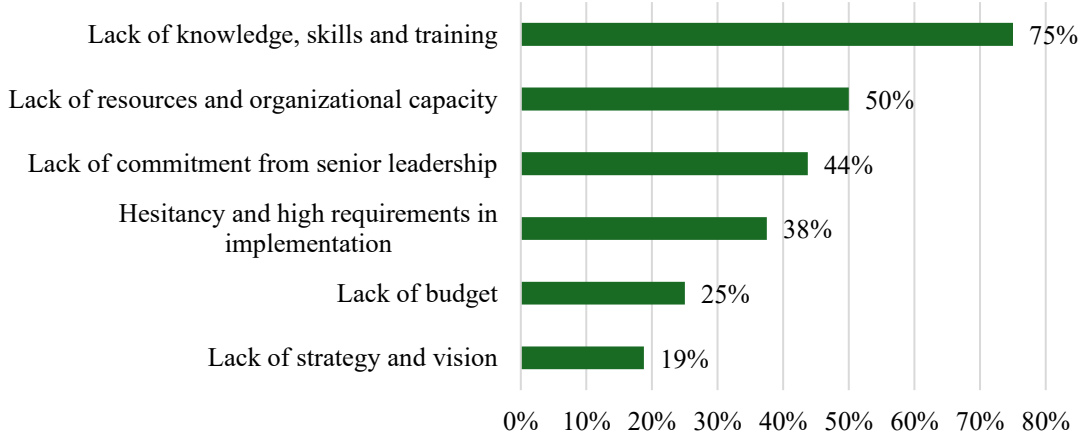

Figure 7. Organizational barriers

Source: authors

4.3.3. External barriers

Figure 8 depicts several external constraints that businesses face when using AI. They include volatile markets and weather conditions, a lack of legal and policy support, technical human resources, technological assistance, limited infrastructure, data ethics, and social responsibility. The most significant external hurdles are data ethics and social responsibility. Companies confront challenges when it comes to data collection and processing. Many customers refuse to complete the survey or provide incorrect answers. Additionally, gathering client data from websites or e-commerce could harm customers' privacy. The performance of AI applications is dependent on the input data. As a result, if the input quality is poor, business decisions that rely on AI outputs will become less effective. Besides, many businesses do not comprehend AI. Thus, they are concerned about data leaks, violations of client privacy, and legal consequences. Consumers will lose trust in an organization if their data is exploited or not protected. This immediately affects the organization's reputation. Furthermore, several organizations highlighted a lack of legal and policy assistance, technical human resources, and technological support. As a result, governments and technology companies must work together to help businesses adopt AI. Similarly, in a report of MIC [18], Vietnam also has concerns about data privacy, liability, and ownership of AI outputs related to undeveloped legal frameworks to support AI innovation in agriculture.

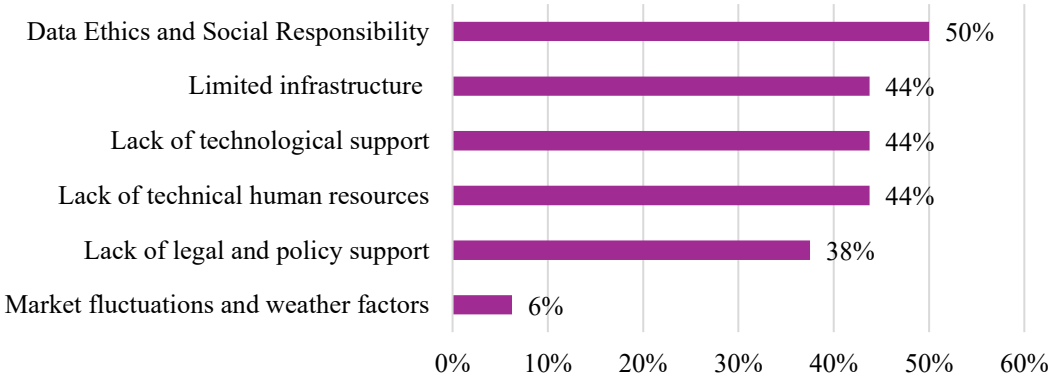

Figure 8. External barriers

Source: authors

5. SOLUTIONS TO ADOPTING AI APPLICATIONS

5.1. Developing effective AI applications

AI provides numerous benefits to business operations, including increased operational efficiency, personalized customer experiences, rapid response to market changes, and innovation of new products and services. Thus, encouraging the use of AI in business is critical to the growth of businesses. AI applications should be cost-effective and integrate seamlessly with existing operations. Governments should assist technical enterprises in developing effective AI applications for Vietnamese conditions, such as offering financial assistance.

Many businesses are financially burdened due to substantial implementation costs. Hence, building affordable AI applications is important to encouraging the use of AI in real-world scenarios. Many small firms have been hesitant to implement AI because they are concerned about the reliability and safety of its usage. Thus, AI vendors might provide a trial version to demonstrate their capabilities. After usage, users will comprehend the significance of those AI applications. Furthermore, AI applications should be seamlessly incorporated into

current processes. AI vendors should analyze and comprehend contemporary business technology and procedures. As a result, they should investigate the activities of present processes that AI can support or enhance.

5.2. Organizing and joining AI training courses

The majority of interviewed organizations suggested that one of the most effective strategies for promoting the deployment of AI in companies is to organize and join AI training courses and program. AI training courses are vital for developing knowledge and abilities of AI for enterprises. Many firms do not fully comprehend AI. Thus, training programs educate both managers and staff by provide basic and updated knowledges of AI. Training programs educate both managers and employees. They provide fundamental and up-to-date AI information as well as how to employ advanced AI applications in real-world scenarios. For example, they may instruct users how to access, collect, and forecast data accurately. Besides, they should teach users what they should consider and avoid in order to preserve the security of companies, such as not revealing sensitive information. Moreover, companies could collaborate with technical companies, research institutes, and universities to design and organize training courses. Furthermore, firms can send staff to training classes to participate in AI courses, either online or offline.

5.3. Building a culture of innovation

In this digital age, applying AI and novel technologies is inevitable to assist organizations remain competitive and achieve long-term growth. Hence, business should build a culture of innovation. Leaders commit to supporting and implementing new AI applications that can help cut expenses, save time, eliminate errors, and boost productivity. Furthermore, employees are encouraged to think creatively and provide innovative solutions without fear of failure. Employees that develop effective solutions that optimize work performance are rewarded with rewards and promotions.

6. CONCLUSION

Agriculture is critical to national and international social and economic growth because it supplies essential nutrition for people's health and survival. AI has helped to revolutionize agricultural supply systems. Numerous studies have proved the efficacy of AI-powered systems such as agricultural forecasting, automated irrigation, crop monitoring, and quality control. Furthermore, many developing countries have faced major difficulties to using such AI technologies.

This research included in-depth interviews with agricultural enterprises in Vietnam. This study collected data from 16 businesses operating at various stages of the agricultural supply chain. This study investigates the major barriers to deploying AI applications, which include technological, organizational, and environmental factors. As a result, this study will make practical recommendations to encourage the use of AI-driven solutions, such as developing effective AI apps, organizing and participating in AI training courses, and cultivating an innovative culture.

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TÓM TẮT

ỨNG DỤNG CÔNG NGHỆ TRONG KINH TẾ XANH: THÚC ĐẨY PHÁT TRIỂN NÔNG NGHIỆP BỀN VỮNG – RÀO CẢN VÀ GIẢI PHÁP

Nguyễn Thị Thúy Hạnh[1], Trần Tuấn Anh[2*]

[1]*Trường Đại học Kinh tế Luật, Đại học quốc gia TP. Hồ Chí Minh, Việt Nam*

[2]*Trường Đại học Công Thương Thành phố Hồ Chí Minh, Việt Nam*

Email: *anhtt@huit.edu.vn*

Nông nghiệp đóng vai trò thiết yếu trong sự phát triển kinh tế – xã hội ở cả cấp quốc gia và toàn cầu, khi cung cấp nguồn dinh dưỡng quan trọng cho sức khỏe và sự tồn tại của con người. Việc xây dựng và quản lý chuỗi cung ứng nông nghiệp bền vững là yếu tố then chốt nhằm đảm bảo chất lượng và số lượng thực phẩm. Tuy nhiên, quá trình này ngày càng gặp nhiều thách thức do nhu cầu thực phẩm toàn cầu gia tăng và tác động của biến đổi khí hậu. Trí tuệ nhân tạo (AI) đã góp phần tạo ra bước chuyển đổi đột phá trong chuỗi cung ứng nông nghiệp. Nhiều nghiên cứu đã chứng minh hiệu quả của các giải pháp ứng dụng AI như dự báo nông nghiệp, tưới tiêu tự động, giám sát cây trồng và kiểm soát chất lượng. Tuy vậy, tại nhiều quốc gia đang phát triển, việc tiếp cận và triển khai các công nghệ AI này vẫn gặp phải nhiều rào cản đáng kể. Nghiên cứu này tập trung phân tích những thách thức chính trong quá trình ứng dụng công nghệ AI vào nông nghiệp thông qua phương pháp định tính, bằng cách thực hiện phỏng vấn chuyên sâu với các doanh nghiệp trong lĩnh vực nông nghiệp. Trên cơ sở đó, nghiên cứu đề xuất các khuyến nghị thực tiễn nhằm hỗ trợ các nhà hoạch định chính sách, giới khoa học và doanh nghiệp ở các nước đang phát triển xây dựng chiến lược triển khai các giải pháp nông nghiệp ứng dụng AI một cách hiệu quả, hướng đến việc xây dựng chuỗi cung ứng nông nghiệp bền vững và thúc đẩy nền kinh tế xanh.

Từ khóa: Ứng dụng AI, Nông nghiệp, Kinh tế xanh, Chuỗi cung ứng nông nghiệp bền vững.