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Environmental Impacts and Strategic Responses in Agricultural Transformation: A SWOT–TOWS Analysis of Dong Nai Province, Vietnam

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ABSTRACT

This study examines the environmental and strategic dimensions of agricultural development in Dong Nai Province, Vietnam, through the application of an integrated SWOT–TOWS analytical framework. Situated within the context of accelerating climate change, land-use pressures, and digital transformation, the research investigates how environmental challenges influence the province's transition toward sustainable agriculture. The analysis reveals that Dong Nai possesses key comparative advantages—including fertile agricultural land, favorable geographic location, and a strong labor base—that provide a foundation for modernization and green growth. However, weaknesses such as limited technological adoption, fragmented value chains, and labor migration continue to constrain ecological efficiency. These vulnerabilities, compounded by external threats such as climate variability, water stress, and market volatility, highlight the urgency of formulating adaptive and environmentally responsible strategies. Through the TOWS matrix, the study identifies five strategic pathways: (1) digital transformation for precision and resource-efficient farming; (2) promotion of climate-smart and low-emission agricultural practices; (3) enhancement of value-chain integration and green certification; (4) mobilization of investment for sustainable infrastructure; and (5) human-capital development for environmental innovation. These strategies are further operationalized through measurable KPIs, implementation timelines, lead agencies, and financing mechanisms aligned with Decision 2327/QĐ-UBND (2023), ensuring policy feasibility and accountability. The findings contribute to the broader discourse on sustainable rural transformation by integrating strategic-management tools with sustainability and environmental-impact assessment principles. The Dong Nai case demonstrates how local agricultural systems can align with global sustainability goals—particularly SDG 2 (Zero Hunger), SDG 9 (Industry, Innovation and Infrastructure), and SDG 13 (Climate Action)—thereby offering a replicable framework for environmentally informed agricultural planning in developing economies.

1. INTRODUCTION

Agriculture remains a cornerstone of sustainable development, particularly in developing economies such as Vietnam, where it plays a vital role in ensuring food security, sustaining rural livelihoods, and maintaining ecological balance [1, 2]. In the contemporary context of globalization and climate uncertainty, the agricultural sector must evolve beyond traditional production-oriented paradigms to embrace environmental sustainability, green innovation, and resilience against climate-related disruptions [3, 4]. This transformation represents a global shift toward environmentally responsible practices that integrate social, economic, and ecological priorities consistent with the Sustainable Development Goals (SDGs).

In Vietnam, agriculture contributes significantly to economic growth and rural employment but faces mounting environmental and structural challenges. Rapid industrialization, urban expansion, and population growth have intensified land-use pressures and resource competition, while climate change has disrupted water cycles, soil fertility, and biodiversity [5, 6]. These stressors underscore the urgent need for environmentally adaptive agricultural strategies that enhance productivity while mitigating ecological degradation. Recent studies further emphasize that sustainable agricultural transformation requires the synergy of technological innovation, smart specialization, and inclusive policy frameworks to align local practices with global sustainability standards [7, 8].

Dong Nai Province, located in Southeast Vietnam adjacent to Ho Chi Minh City, represents one of the country's key agricultural centers with fertile soils, a favorable climate, and strong market connectivity. Its geographic advantage, large rural labor force, and proximity to major consumption centers create favorable conditions for modernization and value-chain expansion. However, the province's agricultural development

is increasingly constrained by climate variability, land conversion, and water stress [9]. Prolonged droughts, salinity intrusion, and unpredictable rainfall patterns have reduced yields, while urbanization and industrial expansion continue to fragment agricultural land [10, 11]. At the same time, socio-cultural transitions and changes in community behavior are reshaping agricultural practices and environmental awareness, requiring integrated strategies that balance economic growth with ecological protection [12].

To address these multidimensional challenges, strategic management tools such as SWOT (Strengths, Weaknesses, Opportunities, Threats) and its derivative TOWS matrix have been widely employed to evaluate internal capacities and external environmental pressures [13-15]. These frameworks facilitate the systematic formulation of adaptive strategies that respond to climate risks, resource constraints, and technological opportunities [16]. Their application in agriculture—particularly in climate-vulnerable regions—has proven effective in developing context-specific strategies for sustainable resource management [17, 18]. Simultaneously, the integration of digital transformation and environmental governance principles within strategic planning has emerged as a powerful approach for enhancing institutional capacity, innovation, and ecological resilience [19, 20].

Existing research on Dong Nai's agriculture has often been descriptive, focusing on production outputs or specific crop studies while neglecting holistic frameworks that integrate environmental, technological, and socio-economic dimensions [9, 21]. Although local authorities have launched high-tech and organic farming initiatives, including Resolution 08/2022/NQ-HDND and Decision 2327/QD-UBND, the coherence between environmental sustainability, digital transformation, and market competitiveness remains limited. Weak value-chain linkages, declining agricultural labor, and insufficient public–private coordination continue to hinder the sector's sustainable growth [5, 7].

In response, this study applies a comprehensive SWOT–TOWS analytical framework to examine the environmental and strategic development challenges of Dong Nai's agricultural sector. The research identifies internal strengths and weaknesses alongside external opportunities and threats that shape the province's agricultural sustainability, formulates strategies that integrate environmental adaptation and digital transformation, and aligns them with the Sustainable Development Goals. By bridging strategic management theory with sustainability and digital-transformation perspectives, this study contributes to the growing literature on environmentally responsible agricultural planning and offers a replicable framework for guiding low-carbon, inclusive, and adaptive agricultural development in Vietnam and other emerging economies [22-25].

2. LITERATURE REVIEW

Agricultural development refers to the quantitative and qualitative advancement of agricultural activities, including the expansion of cultivated land, increased crop output, enhanced productivity, diversification of crop and livestock systems, and improvements in the sector's value-added and socio-economic efficiency. According to Ellis [26], agricultural development is not merely about increasing production but also about improving farmers' livelihoods and protecting natural resources. Similarly, Todaro and Smith [1] emphasize that agricultural development is an integrated process involving technical, economic, and social dimensions, with the overarching goals of improving productivity, increasing rural incomes, reducing poverty, and promoting sustainable and inclusive development. In many developing countries, agriculture functions as a primary engine for national economic growth and social transformation. Vu and Nguyen [27] further demonstrate that sustained agricultural productivity growth in Vietnam has been central to the nation's structural reform and rural transformation, highlighting the continuing role of agrarian productivity in inclusive economic expansion.

Yet agriculture remains heavily dependent on natural conditions—climate, soil quality, water availability, and weather variability—rendering it highly susceptible to risks such as drought, flooding, pest outbreaks, and long-term climate change [24]. Recent empirical studies have confirmed the intensifying impact of climate change on agricultural output. For instance, impact of climate change on agricultural yield: evidence from Vietnam [6] provides macro-level evidence from Vietnam showing that climate variables adversely affect key crops such as sweet potato, cassava, and maize, while rice production exhibits partial resilience. This underscores the urgency of implementing adaptive and resilient agricultural strategies that can withstand shifting climatic patterns. Nhi et al. [10] also reveal that rainfall variability in the upper Dong Nai River Basin substantially influences streamflow and crop productivity, implying that hydrological data integration is crucial for climate-adaptation planning. Similarly, economic impact of climate change on agriculture using Ricardian approach: a case of northwest Vietnam [11] examines the economic losses of climate change in Vietnam's agriculture, reinforcing the sector's vulnerability to changing conditions.

These climate-related threats are compounded by population growth, which is driving global food demand and placing additional stress on agricultural systems. At the same time, resource limitations and ecological degradation necessitate sustainable intensification strategies to optimize input use and minimize environmental harm. Crop seasonality and biological growth cycles cause uneven production outputs, exacerbating market instability and disrupting supply-demand equilibrium [26]. Moreover, traditional agricultural systems reliant on outdated technologies and manual labor often produce low value-added, limiting economic returns and productivity, particularly in developing regions [22]. Vertakova et al. [28] emphasize that adopting green supply chain management principles can help transform such traditional structures by improving efficiency and aligning agricultural production with the sustainable-development paradigm.

In response to these challenges, scholars like Shvets et al. [8] advocate for smart specialization as a guiding strategy for transforming agriculture. Drawing from experiences in Central and Eastern Europe, they argue that integrating smart specialization into agricultural policy fosters cross-sectoral innovation, environmental resilience, and alignment with the SDGs. Kucher et al. [29] extend this argument by situating Agribusiness 4.0 as a pivotal mechanism for innovation in agrarian enterprises, emphasizing digitalization, technological upgrading, and data-driven decision-making as drivers of sustainable competitiveness.

Globalization adds a dual dynamic to agricultural development. On one hand, it provides access to expanded

international markets via trade liberalization and regional integration agreements. On the other hand, it imposes stricter compliance requirements related to food safety, traceability, and environmental standards [3]. The pressure to meet these standards has incentivized modernization across the agri-food sector, particularly through digital transformation. Stadnyk et al. [30] highlight that implementing balanced-development marketing approaches within the food market can strengthen sustainability narratives and improve product positioning under globalization. Tretiak et al. [31] further contend that developing public–private partnership value-added chains in rural territories enhances resource mobilization and institutional coordination—key determinants of successful agricultural modernization.

Industry 4.0 technologies—such as the Internet of Things (IoT), big data analytics, and cloud-based systems—are being adopted to increase productivity, optimize logistics, and enhance sustainability in agriculture [4]. However, recent evidence from the developing-country context demonstrates both potential and constraints: for example, Digitalization and agricultural transformation in developing countries [32] highlight how digitizing agriculture enhances small-holder access to market, weather and extension data.

Simultaneously, towards digital transformation of agriculture for sustainable and inclusive development, Wang et al. [33] show that digital transformation supports green-agricultural practices and inclusive development. In Vietnam, although government-led initiatives have sought to stimulate digital transformation in agriculture, gaps remain in policy accessibility, implementation, and institutional support – as shown by Do Thi et al. [19]. Nguyen et al. [34] add a socio-cultural dimension, revealing that religion and community ethics can significantly influence environmental stewardship and sustainable agricultural behavior, thereby complementing technological and policy-driven transformation. Effective transformation thus requires synchronized efforts across public and private sectors, backed by simplified procedures, financial support, and digital capacity-building.

Despite these innovations, structural and digital divides remain a persistent concern. Rural agricultural enterprises in developing countries often lack the infrastructure, skilled workforce, and capital necessary to fully embrace digital innovation. These disparities threaten to exacerbate existing inequalities and slow the pace of sectoral modernization.

Strategic planning tools such as the SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis are therefore crucial in guiding agricultural transformation. SWOT provides a structured method to assess internal capacities and external pressures, supporting evidence-based strategy development [14, 15]. The TOWS matrix builds on SWOT by translating these diagnostics into strategic responses—leveraging strengths to exploit opportunities, addressing weaknesses to counter threats, and crafting proactive interventions [13]. This strategic framework is increasingly employed to address complex, multifaceted challenges such as climate resilience, digital transition, and sustainable land use [16, 25].

Nonetheless, gaps in the literature persist. Many studies do not sufficiently explore the localized application of strategic tools like SWOT–TOWS in transitional or resource-constrained economies. The integration of environmental sustainability into economic development plans also remains contentious, particularly when short-term gains conflict with long-term ecological integrity. Moreover, there is limited empirical work combining digital-transformation strategies with classical SWOT–TOWS frameworks in agricultural systems of emerging economies [20]. This study aims to bridge these gaps by applying a comprehensive SWOT–TOWS framework to a southern Vietnamese agricultural context. By synthesizing international strategic models with region-specific data, it contributes to the ongoing discourse on sustainable agricultural development in developing economies. In doing so, the study aligns with global commitments to the SDGs, notably SDG 2, SDG 9, and SDG 13, reinforcing both its practical significance and theoretical contributions to the field.

3. METHODOLOGY

This study adopts a mixed-method strategic analysis framework, integrating both qualitative and quantitative approaches to comprehensively assess the opportunities and challenges associated with the sustainable agricultural development of Dong Nai Province (Figure 1). The methodological foundation is based on the SWOT–TOWS framework, a well-established tool in strategic management known for its ability to align internal capacities with external environmental conditions [13, 35]. The overall research design comprises four interrelated stages to ensure analytical rigor, policy relevance, and contextual applicability.

Figure 1. Map of Dong Nai Province highlighting key agricultural districts and infrastructure
Note: Created by the authors using QGIS and Google My Maps, 2025

3.1 Establishment of theoretical framework and literature review

An extensive literature review was conducted to situate the study within the broader academic discourse on agricultural development, climate adaptation, and economic integration. The SWOT framework has been widely recognized for its diagnostic capacity and practical versatility in strategic planning, although several scholars emphasize the need for structured and transparent application to enhance analytical rigor [15, 36]. In addition, recent methodological advances recommend incorporating multi-criteria decision-making (MCDM) techniques to improve the prioritization of strategic options [37]. The review encompassed peer-reviewed journal articles, national and international policy documents, and reports from organizations such as the FAO and OECD, as well as local legislative frameworks including Resolution 08/2022/NQ-HDND. This step ensured the conceptual robustness of the SWOT–TOWS application and anchored the research within global and regional debates on sustainable agricultural planning.

3.2 Collection and analysis of secondary data

Secondary data were systematically collected from authoritative sources, including the Dong Nai Statistical Yearbooks (2019–2023), provincial environmental reports, high-tech agricultural development plans, and organic farming initiatives. Descriptive statistical analysis was applied to summarize key agricultural indicators before strategic formulation, a method commonly combined with qualitative frameworks to outline structural characteristics of regional systems [38]. This enabled the objective identification of internal factors—strengths and weaknesses—and external factors—opportunities and threats—influencing the province's agricultural sector.

No primary surveys or interviews were conducted; all indicators related to technological adoption and production systems were derived from agricultural-extension reports and official provincial documentation. The use of verified government datasets ensures representativeness at the provincial scale, although it may not fully capture micro-level farmer perspectives or emerging informal practices.

3.3 Development of the SWOT–TOWS matrix and strategic formulation

The analytical core of the research involved constructing the SWOT–TOWS matrix through a structured, multi-step process that adheres to established best practices in situational analysis [13, 35]. First, key factors were extracted from empirical data and categorized systematically into the four SWOT dimensions, ensuring methodological consistency and minimizing subjectivity [15]. The SWOT matrix was then cross-analyzed to identify strategic linkages, forming the foundation for the TOWS matrix, which generated four strategic quadrants:

•SO strategies: Leveraging strengths to exploit external opportunities.

•WO strategies: Addressing internal weaknesses to benefit from emerging opportunities.

•ST strategies: Using internal strengths to mitigate external threats.

•WT strategies: Minimizing weaknesses to defend against risks.

Based on these outcomes, a set of policy-oriented strategies was developed, aligning with Dong Nai's socio-economic objectives and the SDGs. This phase translated analytical findings into actionable recommendations tailored to the province's environmental and institutional realities.

3.4 Integration of quantitative and qualitative components

Quantitative indicators—including labor productivity, GRDP contribution, crop production value, and agricultural investment levels—were incorporated to substantiate qualitative findings extracted from literature and policy analysis. Each SWOT factor was then assigned a 1–5 relevance score based on empirical evidence and evaluated by a five-member expert panel, composed of three agricultural economists, one agronomist, and one provincial agricultural-extension specialist (see Appendix A2). The panel scoring achieved substantial agreement (Cohen's $\kappa = 0.71$), enhancing the reliability of the prioritization process.

This integrated approach ensured that the TOWS formulation was not solely conceptual, but empirically grounded, transparent, and reproducible. It supports the development of context-specific agricultural strategies that reflect Dong Nai's socio-economic and environmental dynamics [5]. Future research could expand this methodology by including optimization models such as Analytic Hierarchy Process (AHP) or fuzzy logic, as recommended by Kajanus et al. [37], to further refine strategic weighting and scenario analysis.

4. RESULTS

4.1 SWOT analysis of Dong Nai Province's agricultural sector

SWOT analysis is a vital tool for comprehensively assessing internal factors (strengths and weaknesses) and external factors (opportunities and threats) that influence the development of Dong Nai Province's agricultural sector. By identifying competitive advantages, existing limitations, as well as trends and risks from the external environment, the SWOT analysis provides a scientific foundation for strategic planning and policy recommendations. The results of the SWOT analysis serve as the basis for constructing the TOWS matrix in subsequent steps, aiming to enhance production efficiency, competitiveness, and promote sustainable, modern agricultural development.

4.1.1 Strengths

Dong Nai's agricultural sector benefits from a large and diverse cultivated area, with 278,377 hectares allocated to agricultural production land and a leading position in livestock production—evidenced by over 2,090 thousand pigs, and 24,497 thousand poultry in 2023 [5].

Extensive and Diverse Agricultural Land. According to the Dong Nai Statistics Office [5], the province's total natural area was approximately 586,362 hectares in 2023, with agricultural production land accounting for over 47.48%. Notably, the fertile basalt soil in districts such as Xuan Loc, Long Thanh, and Dinh Quan is highly suitable for perennial industrial crops like rubber, coffee, pepper, and fruit trees such as durian and rambutan. The area dedicated to perennial crops reaches about 219,535 hectares [5], representing more than 78% of total agricultural production land, significantly contributing to the province's export turnover with products like mangoes, bananas, jackfruit, and durians, which have high economic value and strong international demand.

Strategic Geographical Location Connecting Regions and Markets. Dong Nai is part of the Southern Key Economic Region, bordering Ho Chi Minh City, and benefits from a well-developed transportation network, including National Highways 1A and 51, Cai Mep - Thi Vai Port, the Ho Chi Minh City - Long Thanh - Dau Giay Expressway, and Long Thanh International Airport (under construction). This strategic location shortens transportation time for agricultural products to major consumption markets and processing/export hubs.

Abundant and Dynamic Rural Labor Force. According to the Dong Nai Statistical Yearbook [5], the labor force reached 1,785,778 people in 2023, with 227,972 employed in agriculture, accounting for 12.77% of the province's population. This provides a foundation for developing agricultural models that apply technical labor and vocational training. The local population has longstanding experience in

cultivating industrial crops like rubber, coffee, and fruit trees, particularly durian, which requires advanced techniques. Additionally, provincial agricultural training programs have improved farmers' skills, enhancing productivity and product quality.

High Production Efficiency and Continuous Labor Productivity Growth. Dong Nai has maintained stable growth in agricultural product value and labor productivity over the past five years. Specifically, the value of agricultural products per hectare increased from VND 109.4 million in 2019 to VND 139.79 million in 2023, reflecting an average annual growth rate of over 6.3% (Table 1). Simultaneously, labor productivity in agriculture improved significantly, rising from VND 115 million per worker in 2019 to VND 189.5 million per worker in 2023, nearly a 65% increase over five years (Figure 2). The detailed numerical values used to construct Figure 2 are provided in Appendix Table A1. This demonstrates positive transformations in farming techniques, labor efficiency, and investment performance in the province's agricultural sector. Such improvements not only reflect enhanced competitiveness but also facilitate access to markets with high demands for quality and production efficiency.

Table 1. Agricultural product value and labor productivity in Dong Nai's agricultural sector

Year	Agricultural Product Value per ha (million VND)	Annual Growth Rate (%)
2019	109.40	
2020	116.45	6.44%
2021	122.96	5.59%
2022	131.23	6.73%
2023	139.79	6.52%

Source: Dong Nai Statistics Office, 2024

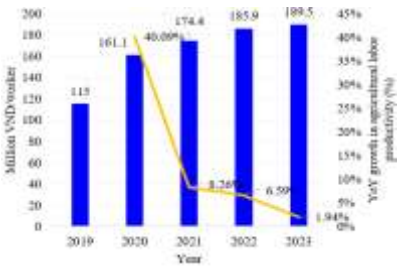

Figure 2. Agricultural labor productivity and year-over-year (YoY) growth in Dong Nai Province, 2019–2023

YoY growth rates are high in 2020 due to a low base value in 2019 and moderate thereafter. Figures reflect value per agricultural worker (million VND), not sectoral GRDP growth.

4.1.2 Weaknesses

The agricultural sector in Dong Nai is heavily dependent on weather conditions and natural risks, being significantly affected by climate change and extreme weather events. According to the Dong Nai Provincial Statistical Office [5], natural disasters in 2023 damaged 292 hectares of rice fields and 72 hectares of other crops. Frequent droughts and floods have consistently reduced crop yields, particularly for perennial industrial crops such as rubber and coffee, which account for a large proportion of the province's agricultural structure. The primary causes include a lack of modern irrigation infrastructure and limited early weather warning systems, especially in Long Thanh and Nhon Trach districts, which are severely impacted by flooding and saltwater intrusion.

The application of advanced technology remains limited. Although Dong Nai has implemented several policies to promote digital transformation and the adoption of Industry 4.0 technologies in agriculture, progress has been slow and inconsistent. By 2023, the area utilizing water-saving irrigation systems reached 59,754 hectares, accounting for approximately 31.27% of key crop areas, while the area using greenhouses and net houses was only 149 hectares, representing less than 0.06% of total agricultural land [39]. Technologies such as IoT, drones, and smart monitoring systems remain at the pilot stage. The adoption rate of organic fertilizers stands at just 9.7%, indicating a low level of technological transition. The main reasons include high initial investment costs, a lack of long-term financial support for farmers, and limited awareness of the benefits of advanced technologies. Additionally, inconsistencies in technology transfer from research institutes to farmers, along with the absence of specialized training centers for Agriculture 4.0 in the province, have hindered the pace of technological adoption.

Labor productivity in agriculture remains significantly lower than in other sectors. Despite improvements, agricultural labor productivity in 2023 reached 189.5 million VND per worker, while productivity in the industrial sector exceeded 261.2 million VND per worker in the same year [5]. The primary reason for this gap is the continued reliance on manual labor and a lack of mechanization, particularly in harvesting and processing stages.

Agricultural production in Dong Nai is still characterized by fragmentation and weak value chain linkages. Farming largely depends on small-scale household operations with low average cultivation areas. The lack of coordination among stakeholders across the value chain—from production and processing to distribution—makes farmers vulnerable to middlemen, price fluctuations, and limited control over market access. The agricultural supply chain in Dong Nai remains disjointed, with most agricultural products exported in raw form, resulting in low value addition. For example, Dong Nai's durians are primarily exported fresh, while processed products such as frozen durian or durian powder account for only a small proportion of total export turnover.

4.1.3 Opportunities

Opportunities for Dong Nai's agricultural sector have expanded significantly due to the implementation of various free trade agreements (FTAs) such as the EVFTA, CPTPP, and RCEP. These agreements offer substantial potential for Dong Nai agriculture to integrate deeper into global supply chains. With key agricultural products like durian, bananas, coffee, and pepper, the province is well-positioned to increase export value, provided it meets stringent standards regarding quality, food safety, and traceability. According to the Dong Nai Provincial Statistical Office [5], in 2023, the export value of agricultural and processed agricultural products reached USD 1,538 million, marking a sharp increase of 64.84% compared to 2019 and accounting for 7.11% of the province's total export turnover. Meanwhile, the seafood sector recorded only USD 128 million, a decline of 5.19% compared to 2018, representing just 0.59% of total exports, highlighting a clear shift towards processed agricultural exports (Table 2). This indicates that by effectively leveraging FTAs, Dong Nai agriculture can enhance value addition and expand international markets, particularly through investment in deep processing and brand development.

Table 2. Selected export value (USD million) and Production volume (tons) of Dong Nai Province, 2019–2023

A. Selected export value (USD million) of Dong Nai Province, 2019–2023						
	2019	**2020**	**2021**	**2022**	**2023**	**Change in 2023 Compared to 2019 (%)**
Value of agricultural products	933	963	1,042	1,001	1,538	64.84%
Value of seafood products	135	136	120	152	128	-5.19%
B. Production volume (tons) of Dong Nai Province, 2019–2023						
	2019	**2020**	**2021**	**2022**	**2023**	**Change in 2023 Compared to 2019 (%)**
Coffee production	237,487	240,779	362,790	197,196	250,531	5.49%
Pepper production	36,183	39,620	62,290	64,017	59,642	64.83%
Cashew production	323,971	294,227	328,787	266,688	406,861	25.59%

Note: Dong Nai Statistics Office, 2024

With its diverse terrain, humid tropical climate, and proximity to major urban centers like Ho Chi Minh City and Bien Hoa, Dong Nai holds great potential for developing eco-agriculture, organic farming, and agri-tourism models. Districts such as Tan Phu, Dinh Quan, and Xuan Loc are emerging as key areas for integrating agriculture with community tourism, experiential education, and eco-resorts. The province also benefits from fertile basalt soil, favorable for organic farming and high-value crops. Pilot circular agriculture models have been implemented in Xuan Loc and Cam My, utilizing organic fertilizers from agricultural waste and biological products as substitutes for chemicals. This provides a foundation for sustainable agricultural development, enhancing product value while creating additional livelihoods for rural communities through agri-tourism and service activities. As consumers increasingly prioritize clean, environmentally friendly products and agricultural experiences, these models not only diversify income sources but also align with green consumption trends and the circular economy, which is a key policy direction of the Vietnamese Government for the 2021–2030 period.

The government and Dong Nai Province are actively promoting policies to encourage the development of high-tech agriculture, organic farming, and circular agriculture. Resolution 08/2022/NQ-HDND prioritizes credit support, land allocation, and workforce training for high-tech and urban agriculture models. Additionally, the National Digital Transformation Program to 2025, with a vision to 2030, presents opportunities for farms and cooperatives in Dong Nai to apply IoT, artificial intelligence, big data, and blockchain in production, supply chain management, and market access.

Dong Nai also has significant potential to attract foreign investment and foster international cooperation in agriculture due to its strategic location and favorable investment policies. Collaborative programs with Japan, South Korea, and the Netherlands are underway to develop high-tech and circular agriculture, particularly in high-tech agricultural zones in Xuan Loc and Long Khanh districts. Furthermore, international initiatives such as carbon funds and World Bank programs for sustainable agriculture offer opportunities for Dong Nai to implement low-carbon agricultural projects, such as integrating perennial industrial crops with forest conservation. These efforts not only strengthen financial resources but also enhance the reputation of Dong Nai's agricultural products in international markets, especially as major markets like the EU increasingly favor sustainably produced goods.

4.1.4 Challenges

Climate change and extreme weather conditions have a direct impact on agricultural production. Dong Nai's agriculture is increasingly affected by climate change, with phenomena such as prolonged droughts, unusual heavy rainfall, and rising temperatures. The Environmental Report indicates that agriculture is among the most vulnerable sectors to the impacts of climate change and extreme weather events like flooding, drought, and pest outbreaks [9]. These factors lead to reduced productivity, lower quality of crops and livestock, and threaten rural livelihoods. Specifically, southern areas of the province such as Bien Hoa, Long Thanh, and Nhon Trach have recorded higher-than-average temperature increases, while extreme rainfall has been on the rise at monitoring stations in Long Khanh, Ta Lai, and Long Thanh, placing significant pressure on irrigation systems and agricultural supply chains.

Fierce competition from imported products and provinces with similar advantages poses another major challenge. In the context of deep economic integration, Dong Nai's agricultural products face direct competition from provinces like Lam Dong, and Dak Lak, which have adopted advanced technologies and possess better production and consumption linkages. Additionally, imports from China, Thailand, and Australia offer competitive prices, abundant supply, and diverse product designs, dominating major domestic distribution channels. For instance, Lam Dong has developed high-tech agricultural models with more extensive greenhouse and net house systems than Dong Nai, enabling year-round vegetable production with higher yields. Meanwhile, Dak Lak leverages value chain linkages in coffee production with major corporations like Nestlé, ensuring stable market access and building the Buon Ma Thuot coffee brand. Thai durian products, with diverse processing methods and professional packaging, currently hold a large market share in Vietnamese supermarkets, creating significant pressure on Dong Nai's durian, which is mainly sold fresh without a strong brand presence.

The pressure to convert agricultural land to non-agricultural purposes is intensifying due to rapid urbanization, especially in areas surrounding Bien Hoa and Long Thanh Airport. According to Dong Nai's master plan to 2030, with a vision to 2050, land allocated for industrial, infrastructure, and urban development is expected to increase significantly, threatening to reduce traditional agricultural production spaces. Additionally, rising agricultural land prices are driving up input costs and limiting land access for young farmers and cooperatives, hindering sustainable production scale expansion.

Based on the above analysis of strengths, weaknesses, opportunities, and threats, the synthesized SWOT matrix for Dong Nai Province's agricultural sector is summarized in Table 3.

Table 3. SWOT matrix of Dong Nai Province's agricultural sector

Strengths	Weaknesses
S1. Extensive and diverse agricultural land	W1. Dependence on weather and natural disasters
S2. Strategic location with developed infrastructure	W2. Limited application of advanced technology
S3. Abundant and dynamic rural labor force	W3. Low labor productivity
S4. High production efficiency, increasing productivity	W4. Fragmented production, weak value chains
Opportunities	**Threats**
O1. Expanding export markets through FTAs	T1. Climate change and extreme weather
O2. Development of eco-agriculture, organic farming, and agri-tourism	T2. Competition from imports and other provinces
O3. Policies promoting high-tech agriculture and digital transformation	T3. Pressure to convert agricultural land to non-agricultural uses
O4. International cooperation and investment attraction	T4. Rural labor shift to industrial and service sectors

Source: Compiled by the authors

The rural labor shift towards industrial and service sectors is becoming more pronounced. With the rapid development of industrial zones such as Amata, Long Thanh, and Giang Dien, many young rural workers are leaving agriculture in search of more stable, higher-paying jobs in industry and services. Agricultural labor now accounts for only 12.77% of the province's total workforce [5], and this proportion is declining annually. This not only leads to a shortage of agricultural labor but also impacts the transmission of traditional skills, making it increasingly difficult to maintain and expand large-scale agricultural models.

4.2 TOWS analysis of Dong Nai Province's agricultural sector

The TOWS analysis is employed to develop specific strategies by combining internal factors (strengths and weaknesses) with external factors (opportunities and threats) within Dong Nai's agricultural sector. The TOWS matrix includes four types of strategies: SO, WO, ST, and WT. The following strategies are proposed based on the previously presented SWOT analysis, aiming to guide sustainable development and enhance the competitiveness of Dong Nai's agriculture.

The SO strategies focus on leveraging Dong Nai's internal strengths to maximize opportunities arising from markets and policies.

SO1. Developing High-Quality Export Agricultural Brands: By capitalizing on the province's vast agricultural land (over 270,000 hectares) and continuously increasing labor productivity, Dong Nai is well-positioned to boost investment in deep processing and improve the quality of key agricultural products such as coffee, pepper, bananas, and durians (Table 2). In 2023, the province achieved a breakthrough in fresh fruit exports, with 121,000 tons of bananas and 50,000 tons of durians exported through official channels, generating an estimated total value of nearly VND 5,000 billion. Additionally, coffee production reached 250,531 tons, continuing to make a significant contribution to the province's agricultural export turnover. Dong Nai currently boasts 220 OCOP (One Commune One Product) certified products from 120 entities, leading the Southeast region in the number of certified products [40]. Trade promotion and market expansion efforts have also yielded positive results, notably the successful official export of fresh bananas and durians to the Chinese market, opening new avenues for Dong Nai's agricultural products internationally while enhancing the value and reputation of local agricultural brands.

SO2. Establishing Eco-Agriculture and Agri-Tourism Models: Leveraging its strategic location near Ho Chi Minh City and developed transportation infrastructure, Dong Nai is promoting organic agriculture integrated with experiential tourism in districts such as Tan Phu, Dinh Quan, and Xuan Loc. According to the provincial organic agriculture development plan for 2021–2030, by 2025, the total area for organic and organic-oriented cultivation is expected to reach 1,322 hectares, representing 0.49% of Dong Nai's agricultural land. This includes 1,250 hectares of organic-oriented cultivation (0.45%) and 72 hectares of certified organic farming (0.03%) [21]. For example, the Bo Cap Vang agri-tourism farm in Nhon Trach combines fruit cultivation with activities such as boating, fruit picking, and local cuisine experiences, attracting a large number of visitors annually, generating stable income for farmers, and promoting Dong Nai's agricultural brand.

SO3. Applying Advanced Technologies in Key Agricultural Production: Dong Nai benefits from an abundant rural labor force (227,972 people, accounting for 12.77% of the provincial workforce), combined with strong government support policies such as Resolution 08/2022/NQ-HDND, which offers incentives in land, credit, and technology transfer for high-tech agriculture. These conditions facilitate the adoption of technologies like the Internet of Things (IoT), smart irrigation systems, environmental sensors, and farm management software. By 2023, the area utilizing greenhouses and net houses was approximately 149 hectares, indicating significant potential for further development. Several localities have pioneered technological applications, including:

Long Khanh, with over 20 high-tech agricultural models, where 65% of crop areas use water-saving irrigation systems and mechanization exceeds 95% in most processes;

Xuan Loc, which applies automated irrigation robots, solar energy, and large-scale greenhouse systems in Xuan Truong commune, increasing profits by 15–25%;

Cam My, which has implemented Israeli irrigation systems across more than 250 hectares of pepper in Lam San commune, along with automated irrigation for over 30 hectares of durians, 15 hectares of which have been granted planting area codes (Table 4).

SO4. Attracting Investment into High-Tech Agricultural Clusters. Dong Nai's logistics advantages (deep-sea ports, expressways, and airport) and proximity to major consumer markets offer the basis for high-tech agricultural zones combining production, processing, and export, strengthening global competitiveness and provincial branding.

The WO strategies focus on addressing internal weaknesses to capitalize on market and policy opportunities.

Table 4. Comparison of technology adoption levels in key agricultural districts of Dong Nai Province

Indicator	Xuan Loc	Long Khanh	Cam My
Greenhouse/ Net House Area	Approximately 13 ha farm in Xuan Truong commune invested in greenhouses for clean vegetable and fruit cultivation meeting VietGAP standards.	Over 20 high-tech farming models, including net houses, greenhouses, drones, and VietGAP standards.	Phu Cuong High-Tech Agriculture Cooperative invested in greenhouses for VietGAP-standard vegetable production.
Smart/Water-Saving Irrigation	Application of automated irrigation robots and solar energy in greenhouse cooling systems.	65% of cultivated land uses advanced, water-saving irrigation technology.	Installation of Israeli water-saving irrigation systems on over 250 ha of pepper in Lam San commune.
Mechanization of Production	Xuan Tien Cooperative applies mechanization and technical advancements, increasing profits by 15–25%.	Mechanization rates: 98% in soil preparation, ~95% in annual crop care, ~97% in perennial crops, ~98% in harvesting.	Durian cooperative in Xuan Dong commune applies automated irrigation on nearly 30 ha, with over 15 ha assigned planting area codes.

Source: Compiled by the Authors from provincial agricultural-extension reports and official government documentation (secondary data only).

WO1. Investing in High-Tech Solutions to Reduce Weather Dependence: Given Dong Nai agriculture's reliance on weather conditions, investment in smart farming systems is essential to increase production autonomy. Currently, water-saving irrigation covers only 59,754 ha, and greenhouse/net house areas are just 149 ha. Therefore, the province should expand models utilizing IoT, sensors, automated climate systems, and real-time production management software. Support policies from Resolution 08/2022/NQ-HDND and the National Digital Transformation Program serve as foundational tools to achieve this goal.

WO2. Strengthening Value Chain Linkages to Enhance Competitiveness: Agricultural production in Dong Nai remains fragmented, lacking strong value chain connections from production to processing and consumption. Meanwhile, international markets, especially under active FTAs, impose strict requirements on quality, traceability, and food safety. The province should promote the development of new cooperative models, logistics centers, processing plants linked to raw material areas, and encourage enterprises to invest in high-tech agriculture under the "four-party linkage" model (State – Scientists – Enterprises – Farmers).

WO3. Improving Labor Productivity through Training and Mechanization: To overcome low agricultural labor productivity (VND 189.5 million per worker compared to VND 261.2 million per worker in industry in 2023), Dong Nai should leverage vocational training programs and international cooperation to apply mechanization and Industry 4.0 technologies. However, the proportion of skilled rural labor remains low and needs improvement through interdisciplinary programs and international partnerships.

WO4. Developing Organic Agriculture to Meet Market Trends: Addressing technological limitations by leveraging fertile basalt soils and green consumption trends to expand organic farming areas (expected to reach 3,242 hectares by 2030) [21]. World Bank and Carbon Fund programs could support the establishment of circular agriculture models in Xuan Loc and Cam My.

The ST strategies utilize strengths to address external environmental challenges.

ST1. Enhancing Climate Change Adaptation: Utilizing extensive agricultural land and abundant labor to implement drought-resistant crop varieties and smart irrigation systems, mitigating climate change impacts. Scaling up smart agriculture models and flexible farming adapted to climatic zones will reduce risks and improve agricultural ecosystem resilience.

ST2. Improving Agricultural Product Quality for International Competitiveness: Leveraging favorable geography and transportation infrastructure to establish agricultural quality inspection centers, ensuring compliance with strict EU and US standards, and enhancing competitiveness against countries like Thailand and Indonesia.

ST3. Protecting Agricultural Land Amid Urbanization Pressure: Using high production efficiency (product value of VND 139.79 million/ha) and rural development policies to safeguard agricultural land. To counter land conversion trends, the province should implement centralized production zoning, apply GIS for land-use planning, and protect ecological buffer zones. Developing high-tech agricultural zones in Long Khanh and Xuan Loc with high land-use efficiency will demonstrate the long-term economic advantage of preserving agricultural land.

ST4. Retaining Rural Labor through Modern Agricultural Models: Harnessing a dynamic labor force and traditional farming experience to develop high-tech agriculture and agri-tourism models, reducing labor migration to industrial sectors. Diversifying agricultural professions with value-added and innovative approaches is key to retaining and enhancing rural labor quality. For instance, the organic durian farming model in Cam My district has increased incomes and attracted young workers.

The WT strategies focus on minimizing weaknesses and avoiding threats to ensure sustainable development.

WT1. Developing a Disaster Risk Management System and Climate Change Adaptation: Establishing early warning systems for extreme weather events and applying GIS technology to map flood and drought risk areas in districts such as Long Thanh, Nhon Trach, and Long Khanh. Implementing smart irrigation infrastructure, including reservoirs and water-saving irrigation systems, to mitigate damage from droughts and floods.

WT2. Strengthening Value Chain Linkages and Building Agricultural Brands to Reduce International Competition: Reducing fragmented production by establishing cooperatives and integrated supply chains to avoid reliance on middlemen and competition from imported products (Thailand, China). Successful value chain models from Lam Dong can serve as references.

WT3. Developing a High-Quality Workforce and Diversifying Livelihoods to Retain Rural Labor: Addressing labor migration trends by enhancing skills through high-tech training and creating attractive job opportunities in agriculture. Vocational training programs should be expanded to meet Industry 4.0 demands.

WT4. Promoting Mechanization and Technology Transfer to Reduce Dependence on Manual Labor and Enhance Competitiveness: Dong Nai should accelerate comprehensive mechanization across all stages, from land preparation and planting to care, harvesting, and processing. This is an

effective way to reduce reliance on manual labor, especially as young workers shift towards industrial and service sectors. Additionally, the transfer of modern technologies—including smart machinery, sensors, agricultural robots, and precision farming systems—will help Dong Nai close the gap with provinces and countries with advanced agricultural sectors, thereby improving competitiveness in the context of deepening international integration.

The SWOT-TOWS matrix analysis (Table 5) reveals that Dong Nai's agricultural sector possesses significant development potential due to its natural advantages in land, geographic location, labor resources, and production efficiency. However, weaknesses such as dependence on natural conditions, limited technological adoption, and weak value chain linkages remain major obstacles if not systematically addressed. Therefore, the strategies proposed through the TOWS matrix not only guide the future development of Dong Nai's agriculture but also serve as a foundation for policy formulation, investment attraction, and the promotion of green, inclusive, and sustainable growth in the agricultural sector.

Table 5. Integrated SWOT–TOWS strategic matrix for sustainable agricultural development in Dong Nai Province

Strategy Type	Strategy Description	Linked SWOT Factors
SO1. Export-oriented development of high-value perennial crops	Branding and expanding durian, jackfruit, banana, and coffee for premium markets; investing in cold-chain logistics and traceability.	S1, S4 + O1, O4
SO2. Smart-agriculture adoption in key perennial zones	Scaling precision irrigation, automated pest traps, and digital monitoring for high-value crops in basalt-based regions.	S1, S3 + O3
SO3. Agri-tourism and eco-label diversification	Linking ecological farming, tourism services, and regional branding in Long Thanh, Cam My, Xuan Loc.	S1, S2 + O2
WO1. Cooperative-driven value-chain integration	Forming blockchain traceability cooperatives, linking farmers with exporters and processors.	W4 + O1, O4
WO2. Incentive programs for smallholder technology adoption	Credit subsidies, tax reductions, and equipment-sharing for IoT, smart irrigation, and greenhouse systems.	W2 + O3
WO3. Skills upgrading and digital literacy training	Training farmers on smart farming, quality compliance, and export standards through extension centers.	W3 + O1, O3
ST1. Climate-resilient crop restructuring	Introducing drought-tolerant varieties (cassava, maize), intercropping pepper–coconut, and water-saving technologies.	S1, S3 + T1
ST2. Land-use protection through smart specialization	Protecting high-value farming areas from industrial conversion by zoning and PPP-backed smart farming investment.	S1, S2 + T3
ST3. Biosecurity and disease monitoring systems	Digital surveillance for livestock and perennial crop diseases; risk dashboards for pest outbreaks.	S3 + T1, T2
WT1. Circular-economy waste minimization	Livestock waste biogas, fruit-processing byproducts for feed/compost, and low-emission fertilizer systems.	W1, W4 + T1
WT2. Disaster-risk insurance and livelihood stabilization	Climate and market insurance linked with cooperative contracts to reduce income volatility.	W1, W3 + T1, T2
WT3. Land consolidation through lease pooling and PPPs	Leasing idle land to cooperatives and agribusinesses to counter fragmentation and outmigration pressures.	W4 + T3, T4

Note: SWOT factor codes (e.g., S1, W2, O3, T1) correspond to scoring results in Appendix A2. Strategies were prioritized based on weighted factor relevance (1–5) with expert validation (Cohen's $\kappa = 0.71$). The detailed expert scoring sheet and factor prioritization process are presented in Appendix Table A2.

5. DISCUSSION

The results of this study substantiate the argument that strategic planning grounded in comprehensive internal–external analysis is indispensable for enhancing the resilience and competitiveness of Dong Nai's agricultural sector. The SWOT–TOWS framework confirmed that the province possesses considerable internal strengths and external opportunities, yet simultaneously faces significant structural weaknesses and environmental threats. These findings reinforce the theoretical position advanced by David [16] and Weihrich [13], who assert that integrating internal and external diagnostics provides the foundation for adaptive, evidence-based strategic design. In Dong Nai's case, the formulation of SO, WO, ST, and WT strategies functions as both a diagnostic and prescriptive mechanism—addressing vulnerabilities while transforming latent advantages into levers for sustainable development [24, 25].

Importantly, the present study demonstrates that the prioritization of strategic pathways was not based solely on qualitative interpretation. A 1–5 empirical scoring system was applied to all SWOT factors, using a five-member expert panel whose evaluations achieved substantial inter-rater reliability (Cohen's $\kappa = 0.71$). This transparent weighting mechanism ensured that strategies leveraging Dong Nai's strong perennial crop base, logistics advantages, and export potential received higher priority, while defensive strategies—such as value-chain consolidation and disaster mitigation—were positioned as support measures. In doing so, the TOWS matrix reflects empirical relevance rather than subjective preference.

This argument is consistent with a growing body of research emphasizing the strategic value of structured frameworks in agricultural modernization. Dyson [15] and Hill and Westbrook [14] demonstrated that SWOT-based methodologies enable the identification of dynamic capacities within agricultural systems, while Weihrich [13] highlighted the importance of translating such analytical insights into actionable strategic responses. In line with these studies, the present research advances a more holistic approach by integrating environmental, technological, and socio-economic considerations into Dong Nai's agricultural planning. This marks a departure from prior analyses by DAR Dong Nai [39] and the People's Committee of Dong Nai Province [21], which largely focused on production outcomes rather than strategic sustainability.

The weighted scoring results further reinforce that strategies capitalizing on strengths and opportunities (SO, ST) offer the highest immediate returns. Conversely, WO and WT

strategies—though important—require greater institutional coordination, financial support, and governance reform before they can generate equivalent impact. This tiered prioritization aligns with strategic management principles that differentiate between growth-driving actions and risk-reducing interventions. To ensure that these strategic pathways can be operationalized rather than remaining conceptual, measurable indicators, implementation timelines, responsible agencies, and financing mechanisms were defined in accordance with Decision 2327/QĐ-UBND [21]. The resulting policy-integrated implementation matrix is presented in Table 6.

Table 6. Policy-aligned strategic pathways with KPIs, implementation timelines, lead agencies, and financing sources for Dong Nai's agricultural sector (2024–2030)

Strategy	Key KPIs (by 2030)	Timeline	Lead Agencies	Budget Range & Financing Sources
A. SO Strategies – Strength–Opportunity Actions				
SO1: High-Value Export Agriculture & Branding	•≥ 20,000 ha export-standard durian, banana, jackfruit, coffee. •≥ 15 provincial brands certified (OCOP, VietGAP/GlobalGAP).	2024–2030	DONRE; Dept. of Agriculture & Rural Development (DARD); Export Enterprises	1,200–1,800 billion VND, from enterprise capital + PPP + branding support funds (Resolution 08/2022/NQ-HĐND).
SO2: Eco-Agriculture & Agri-Tourism Models	•≥ 50 ecotourism farm models (Long Khánh, Cẩm Mỹ, Xuân Lộc). •Revenue growth ≥ 10%/year from integrated agriculture–tourism services.	Pilot 2025; scale 2026–2030	People's Committees of districts; DARD; Tourism Dept.	300–450 billion VND, PPP + tourism innovation funds + rural development budgets.
SO3: Precision Farming (IoT, Smart Irrigation)	•Smart irrigation ≥ 60,000 ha; IoT monitoring ≥ 10,000 ha. •Greenhouse/net house ≥ 300 ha.	2024–2028, expansion to 2030	DARD; High-Tech Centers; Farmers' Cooperatives	900–1,400 billion VND, PPP + digital innovation funding + enterprise capital.
SO4: High-Tech Agricultural Clusters	•7–10 certified high-tech zones (Long Thành, Long Khánh, Cẩm Mỹ). •≥ 30 deep-processing facilities.	2024–2030	Provincial People's Committee; Dept. of Planning & Investment; Industrial Parks Authority	3,800–4,500 billion VND, enterprise capital + foreign investment + PPP incentives.
B. WO Strategies (Weakness Reduction + Opportunity Capture)				
WO1: Tech Investment to Reduce Climate Dependence	•Automated climate systems ≥ 5,000 ha. •Smart irrigation in drought zones (Xuân Lộc, Cẩm Mỹ).	2024–2028	DARD; Irrigation Dept.	1,000–1,600 billion VND, PPP + tech subsidies (Decision 2327/QĐ-UBND). Decision 2327 QD-UBND 2023
WO2: Value-Chain Cooperatives & Traceability	•≥ 200 cooperatives linked to certified buyers. •100% traceability for exporting crops.	2024–2030	DARD; Cooperative Alliances; DTI	350–600 billion VND, digital transformation funds + enterprise contract capital.
WO3: Workforce Productivity & Mechanization Training	•≥ 30,000 trained farmers/year. •Mechanization rate ≥ 90% in perennial crops.	2025–2030	Vocational Colleges; International Partners	250–450 billion VND, national training funds + ODA.
WO4: Organic Agriculture Expansion	•3,242 ha certified organic by 2030. •16–20 supply chain contracts for organic livestock/fruit.	2024–2030	DARD; DONRE; International NGOs	600–900 billion VND, World Bank + Carbon Fund + provincial support. Decision 2327 QD-UBND 2023.
ST Strategies (Strengths Against Threats)				
ST1: Climate-Resilient Crops	•Drought crop restructuring ≥ 15,000 ha (cassava, maize, pepper-coconut).	2024–2027; expansion 2030	DARD; Research Institutes	200–350 billion VND, climate adaptation funds.
ST2: Quality Compliance Centers	•2–3 export inspection centers meeting EU/US/China standards.	2025–2030	DARD; Provincial Trade Dept.	500–800 billion VND, PPP + enterprise compliance fees.
ST3: Land-Use Protection & Smart Zoning (GIS)	•No net loss of agricultural land in priority areas.	2024–2030	DONRE; GIS Centers	150–250 billion VND, land-use & digital planning budgets.
ST4: Retention of Youth Labor	•20% increase in youth employment in high-tech agriculture.	2026–2030	Youth Union + Tech Enterprises	200–300 billion VND, enterprise training contracts.
WT Strategies (Weakness & Threat Mitigation)				
WT1: Smart Disaster Risk Management	•Flood–drought GIS mapping for all districts.	2024–2027	DONRE; DARD	350–700 billion VND, climate resilience + disaster funds.
WT2: Branding vs Import Competition	•30 brand-protected value chains.	2024–2030	Provincial Trade Dept.; DARD	150–250 billion VND, export promotion funding.
WT3: Workforce Diversification	•≥ 20 smart-service/agri-tech occupations certified.	2025–2030	Vocational Institutes	100–180 billion VND national training budgets.
WT4: Robotic & Full Mechanization Deployment	•≥ 50% reduction in labor hours/ha.	2025–2030	DARD; Machinery Enterprises	1,200–1,800 billion VND, enterprise + PPP + ODA.

Although Table 6 establishes institutional feasibility, strategic pathways must also reflect the agro-ecological realities of Dong Nai's cropping pattern. Environmental adaptation cannot be uniform because climate sensitivity, water requirements, and value-chain potential vary significantly across crop types. Accordingly, this study develops a crop-specific adaptation menu that differentiates between staple and industrial crops (cassava, maize, sweet potato, rice) and high-value perennial fruit systems. These measures operationalize ST and WO strategies through practices such as drought-tolerant variety selection, IoT-enabled water management, minimum tillage, circular fertilizer inputs from livestock waste, and cold-chain linkages for post-harvest quality. Table 7 summarizes these targeted interventions.

In addition to the strategic pathways summarized above, crop-specific adaptation measures were developed to align environmental resilience with Dong Nai's actual cropping pattern. These measures differentiate between staple and industrial crops (cassava, maize, sweet potato, rice) and high-value perennial fruit systems, ensuring that climate adaptation corresponds directly to local production realities. Table 7 presents a targeted adaptation menu, incorporating drought-tolerant varieties, soil moisture management, IoT-enabled irrigation, and circular agriculture inputs derived from livestock by-products.

The incorporation of these KPIs and institutional roles directly links strategic planning to implementable outcomes, reflecting current provincial commitments under programs for high-tech agriculture, digital transformation, and climate resilience. Empirical evidence further supports the contention that a multi-dimensional approach to agricultural strategy—incorporating digital transformation, value-chain integration, and environmental adaptation—can yield more durable outcomes than production-oriented planning alone. The present study extends the contributions of Mitev [17] and Nguyen and Truong [18] by demonstrating that the SWOT–TOWS framework can be expanded to include eco-agriculture and technological innovation, thereby capturing the complex interplay between environmental pressures and socio-economic transitions. Similarly, the findings resonate with Do Thi et al. [19], who emphasize that digitalization and innovation constitute essential drivers of competitiveness in emerging agricultural economies. However, this research challenges the notion that policy design alone is sufficient; instead, it argues that institutional coordination and digital literacy remain critical bottlenecks preventing the realization of Dong Nai's strategic potential.

Despite the existence of governmental initiatives such as Resolution 08/2022/NQ-HDND and Decision 2327/QD-UBND [21], the province's rate of technological adoption and value-chain integration lags behind more advanced regions like Lam Dong, as well as international benchmarks [4]. This discrepancy suggests that Dong Nai's development trajectory is not constrained by strategic intent but by implementation inefficiencies and fragmented governance. Thus, the study emphasizes that institutional coherence, coordinated policy execution, and strengthened extension services are prerequisites for translating strategic frameworks into measurable outcomes.

Table 7. Climate adaptation menu for key crops in Dong Nai Province

Crop	Climate Risks	Recommended Adaptation Measures	Supporting Policies
Cassava (major industrial crop in Xuân Lộc, Cẩm Mỹ)	Drought, soil degradation, pest outbreaks	•Use high-yield drought-tolerant varieties (KM419, KM140). •Intercrop with coconut or pepper to reduce evapotranspiration. •Apply drip irrigation + moisture sensors. •Composting livestock waste into organic fertilizer to reduce soil depletion.	Decision 2327/QĐ-UBND (organic inputs + tech)
Maize (livestock feed crop in Thống Nhất, Trảng Bom)	Heat stress, drought, lower yields	•Adopt drought-tolerant hybrids (LVN10, NK66). •Mulching and minimum tillage to reduce water loss. •Smart fertilization based on soil sensors. •Integrate with biogas residue fertilizer from livestock.	Resolution 08/2022/NQ-HĐND (support for smart farming)
Sweet Potato (local food security crop in Cẩm Mỹ, Long Thành)	Irregular rainfall, pests, storage losses	•Ridge planting with plastic mulch to retain soil moisture. •Biological pest management (Bacillus thuringiensis). •Cold-chain storage linked to processing cooperatives.	Provincial OCOP & value-chain development program
Rice (smaller share but climate sensitive in Nhơn Trạch, Long Thành)	Salinity intrusion, flood risk, water scarcity	•Alternate Wetting and Drying (AWD) irrigation. •Short-cycle climate-resistant varieties (OM5451, ST24). •Laser land-leveling to reduce irrigation needs. •Flood-risk mapping using GIS for zoning.	DARD + DONRE climate zoning program
Fruit Trees (Durian, Jackfruit)	Extreme heat, pests, root rot	•Automated micro-sprinkler cooling systems. •Early warning via IoT pest-monitoring stations. •Organic soil amendments to reduce chemical stress.	Decision 2327/QĐ-UBND high-tech fruit zones
Livestock–Crop Integration (supports cassava, maize)	Waste accumulation, methane emissions	•Biogas + digestate reuse as organic fertilizer. •Circular feed models using cassava/maize by-products.	Circular Economy Pilot Program (World Bank, 2025)

Theoretically, this study contributes to ongoing debates about agricultural modernization in transitional economies. It substantiates Ellis's [26] and Todaro and Smith's [1] contention that development must transcend narrow productivity metrics and embrace social, technological, and environmental dimensions. Furthermore, it affirms Shvets et al.'s [8] proposition that smart specialization is essential for driving sustainable transformation, particularly when coupled with adaptive governance mechanisms. By synthesizing localized SWOT–TOWS applications with broader theoretical constructs such as Porter's [23] competitive advantage model and FAO's [2, 3] sustainability paradigms, the study bridges the gap between global theoretical frameworks and region-specific realities.

From a practical standpoint, the findings reinforce the argument that environmental sustainability and economic competitiveness are mutually reinforcing rather than conflicting objectives. Strengthening climate resilience through investments in climate-smart technologies, early warning systems, and water-efficient infrastructure is essential to mitigate the escalating risks associated with climate variability [6]. Moreover, the development of integrated value chains—supported by cooperative models, improved logistics, and product branding—can position Dong Nai's agriculture to meet the traceability and quality standards demanded by global markets. These measures are not merely technical recommendations but strategic imperatives for enhancing long-term competitiveness under liberalized trade regimes.

The weighting-based prioritization also reveals that digital transformation and human-capital development must be treated as enabling conditions rather than isolated solutions. Digital literacy programs, vocational training in smart agriculture, and enterprise–farmer–government partnerships are essential to amplify the benefits of IoT, smart irrigation, blockchain-linked traceability, and GIS-based land management.

In sum, this study advances the argument that the effective transformation of Dong Nai's agricultural sector depends not solely on identifying strategic priorities but on institutionalizing them through coordinated governance, technological capability, and environmental responsibility. By embedding empirical scoring, expert validation, and reliability testing into the SWOT–TOWS methodology, this research demonstrates that strategic planning can serve as a powerful instrument for reconciling growth, equity, and ecological stewardship. The resulting model provides both a conceptual advancement and a practical guide for provinces facing similar socio-economic and environmental transitions.

6. CONCLUSION

This study evaluated the strategic trajectory of Dong Nai's agricultural sector using an integrated SWOT–TOWS framework under conditions of climate change, market liberalization, and digital transformation. The analysis demonstrates that while the province holds significant structural advantages—fertile perennial-crop zones, proximity to major logistics hubs, and a dynamic labor base—its agricultural development remains constrained by low technological penetration, fragmented value chains, and ongoing labor transitions toward non-farm sectors. When combined with increasing climate variability and import competition, these weaknesses underscore the imperative for timely, adaptive, and sustainability-oriented planning.

Through empirical scoring and expert validation (Cohen's $\kappa = 0.71$), five strategic priorities emerged. SO and ST strategies are positioned as highest-impact interventions due to their role in export competitiveness, climate resilience, and value-chain upgrading—especially in durian, coffee, jackfruit, and other high-value crops. WO and WT strategies, while essential, require greater institutional coordination and financing before generating full returns. These findings provide a sequenced pathway for policy execution, in alignment with Decision 2327/QĐ-UBND [21] on high-tech agricultural development and Resolution 08/2022/NQ-HĐND on digital innovation and sustainable farming.

Theoretically, the study contributes a hybrid sustainability–strategy model by embedding climate adaptation, digital transformation, and smart specialization into a classical SWOT–TOWS framework. This enriches strategic-management literature by demonstrating how adaptive governance and technological ecosystems can jointly accelerate sustainable agricultural transitions. Practically, the research offers a replicable and evidence-driven tool for provincial agricultural planning, particularly in emerging economies where climate shocks, fragmented markets, and technological gaps compound systemic vulnerabilities.

The operationalization of strategies into measurable indicators—KPIs, timelines, financing sources, lead agencies, and crop-specific adaptation menus—strengthens accountability and facilitates policy monitoring. The full implementation framework and KPI matrix are detailed in Appendix Table B1. This alignment with SDG 2 (Zero Hunger), SDG 9 (Industry, Innovation and Infrastructure), and SDG 13 (Climate Action) illustrates how subnational agricultural planning can actively contribute to global sustainability commitments. The findings further emphasize that climate resilience, digital literacy, and circular agriculture (e.g., biogas–organic fertilizer loops) are not marginal options but foundational pillars for achieving a competitive and low-carbon agricultural economy.

Beyond Dong Nai, the proposed framework provides a scalable model for Vietnam and other transitioning regions seeking to modernize agriculture while upholding environmental stewardship. However, future research should incorporate longitudinal farmer-level data, advanced decision-support tools (e.g., AHP, fuzzy modeling), and digital-traceability analytics to deepen micro-level insights and refine strategic weighting. Ultimately, this study reinforces that effective agricultural transformation depends not only on identifying priorities but on institutionalizing them through coordinated governance, inclusive capacity building, and climate-responsive technological investment—thereby advancing resilient, innovative, and inclusive agricultural growth.

7. LIMITATIONS AND FUTURE RESEARCH

This study presents a strategic framework for the sustainable development of Dong Nai's agricultural sector through a SWOT–TOWS analysis; however, several limitations warrant acknowledgment. First, the research is based mainly on secondary data from official reports and yearbooks, which, despite their credibility, may not capture farmers' real-time perspectives or recent shifts in technology and markets. The absence of primary data such as stakeholder

surveys or interviews may limit the contextual depth of findings.

Second, while the SWOT–TOWS approach provides a structured basis for strategy formulation, it still involves interpretive judgment in selecting and ranking strategic factors. Although an expert scoring system and reliability testing (Cohen's $\kappa = 0.71$) were applied to reduce subjectivity, the weighting process would benefit from more advanced quantitative validation techniques such as the Analytic Hierarchy Process (AHP), fuzzy modeling, or multi-criteria decision analysis.

Third, the agricultural environment of Dong Nai is rapidly evolving under the influence of climate change, trade dynamics, and digital transformation. As such, the proposed strategies require periodic reassessment to ensure continued relevance. Future studies should adopt longitudinal tracking to verify whether prioritized strategies (e.g., digital agriculture, climate-smart production, value-chain integration) maintain their relative impact under changing environmental and market conditions.

Future research should integrate primary data collection and participatory methods to refine the understanding of local needs and validate proposed strategies. Combining qualitative insights with multi-criteria decision-making tools (e.g., AHP, ANP, fuzzy logic) would enhance the robustness of prioritization. Additionally, research exploring the cost-effectiveness and scalability of digital and climate-smart agricultural practices would provide stronger evidence for investment planning. Longitudinal and comparative studies—examining digitalization, circular economy adoption, and climate-smart practices across provinces or countries—would deepen insights into adaptive policy design. Further exploration of governance and public–private collaboration mechanisms is also recommended to strengthen institutional capacity for sustainable agricultural transformation in emerging economies.

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NOMENCLATURE

κ kappa

APPENDIX

Appendix A. Yearly data supporting Figure 2 (Agricultural labor productivity, 2019–2023)

Table A1. Yearly labor productivity data and year-over-year growth supporting Figure 2 (2019–2023)

Year	Labor Productivity (million VND/worker)	YoY Growth (%)
2019	115.0	—
2020	161.1	40.09%
2021	174.4	8.26%
2022	185.9	6.59%
2023	189.5	1.94%

Source: Dong Nai Statistics Office, 2024

Appendix A2. Scoring Sheet for SWOT Factor Prioritization and Expert Panel Composition

To reduce subjectivity in the SWOT–TOWS matrix and ensure transparency in prioritizing strategic factors, each SWOT element was evaluated on a 1–5 relevance scale, where 1 indicates minimal significance and 5 represents critical importance to Dong Nai's agricultural development. Scores were assigned based on statistical evidence from provincial data, government strategies, and observed market trends.

Table A2. Scoring Sheet for SWOT Factors

Code	SWOT Factor	Score (1–5)	Panel Justification
S1	Extensive and diverse perennial agricultural land	5	Provides high-value crop portfolio (durian, banana, coffee) with strong export potential and suitability to basalt soil conditions.
S2	Strategic location with multimodal logistics	4	Reduces delivery time and logistics cost; airport, ports, expressways enhance competitiveness for high-value perishable exports.
S3	Abundant rural labor force with crop-specific experience	4	Supports labor-intensive perennial crop production (e.g., durian, pepper), but requires skill upgrading for digital and climate-smart agriculture.
S4	Increasing productivity and output value per hectare	5	Productivity growth of nearly 65% (2019–2023) strengthens cost efficiency and access to demanding markets (see Figure 2).
W1	High sensitivity to weather and disasters	5	Frequent drought/flood losses impair perennial crops; major cause of unstable farm incomes and technology demand.
W2	Limited adoption of high-tech farming	4	Smart irrigation and greenhouse usage remain below 1%; high entry cost restricts smallholders despite policy incentives.
W3	Low labor productivity relative to industry	3	Productivity rising but still lower than industrial labor; mechanization and technical skills gap persist.
W4	Fragmented production and weak value chains	5	Household farming hinders traceability, deep processing, and FTA compliance; cooperatives and enterprise links remain limited.
O1	Free trade agreements (EVFTA, CPTPP, RCEP)	4	Preferential tariffs and market access for fruit/industrial crops but require strict standards and certification.
O2	Growing demand for eco/organic agriculture & agri-tourism	3	Market trend positive, but organic baseline area remains small; scalability dependent on incentives and training.
O3	Policies supporting digital and high-tech agriculture	4	Resolution 08/2022/NQ-HDND and digital programs offer financing, training, and technology access; implementation rate remains uneven.
O4	Foreign investment and international cooperation	3	Opportunities present (Japan, Netherlands), but dependent on infrastructure readiness and market linkage.
T1	Climate variability (heat stress, rainfall fluctuation)	5	Directly threatens perennial crops and water availability; adaptation is essential for long-term productivity.
T2	Competition from imported and regional products	4	Strong competition (Thailand durian, Dak Lak coffee, Lam Dong vegetables) in both price and value-added branding.
T3	Pressure for land conversion to industry/urban uses	4	Reduces agricultural land base and increases production cost; especially in peri-urban districts (Bien Hoa, Long Thanh).
T4	Labor migration to industry and services	3	Labor shift restricts skill retention; mitigable through high-income smart farming and agri-tourism models.

Expert panel composition and robustness of scoring

The scoring was performed by a 5-member expert panel composed of:

•Three agricultural economists specializing in value-chain development, farm competitiveness, and trade policy.

•One agronomist experienced in perennial crop cultivation, organic farming, and smart irrigation systems.

•One provincial agricultural-extension specialist with over 10 years of field expertise in farmer training and technology transfer.

To assess consistency, inter-rater reliability was calculated using Cohen's κ (kappa) coefficient, resulting in: $\kappa = 0.71$, indicating substantial agreement among evaluators.

This statistical reliability measure enhances the credibility of the SWOT–TOWS prioritization, reduces subjectivity, and provides a verifiable methodological basis for strategic formulation.

Appendix B. Short KPI definitions for agricultural strategy implementation (2024–2030)

Table B1. Short KPI Definitions for Strategic Pathway Monitoring (2024–2030)

KPI	Definition (Measurable Indicator)	Measurement Source
Export-standard cultivated area (ha)	Total area certified under VietGAP, GlobalGAP, or equivalent FTAs export standards for durian, banana, jackfruit, coffee, pepper.	Certification records of DARD; Cooperative contracts.
Certified agricultural brands (OCOP/VietGAP/GlobalGAP)	Number of branded agricultural products receiving official quality certification (OCOP, organic, GAP).	Provincial OCOP Office; DARD quality inspection.
Ecotourism farm models	Agricultural production sites offering integrated tourism services and receiving district/provincial approval.	Tourism Dept. & District People's Committees.
Smart irrigation area (ha)	Land area using automated IoT irrigation systems or water-efficient digital control systems.	Irrigation Dept.; High-Tech Centers; Field audits.
IoT-monitored production area (ha)	Area equipped with IoT sensors for pest monitoring, climate control, soil moisture, and yield prediction.	High-Tech Agricultural Centers; Enterprise reports.
Greenhouse/net-house development (ha)	Area of high-tech controlled-environment structures used for high-value horticulture.	DARD statistics & PPP investment reports.
Number of cooperatives with traceability systems	Cooperatives using blockchain, QR traceability, or digital ledger systems for export or domestic retail compliance.	Cooperative Alliance; DTI digital database.
Farmers trained per year (persons)	Number of participants completing certified vocational training in digital agriculture, standards compliance, or mechanization.	Vocational Colleges; Agricultural Extension Centers.
Mechanization rate (%)	Share of farming operations using machines in land	DARD mechanization surveys;

	preparation, planting, cultivation, and harvesting.	Enterprise leasing data.
Organic agricultural area (ha)	Certified organic land conforming to national or international organic standards.	Certification bodies; Organic Agriculture Office.
Climate-resilient crop restructuring (ha)	Area converted to drought-/flood-tolerant crops or mixed systems (pepper–coconut, cassava varieties, etc.).	DARD crop-transition programs; District annual reports.
Inspection/compliance centers established	Provincial-level laboratories/testing facilities compliant with EU/US/China import standards.	Provincial Trade Dept.; Food Safety & Inspection Center.
Agricultural youth employment (%)	Percentage of agricultural workforce aged 18–35 in high-tech or value-added agricultural jobs.	Labor Dept.; Youth Union; Cooperative workforce data.
Smart disaster-risk mapping coverage (districts)	Number of districts with GIS-based flood and drought risk maps integrated into agricultural zoning.	DONRE; GIS Centers; Provincial environmental database.
Agricultural value chains with brand protection	Number of registered and certified value chains (raw material zones + processing + branding + traceability).	Trade Dept.; OCOP program; Cooperative Alliance.