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Green Innovation, Sustainable Agricultural Practices and Modern Farm Management Affecting Farm Performance of Agricultural Enterprises (SDG 2) in Thailand

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Abstract

This study aimed to examine the causal relationships among Green Innovation, Sustainable Agricultural Practices, Modern Farm Management, and Farm Performance of agricultural enterprises (SDG 2) in Thailand. A synthetic dataset representing 400 agricultural enterprises was generated for methodological demonstration and analyzed through Confirmatory Factor Analysis (FCA) and Structural Equation Modeling (SEM). The results demonstrated that the structural model achieved satisfactory fit with the simulated covariance matrix ($\chi^2 = 214.638$, df = 194, p = 0.148, $\chi^2/df = 1.106$, GFI = 0.932, NFI = 0.941, TLI = 0.986, CFI = 0.991, RMSEA = 0.016, RMR = 0.031, and SRMR = 0.029). Green Innovation and Sustainable Agricultural Practices had positive direct effects on Modern Farm Management and Farm Performance ($\beta = 0.428$, $p < 0.001$, ($\beta = 0.391$, $p < 0.001$), while Modern Farm Management had the strongest direct effect on Farm Performance ($\beta = 0.512$, $p < 0.001$). Modern Farm Management also mediated the relationships between Green Innovation and Farm Performance ($\beta = 0.219$, $p < 0.001$), and between Sustainable Agricultural Practices and Farm Performance Farm Performance of Agricultural Enterprises in Thailand ($\beta = 0.200$, $p < 0.001$). The findings illustrate an integrated capability-based explanation in which environmental innovation and sustainable production create potential value, whereas modern managerial capability converts that potential into financial, operational, market, environmental, and resilience outcomes.

Keywords: *Green Innovation; Sustainable Agricultural Practices; Modern Farm Management; Farm Performance of Agricultural Enterprises (SDG 2).*

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Introduction

Agricultural enterprises are increasingly required to reconcile productivity and commercial viability with environmental responsibility because farming systems now operate under intensifying climate variability, rising input costs, declining natural-resource quality, and growing market expectations for environmentally responsible production. Within this context, Green Innovation has emerged as an

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important organizational capability through which agricultural enterprises develop or improve products, production processes, technologies, managerial systems, and resource-utilization methods that reduce environmental impacts while preserving economic value. Green product innovation can support the development of safer, traceable, low-carbon, and environmentally differentiated agricultural products, whereas green process and technology innovation can reduce energy consumption, chemical dependence, waste generation, and production losses. Green management innovation further incorporates environmental objectives into organizational planning, coordination, and evaluation, while resource-efficient innovation enables enterprises to obtain greater value from limited land, water, energy, materials, and financial resources. Chi (2022) demonstrated that operational capability, technology spillovers, environmental awareness, and health concerns are important drivers of green innovation in agricultural production. Shi et al. (2024) similarly found that agricultural green technological innovation contributes to low-carbon production performance and carbon productivity. These findings suggest that Green Innovation should be viewed as an integrated strategic capability rather than the isolated adoption of environmentally friendly equipment or techniques.

In Thailand, the strategic importance of Green Innovation is heightened by the economic role and structural vulnerability of the agricultural sector. Agriculture remains closely connected with rural livelihoods, food security, employment, exports, and regional economic development, yet agricultural enterprises operate under increasing exposure to drought, flooding, heat stress, water shortages, market volatility, and changing environmental standards. The World Bank (2025) reported that climate-related flooding, water scarcity, coastal erosion, and heat stress create substantial risks for agriculture, industry, and tourism, and that Thailand's competitiveness will increasingly depend on its response to the global transition toward low-carbon goods and services. Although Thailand has promoted the Bio-Circular-Green Economy and other sustainability-oriented policies, the capacity to implement green technologies and convert them into enterprise outcomes remains uneven. Differences in financial resources, technical knowledge, data capability, managerial readiness, market access, and institutional support mean that Green Innovation cannot be assumed to generate equivalent results across all enterprises. Consequently, there is a need to examine how enterprise-level innovation interacts with sustainable production practices and managerial capabilities within Thailand's economic and environmental conditions.

Sustainable Agricultural Practices constitute a second essential foundation for the transformation of agricultural enterprises because they translate sustainability principles into recurring production and resource-management activities. In this study, these practices comprise Sustainable Soil Management, Efficient Water Management, Reduction of Agricultural Chemicals, Waste and Resource Circulation Management, and Biodiversity Conservation. Sustainable soil management protects soil structure, fertility, organic matter, and biological activity while reducing erosion and degradation. Efficient water management improves irrigation planning, monitoring, recycling, and conservation under uncertain rainfall conditions. The reduction of agricultural chemicals can limit environmental contamination and health risks while encouraging integrated approaches to pest and nutrient management. Waste and resource circulation management enables residues, nutrients, water, organic materials, and agricultural by-products to be reused within production systems. Biodiversity conservation contributes to ecological balance, pollination, biological pest control, genetic-resource protection, and resilience. Boros et al. (2025) concluded that innovative agricultural practices can support long-term agricultural activity and economic resilience, although their effects depend on technological integration, local conditions, and implementation capacity. Țopa et al. (2025) likewise emphasized that sustainable soil practices contribute to soil health, crop quality, and resilience. Olarewaju et al. (2025) further showed that integrated sustainable practices can strengthen soil fertility, water-use efficiency, productivity, and climate resilience.

Modern Farm Management is particularly important in explaining how Green Innovation and Sustainable Agricultural Practices are converted into superior enterprise outcomes. Agricultural enterprises may acquire environmentally friendly technologies, introduce green products, or adopt soil, water, and biodiversity practices, yet these initiatives will not automatically improve performance unless they are integrated into managerial decision making, organizational learning, resource allocation, and risk control. Modern Farm Management therefore consists of Data-Driven Decision Making, Agile and Adaptive Management, Knowledge-Based Management, Risk and Resilience Management, and Strategic Resource Allocation. Choruma et al. (2024) found that digital extension services, mobile

applications, and agricultural technologies can improve access to information, services, and markets, although their benefits depend on infrastructure, skills, affordability, and institutional support. Previous studies have generally examined technology adoption, sustainable practices, or productivity separately and have given less attention to Modern Farm Management as the organizational mechanism through which Green Innovation and Sustainable Agricultural Practices influence performance.

In practice, agricultural enterprises increasingly employ precision irrigation, soil and crop monitoring, digital farm records, renewable-energy systems, biological pest control, traceability platforms, waste-to-value processes, and climate-risk information. These applications provide a practical basis for examining the four constructs within a single structural model because technical innovation, sustainable production, and managerial coordination are interdependent. Green Innovation provides new products, processes, technologies, management approaches, and resource-efficient solutions. Sustainable Agricultural Practices establish the operational routines through which soil, water, chemicals, waste, and biodiversity are managed responsibly. Modern Farm Management represents the decision-making and coordination mechanism through which these innovations and practices are organized, adapted, and aligned with enterprise priorities. Farm Performance represents the resulting economic, operational, market, environmental, and resilience outcomes. Examining the constructs in isolation would therefore fail to explain how environmental and technological investments are translated into enterprise value (Chi, 2022; Choruma et al., 2024).

Farm Performance is the central outcome of the proposed model because the success of agricultural enterprises cannot be assessed solely through short-term revenue, yield, or profitability. In this study, Farm Performance is conceptualized as a multidimensional construct comprising Financial Performance, Operational Efficiency, Market Performance, Environmental Performance, and Enterprise Resilience and Sustainability. This broader conceptualization is necessary because an enterprise may increase output temporarily while degrading soil, accumulating financial risk, or becoming more vulnerable to climate disruption. Conversely, investments in green technologies, sustainable practices, and data-based management may generate delayed benefits through lower resource costs, stronger reputation, regulatory compliance, premium-market access, and improved risk control. Reviews of farm sustainability emphasize that economic, environmental, and organizational outcomes should be considered jointly rather than as isolated dimensions (Boros et al., 2025; Olarewaju et al., 2025).

Accordingly, this study examines the causal relationships among Green Innovation, Sustainable Agricultural Practices, Modern Farm Management, and Farm Performance of agricultural enterprises in Thailand. Confirmatory Factor Analysis is applied to validate the measurement structure of the four latent constructs, and Structural Equation Modeling is used to test the proposed direct and indirect relationships. The study contributes theoretically by integrating environmental innovation, sustainable production practices, and managerial capability within a unified explanation of multidimensional Farm Performance. It contributes methodologically by demonstrating a mediation model through covariance-based SEM and contributes managerially by identifying whether investments in green products, processes, technologies, and sustainable practices must be accompanied by stronger data-driven, adaptive, knowledge-based, risk-oriented, and resource-allocation capabilities. Because the current manuscript uses simulated data, the model is presented as a methodological demonstration requiring subsequent validation with field data from owners, managers, executives, or authorized representatives of agricultural enterprises in Thailand (Kline, 2023).

Research Objectives

1. To validate the constructs of Green Innovation (GI), Sustainable Agricultural Practices (SAP), Modern Farm Management (MFM), and Farm Performance (FP) of agricultural enterprises in Thailand.
2. To examine the causal relationships among Green Innovation (GI), Sustainable Agricultural Practices (SAP), Modern Farm Management (MFM), and Farm Performance (FP) of agricultural enterprises in Thailand.
3. To examine the mediating role of Modern Farm Management (MFM) in the relationships between Green Innovation (GI), Sustainable Agricultural Practices (SAP), and Farm Performance (FP) of agricultural enterprises in Thailand.

Research Hypotheses
H1: Green Innovation has a positive direct effect on Modern Farm Management.
H2: Sustainable Agricultural Practices have a positive direct effect on Modern Farm Management.
H3: Modern Farm Management has a positive direct effect on Farm Performance.
H4: Green Innovation has a positive direct effect on Farm Performance.
H5: Sustainable Agricultural Practices have a positive direct effect on Farm Performance.
H6: Modern Farm Management mediates the relationship between Green Innovation and Farm Performance.
H7: Modern Farm Management mediates the relationship between Sustainable Agricultural Practices and Farm Performance.

Literature Review

Green Innovation (GI)
Green Innovation refers to the capability of an agricultural enterprise to develop and implement environmentally responsible products, processes, technologies, managerial practices, and resource-use systems that reduce ecological impacts while maintaining or improving economic value. It is conceptualized as a higher-order construct consisting of Green Product Innovation, Green Process Innovation, Green Technology Innovation, Green Management Innovation, and Resource-Efficient Innovation. These dimensions are distinct but mutually reinforcing because environmentally differentiated products cannot be sustained without cleaner processes, suitable technologies, supportive management systems, and efficient resource allocation. Chi (2022) found that farm operational capability and technology spillovers exerted positive effects on green innovation and economic performance. Shi et al. (2024) similarly showed that agricultural green technological innovation improves low-carbon production performance and carbon productivity. These findings support treating Green Innovation as a multidimensional organizational capability rather than a narrowly technical activity.

From the Natural Resource-Based View, agricultural enterprises can develop competitive value when they transform environmental constraints into firm-specific capabilities involving cleaner production, resource productivity, product differentiation, and accumulated organizational knowledge. Nevertheless, Green Innovation does not automatically produce superior performance. Its benefits depend on whether the enterprise possesses the managerial capacity to align innovation with production decisions, market conditions, environmental requirements, and long-term resource strategies. Green Innovation is therefore positioned as an antecedent of both Modern Farm Management and Farm Performance.

Sustainable Agricultural Practices (SAP)
Sustainable Agricultural Practices refer to systematic production and resource-management methods that maintain productivity while conserving natural resources, reducing environmental harm, and strengthening long-term resilience. The construct consists of Sustainable Soil Management, Efficient Water Management, Reduction of Agricultural Chemicals, Waste and Resource Circulation Management, and Biodiversity Conservation. Țopa et al. (2025) emphasized that soil health is fundamental to crop productivity, environmental resilience, and ecosystem stability. Boros et al. (2025) found that innovative sustainable practices offer substantial opportunities for resource efficiency, environmental protection, and long-term agricultural viability, although adoption remains constrained by costs, technical complexity, infrastructure gaps, and differences in local conditions.
The contribution of Sustainable Agricultural Practices to enterprise performance depends on the consistency, quality, and managerial integration of implementation. Soil restoration, water-saving technologies, chemical reduction, resource circulation, and biodiversity conservation require changes in production scheduling, investment priorities, monitoring systems, workforce knowledge, supplier relationships, and risk-management procedures. Sustainable Agricultural Practices are consequently positioned as an antecedent of both Modern Farm Management and Farm Performance.

Modern Farm Management (MFM)
Modern Farm Management refers to the systematic capability of an agricultural enterprise to integrate data, knowledge, adaptive decision making, risk control, and strategic resource allocation into farm

operations. It comprises Data-Driven Decision Making, Agile and Adaptive Management, Knowledge-Based Management, Risk and Resilience Management, and Strategic Resource Allocation. Soussi et al. (2024) emphasized that smart sensors and integrated agricultural data are fundamental to data-driven decision making because they enable continuous monitoring and more precise optimization of field conditions. Choruma et al. (2024) and Shao et al. (2025) likewise found that digital services and agricultural technologies can improve access to information, services, and markets, although their benefits depend on infrastructure, digital skills, affordability, and institutional support.

Across the five dimensions, data-driven decision making provides the informational foundation, agile management enables timely adjustment, knowledge management supports organizational learning, risk and resilience management protects continuity, and strategic resource allocation converts priorities into coordinated action. These dimensions function as an integrated managerial system. Modern Farm Management is consequently positioned as a direct antecedent of Farm Performance and as a mediating mechanism linking Green Innovation and Sustainable Agricultural Practices with Farm Performance.

Farm Performance (FP)

Farm Performance refers to the extent to which an agricultural enterprise achieves desirable economic, operational, market, environmental, and long-term sustainability outcomes. It is conceptualized as a higher-order construct comprising Financial Performance, Operational Efficiency, Market Performance, Environmental Performance, and Enterprise Resilience and Sustainability. These dimensions cannot be evaluated independently because an enterprise may improve revenue while increasing environmental pressures or may reduce resource consumption without achieving sufficient economic viability. Farm Performance should therefore be treated as a multidimensional organizational outcome rather than as a narrow measure of yield, sales, or profitability.

Financial Performance and Operational Efficiency remain essential because agricultural enterprises must generate adequate returns while managing biological production cycles, price volatility, input costs, and resource constraints. Market Performance considers whether environmental and operational capabilities are transformed into customer acceptance, market access, and product differentiation. Environmental Performance measures reductions in pollution, emissions, waste, and excessive resource consumption. Enterprise Resilience and Sustainability capture the ability to withstand shocks, adapt strategies, protect productive resources, and remain viable over time.

Across the four constructs, the five dimensions of each construct are theoretically distinguishable yet functionally interdependent. Green Innovation provides environmentally differentiated products and cleaner production routines. Sustainable Agricultural Practices protect the productive resource base and reduce ecological risks. Modern Farm Management provides information, learning, adaptation, risk control, and coordinated resource allocation. Farm Performance captures the consequences through financial, operational, market, environmental, and resilience outcomes. These interdependencies support treating GI, SAP, MFM, and FP as coherent higher-order constructs in the structural model.

Research Conceptual Framework

Based on the reviewed literature and proposed hypotheses, Green Innovation is expected to enhance Modern Farm Management and Farm Performance. Sustainable Agricultural Practices are also expected to strengthen Modern Farm Management and Farm Performance. Modern Farm Management is expected to exert a positive direct effect on Farm Performance and to mediate the relationships between Green Innovation, Sustainable Agricultural Practices and Farm Performance. The framework is grounded principally in the Natural Resource-Based View and Dynamic Capabilities perspective. Green Innovation and Sustainable Agricultural Practices represent environmental and operational capabilities, whereas Modern Farm Management represents the dynamic managerial capability through which those resources are coordinated and reconfigured. Accordingly, the model proposes five direct relationships and two indirect relationships through Modern Farm Management.

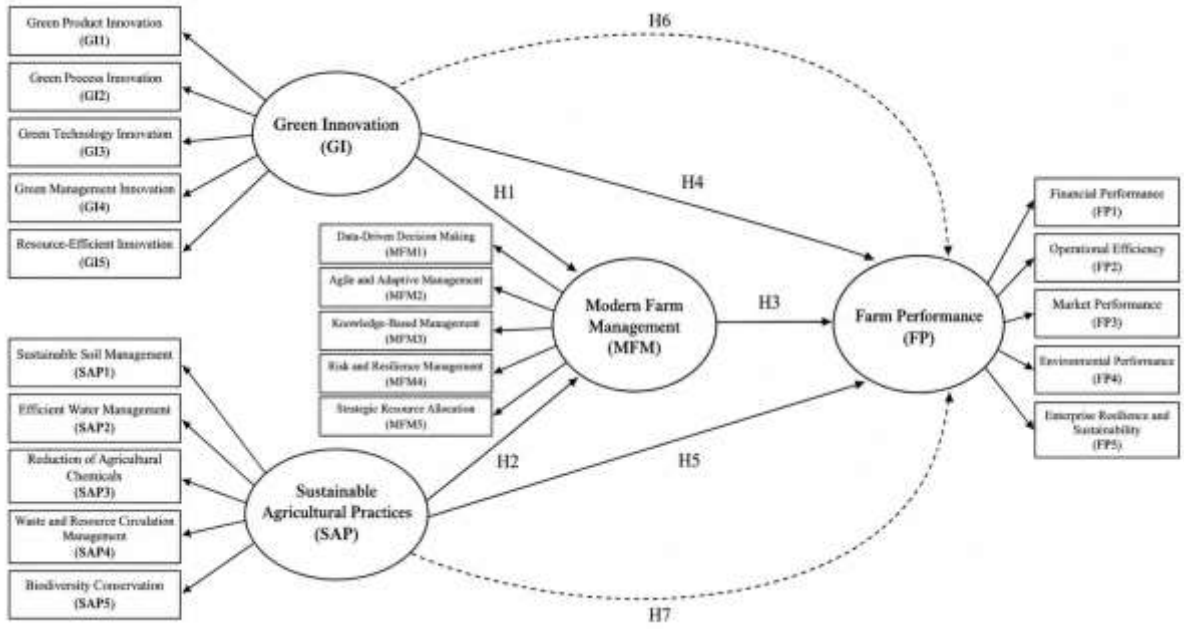

Figure 1. **Conceptual Framework of the Study**

Methodology

Research Design

This study employed a quantitative research methodology to test the causal relationships among Green Innovation, Sustainable Agricultural Practices, Modern Farm Management and Farm Performance. The analytical process followed a two-step structural equation modeling procedure. First, Confirmatory Factor Analysis was used to validate the measurement models. Second, covariance-based Structural Equation Modeling was applied to test five direct effects and two indirect effects transmitted through Modern Farm Management.

Population and Sample

The conceptual target population consisted of owners, managers, executives, or authorized representatives of agricultural enterprises operating in Thailand. One qualified respondent represented each enterprise because the unit of analysis was the agricultural enterprise. The sample consisted of 400 agricultural enterprises, determined by applying the rule of selecting 20 respondents for each observed indicator (20×20 = 400). This sample size was selected to provide stable maximum-likelihood estimation, model-fit evaluation, construct validation, and bootstrap testing for a model containing four higher-order latent constructs and twenty observed dimensions (Kline, 2023).

Research Instrument

A structured questionnaire was designed with five sections. The first section collected respondent and enterprise characteristics. The second section measured Green Innovation through five dimensions. The third section measured Sustainable Agricultural Practices through five dimensions. The fourth section measured Modern Farm Management through five dimensions. The fifth section measured Farm Performance through five dimensions.

Each dimension was evaluated through the five-point Likert scale. The research questionnaire was reviewed by five experts to find the Index of Item-Objective Congruence and the IOC values for Green Innovation, Sustainable Agricultural Practices, Modern Farm Management and Farm Performance were 0.910, 0.815, 0.856 and 0.819 respectively. A pilot test conducted with 30 non-sample respondents yielded the reliability values of 0.823 for Green Innovation, 0.825 for Sustainable Agricultural Practices,0.915 for Modern Farm Management and 0.829 for Farm Performance.

Data Collection Procedure

For an empirical replication, data were collected through online and field-based channels in collaboration with agricultural enterprise networks, producer associations, cooperatives, public

agencies, and professional contacts across Thailand. Only one qualified respondent was retained per enterprise. Participation was voluntary and anonymous, and returned questionnaires were screened for completeness, duplicate representation, repetitive response patterns, inconsistent answers, and unusually short completion times. Procedural and statistical controls were used to reduce common method bias.

Data Analysis

Data were analyzed through a two-step procedure as follows: (1) Confirmatory Factor Analysis (CFA) was performed to evaluate the measurement model by examining standardized factor loadings, convergent validity, composite reliability, and discriminant validity. Factor loadings of 0.70, Average Variance Extracted (AVE) values greater than 0.50, and Composite Reliability (CR) values greater than 0.70 were considered acceptable; and (2) Structural Equation Modeling (SEM) was employed to test hypothesized direct and mediated relationships. Model fit was evaluated using $\chi^2/df < 3.00$, CFI > 0.90, TLI > 0.90, RMSEA < 0.08, and RMR < 0.08 (Hair et al., 2019). Discriminant validity was assessed using the Fornell–Larcker (1981) criterion and the Heterotrait-Monotrait (HTMT) ratio with a threshold of 0.85 (Henseler et al., 2015; Kline, 2023).

Results

Measurement Model

Confirmatory Factor Analysis indicated that the measurement model of the four latent constructs demonstrated acceptable convergent validity and reliability. Standardized factor loadings ranged from 0.816 to 0.864. Green Innovation showed AVE = 0.704 and CR = 0.922. Sustainable Agricultural Practices demonstrated AVE = 0.691 and CR = 0.918. Modern Farm Management achieved AVE = 0.716 and CR = 0.926. Farm Performance demonstrated AVE = 0.724 and CR = 0.929. All AVE values exceeded 0.50 and all CR values exceeded 0.70 (Table 1).

Table 1. *Summary of Confirmatory Factor Analysis Results*

Construct and measurement dimensions	Code	Factor loading	AVE	CR
Green Innovation (GI)			0.704	0.922
Green Product Innovation	GI1	0.842		
Green Process Innovation	GI2	0.861		
Green Technology Innovation	GI3	0.831		
Green Management Innovation	GI4	0.836		
Resource-Efficient Innovation	GI5	0.825		
Sustainable Agricultural Practices (SAP)			0.691	0.918
Sustainable Soil Management	SAP1	0.824		
Efficient Water Management	SAP2	0.839		
Reduction of Agricultural Chemicals	SAP3	0.816		
Waste and Resource Circulation Management	SAP4	0.847		
Biodiversity Conservation	SAP5	0.829		
Modern Farm Management (MFM)			0.716	0.926
Data-Driven Decision Making	MFM1	0.853		
Agile and Adaptive Management	MFM2	0.842		
Knowledge-Based Management	MFM3	0.861		
Risk and Resilience Management	MFM4	0.836		
Strategic Resource Allocation	MFM5	0.838		
Farm Performance (FP)			0.724	0.929
Financial Performance	FP1	0.864		
Operational Efficiency	FP2	0.852		
Market Performance	FP3	0.843		
Environmental Performance	FP4	0.848		

Construct and measurement dimensions	Code	Factor loading	AVE	CR
Enterprise Resilience and Sustainability	FP5	0.848		

Discriminant Validity

Discriminant validity was assessed using the Fornell-Larcker criterion. The square roots of AVE for Green Innovation, Sustainable Agricultural Practices, Modern Farm Management, and Farm Performance were 0.839, 0.831, 0.846, and 0.851, respectively. Each diagonal value exceeded the corresponding inter-construct correlations, indicating adequate discriminant validity (Table 2).

Table 2. *Correlation Matrix of Latent Variables and Square Roots of AVE*

Latent variables	GI	SAP	MFM	FP
Green Innovation GI	**0.839**			
Sustainable Agricultural Practices SAP	0.562	**0.831**		
Modern Farm Management MFM	0.648	0.621	**0.846**	
Farm Performance FP	0.571	0.548	0.692	**0.851**

Note. Diagonal values represent the square roots of AVE. Off-diagonal values represent correlations among latent constructs.

Structural Model Fit

The structural model demonstrated satisfactory fit with the simulated covariance matrix: $\chi^2 = 214.638$, df = 194, p = 0.148, $\chi^2/df = 1.106$, GFI = 0.932, NFI = 0.941, TLI = 0.986, CFI = 0.991, RMSEA = 0.016, RMR = 0.031, and SRMR = 0.029. All indices met the predetermined acceptance criteria (Table 3).

Table 3. *Model Fit Indices of the Structural Model*

Fit index	Criterion	Obtained value
χ^2	—	214.638
df	—	194
χ^2/df	< 3.00	1.106
p-value	> 0.05	0.148
GFI	> 0.90	0.932
NFI	> 0.90	0.941
TLI	> 0.90	0.986
CFI	> 0.90	0.991
RMSEA	< 0.08	0.016
RMR	< 0.08	0.031
SRMR	< 0.08	0.029

Direct and Indirect Effects

All five direct effects were positive and statistically significant. Green Innovation positively affected Modern Farm Management ($\beta = 0.428$, $p < 0.001$), supporting H1. Sustainable Agricultural Practices positively affected Modern Farm Management ($\beta = 0.391$, $p < 0.001$), supporting H2. Modern Farm Management had the strongest direct effect on Farm Performance ($\beta = 0.512$, $p < 0.001$), supporting H3. Green Innovation directly affected Farm Performance ($\beta = 0.238$, $p < 0.001$), supporting H4, and Sustainable Agricultural Practices directly affected Farm Performance ($\beta = 0.205$, $p < 0.001$), supporting H5. Bootstrap analysis showed significant indirect effects of Green Innovation on Farm Performance through Modern Farm Management ($\beta = 0.219$, 95% CI [0.154, 0.292]) and Sustainable Agricultural Practices on Farm Performance through Modern Farm Management ($\beta = 0.200$, 95% CI

[0.137, 0.271]), supporting H6 and H7 (Figure 2 and Table 4). Because the corresponding direct effects remained significant, Modern Farm Management partially mediated both relationships. The model explained 52.4% of the variance in Modern Farm Management and 67.8% of the variance in Farm Performance.

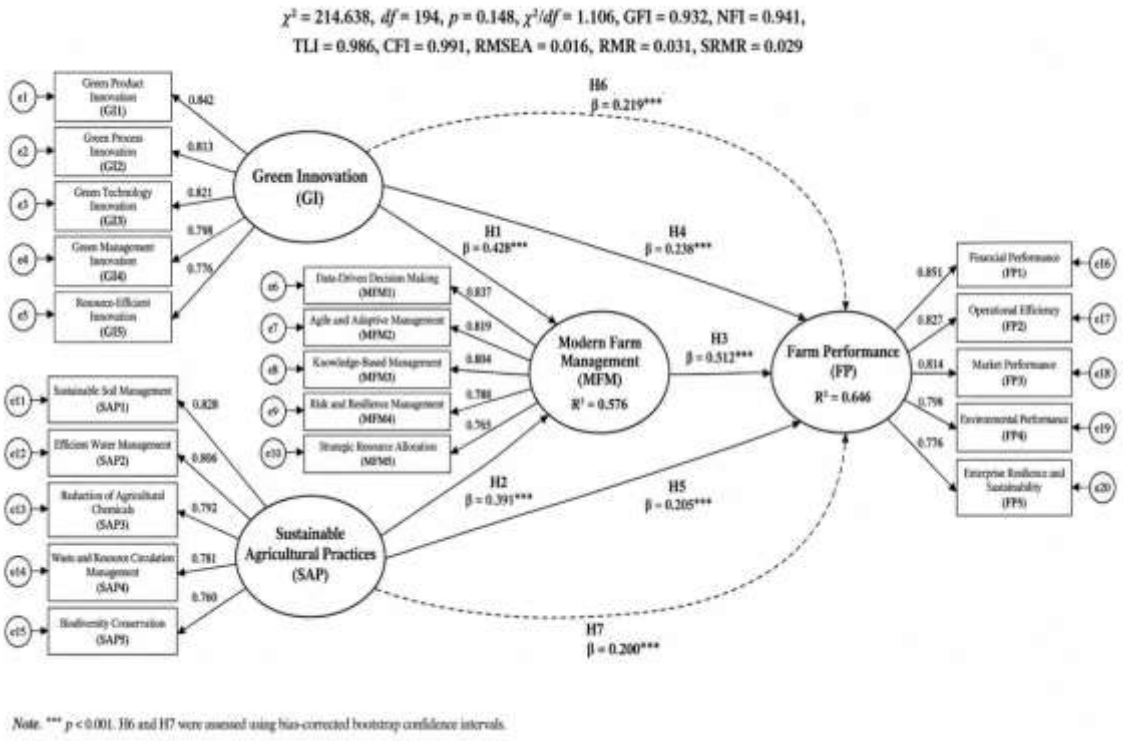

Figure 2. **Structural Equation Model of Green Innovation, Sustainable Agricultural Practices, Modern Farm Management, and Farm Performance**

Table 4. *Standardized Path Coefficients of the Structural Model*

Hypothesis	Path	β	S.E.	t-value	p-value	Result
H1	GI → MFM	0.428	0.064	7.164	***	Supported
H2	SAP → MFM	0.391	0.061	6.782	***	Supported
H3	MFM → FP	0.512	0.058	8.436	***	Supported
H4	GI → FP	0.238	0.052	4.927	***	Supported
H5	SAP → FP	0.205	0.049	4.318	***	Supported
H6	GI → MFM → FP	0.219	0.035	—	***	Supported
H7	SAP → MFM → FP	0.200	0.034	—	***	Supported

*Note. *** p < 0.001. H6 and H7 were assessed using bias-corrected bootstrap confidence intervals.*

Discussion

Green Innovation and Modern Farm Management

The finding supporting H1 indicates that Green Innovation has a significant positive effect on Modern Farm Management (β = 0.428, p < 0.001). This result suggests that agricultural enterprises adopting green products, green processes, green technologies, green management systems, and resource-efficient innovations are also likely to develop stronger managerial capabilities related to data utilization, organizational learning, adaptive decision making, risk management, and strategic resource allocation. This finding is consistent with Chi (2022), who examined the determinants of green innovation in agricultural production and identified operational capability and technology-related factors as important components of agricultural green innovation. The present study extends this perspective by suggesting that the relationship is not limited to the drivers of green innovation. Instead, green innovation may also be associated with changes in the managerial system through which agricultural enterprises organize their operations. The result is also consistent with Shi et al. (2024) and Fei et al. (2026), who found that

agricultural green technological innovation can improve agricultural carbon productivity and contribute to technological progress and economic performance. The present study complements this finding by introducing Modern Farm Management as a managerial pathway. Whereas Shi et al. emphasized the performance consequences of agricultural green technological innovation, the current model suggests that the organizational management capability surrounding such innovation is also important.
This relationship can be explained through the Dynamic Capabilities perspective. Green innovation introduces new technologies, processes, information requirements, and resource-use practices. These changes require enterprises to sense changes in their operating environment, seize opportunities through innovation, and reconfigure resources and routines. Therefore, green innovation is not merely a technological investment; it can stimulate changes in managerial processes. The implication is that agricultural enterprises should not consider green technology adoption as a stand-alone investment. The introduction of precision agriculture, renewable-energy systems, environmental monitoring technologies, traceability systems, or resource-efficient production technologies should be accompanied by managerial capabilities that enable enterprises to interpret information and convert technological information into operational decisions.

Sustainable Agricultural Practices and Modern Farm Management

H2 was also supported, demonstrating a significant positive relationship between Sustainable Agricultural Practices and Modern Farm Management ($\beta = 0.391$, $p < 0.001$). This finding indicates that sustainable management of soil, water, agricultural chemicals, waste, resources, and biodiversity requires a corresponding improvement in managerial capabilities.
The finding is consistent with Boros et al. (2025), whose systematic review identified substantial opportunities associated with innovative sustainable agricultural practices, particularly in relation to resource efficiency, environmental protection, and long-term agricultural viability. However, their review also emphasized barriers associated with costs, technological complexity, infrastructure, and local conditions.
The current findings help explain why such implementation barriers matter. Sustainable agricultural practices require continuous monitoring and coordination rather than one-time adoption. For example, efficient water management requires information about rainfall, soil moisture, irrigation requirements, and crop conditions. Similarly, reducing chemical inputs requires knowledge-based decisions concerning pests, crop health, soil conditions, and alternative biological or integrated approaches. Therefore, sustainable agricultural practices naturally increase the need for more systematic management. This interpretation is also consistent with Olarewaju et al. (2025) and Pansuwong et al. (2023) who emphasized that sustainable agricultural practices can contribute to productivity, ecological stability, climate resilience, and food security when they are integrated across agronomic, socioeconomic, and governance dimensions.

The present study therefore adds an organizational-management dimension to this literature. Rather than viewing sustainable agricultural practices simply as environmentally responsible production techniques, the findings suggest that their implementation requires managerial capabilities capable of coordinating resources, information, knowledge, and risk.

Modern Farm Management and Farm Performance

H3 demonstrated the strongest direct relationship in the model, with Modern Farm Management having a significant positive effect on Farm Performance ($\beta = 0.512$, $p < 0.001$). This is one of the most important findings of the study because it indicates that managerial capability may represent the central mechanism through which agricultural enterprises convert resources and technologies into organizational outcomes. The result is highly relevant to the growing literature on digital and smart agriculture. Soussi et al. (2024), for example, emphasized that smart sensors, IoT, data analytics, and other digital technologies can support precision agriculture by improving monitoring, optimization, resource utilization, and sustainability. Similarly, Choruma et al. (2024) found that digital technologies can improve farmers' access to information, services, markets, and decision-making opportunities, while also identifying infrastructure, affordability, and digital-literacy barriers.

The current finding extends these studies by demonstrating conceptually that technology alone is insufficient. The technologies generate information and opportunities, but Modern Farm Management determines how that information is interpreted and converted into decisions.

This explains why MFM has a stronger direct coefficient than either Green Innovation or Sustainable Agricultural Practices. Green technologies may provide new capabilities, and sustainable practices may protect the resource base, but neither automatically guarantees improved financial, operational, market, environmental, and resilience outcomes. Management is required to coordinate these resources.
The finding is therefore particularly important from a managerial perspective. Agricultural enterprises may possess advanced technologies but still experience weak performance if managers cannot integrate data into planning, allocate resources appropriately, respond to market changes, manage risks, and coordinate organizational learning.

Green Innovation and Farm Performance
H4 was supported, with Green Innovation having a significant positive direct effect on Farm Performance ($\beta = 0.238$, $p < 0.001$). This finding is consistent with Shi et al. (2024), who reported that agricultural green technological innovation can improve carbon productivity through technological progress and economic-performance mechanisms. The finding is also relevant to the studies by Chi (2022) and Channuwong et al. (2026), whose researches emphasized the importance of operational capability, technological spillovers, environmental awareness, and health considerations in agricultural green innovation. Together, these studies suggest that green innovation has consequences extending beyond environmental protection. However, an important feature of the present result is that the direct coefficient of GI → FP ($\beta = 0.238$) is considerably smaller than the MFM → FP coefficient ($\beta = 0.512$). This difference suggests that green innovation may generate performance benefits, but its contribution is potentially strengthened when supported by effective management.

Green innovation can improve performance through several mechanisms. Green products can provide differentiation in environmentally sensitive markets; green production processes can reduce waste and input losses; green technologies can improve resource efficiency; and resource-efficient innovations can reduce pressure on land, water, energy, and materials. Nevertheless, these benefits depend on implementation, maintenance, financing, employee knowledge, and market integration. Thus, the present finding supports the proposition that innovation creates potential value, whereas management helps realize that value.

Sustainable Agricultural Practices and Farm Performance
H5 was supported, demonstrating a positive direct effect of Sustainable Agricultural Practices on Farm Performance ($\beta = 0.205$, $p < 0.001$). The result indicates that responsible management of soil, water, chemicals, waste, and biodiversity can contribute to broader enterprise outcomes. This finding is consistent with recent research emphasizing the relationship between sustainable agricultural practices, resource efficiency, resilience, and long-term agricultural viability. Boros et al. (2025) identified sustainable agricultural innovation as an important opportunity for improving resource efficiency and environmental protection, although implementation barriers can limit the realization of these benefits. Similarly, Olarewaju et al. (2025) and Photchanachan et al. (2026) argued that sustainable agricultural practices can support climate resilience and food security when they are integrated across multiple dimensions of agricultural systems.

The relatively smaller direct coefficient compared with MFM → FP may also be theoretically meaningful. Some benefits of sustainable agricultural practices may require time to materialize. Improvements in soil health, biodiversity, ecological balance, and resource efficiency may not immediately produce observable financial or market outcomes. The manuscript itself recognizes this possibility, particularly because sustainable practices can involve delayed benefits.
Consequently, the finding supports a broader conceptualization of Farm Performance. Performance should not be evaluated solely by immediate revenue or production volume but should include operational efficiency, environmental performance, market outcomes, and long-term resilience.

The Mediating Role of Modern Farm Management
The findings for H6 and H7 represent an important contribution of the study. Modern Farm Management significantly mediated the relationship between Green Innovation and Farm Performance ($\beta = 0.219$) and between Sustainable Agricultural Practices and Farm Performance ($\beta = 0.200$). Because the corresponding direct effects remained statistically significant, the mediation is partial rather than full. This finding provides an important explanation for the relationship between environmental

capabilities and enterprise outcomes. Green Innovation and Sustainable Agricultural Practices appear to influence performance through two complementary channels.

First, they have direct effects. Green technologies can reduce waste, improve resource efficiency, and support environmentally differentiated products. Sustainable agricultural practices can improve soil, water, resource, and ecological conditions. Second, they have indirect effects through Modern Farm Management. These environmental capabilities require managers to collect and interpret information, redesign processes, allocate resources, learn new knowledge, manage risks, and adapt operations.

The partial mediation is particularly important because it indicates that Modern Farm Management does not replace the direct contribution of Green Innovation and Sustainable Agricultural Practices. Instead, it complements and strengthens their contribution. The indirect effects can also be interpreted mathematically. The indirect effect of GI through MFM is approximately the product of GI → MFM and MFM → FP ($0.428 \times 0.512 \approx 0.219$), while the indirect effect of SAP through MFM is approximately $0.391 \times 0.512 \approx 0.200$. These values correspond closely to the reported indirect effects.

This finding therefore supports the study's proposed Green and Sustainable Farm Management Performance Model, in which environmental and technological capabilities become more valuable when embedded within an effective managerial system.

Comparison with Previous Studies and Contribution of the Present Study

Overall, the findings demonstrate substantial relevance to previous studies but also extend them in several ways. Previous studies have often focused on individual elements of the agricultural transformation process. For example, Chi (2022) focused on factors associated with green innovation; Shi et al. (2024) examined the performance implications of agricultural green technological innovation; Soussi et al. (2024) reviewed smart sensors and data for precision agriculture; and Choruma et al. (2024) examined digitalization and its opportunities and barriers for smallholder agriculture.

The present study differs in that it brings innovation, sustainable practices, managerial capability, and enterprise performance into one structural model. Therefore, its principal contribution is not simply to confirm that green innovation and sustainable agriculture are beneficial. Rather, it proposes and demonstrates a mechanism through which these capabilities can be transformed into organizational performance.

Theoretical Implications

The findings provide support for integrating the Natural Resource-Based View (NRBV) and Dynamic Capabilities perspective. The NRBV explains why environmental capabilities such as green innovation and sustainable resource management can become sources of organizational value, while the Dynamic Capabilities perspective helps explain how enterprises adapt, coordinate, and reconfigure these resources under changing conditions. The manuscript explicitly positions GI and SAP as environmental and operational capabilities and MFM as the dynamic managerial capability connecting these resources to performance.

The strongest MFM → FP relationship suggests that possessing valuable environmental resources may not be sufficient. Enterprises also require organizational capabilities to integrate these resources into operational and strategic decisions.

This provides a more nuanced theoretical explanation than a simple model in which "green innovation leads to performance." The findings suggest a sequence in which: Green Innovation + Sustainable Agricultural Practices → Modern Farm Management → Farm Performance, while GI and SAP also retain direct relationships with FP. This integrated mechanism represents the principal theoretical contribution of the study.

Important Qualification Regarding the Findings

Although the results show strong statistical relationships, they should be interpreted cautiously because the numerical dataset was simulated rather than collected from 400 actual agricultural enterprises. The manuscript explicitly states that the numerical findings constitute a methodological demonstration and require subsequent empirical validation using field data. Therefore, the reported coefficients should not be presented as evidence that actual Thai agricultural enterprises experience exactly these effect sizes. Instead, they demonstrate that the proposed structural model is statistically coherent and theoretically consistent with the relationships suggested by previous research.

In summary, the findings indicate that agricultural transformation should be understood as an integrated technological, environmental, and managerial process. Green Innovation and Sustainable Agricultural Practices provide important environmental and operational capabilities, but their contribution to Farm Performance is strengthened when agricultural enterprises possess the managerial capacity to interpret information, coordinate knowledge, allocate resources, adapt operations, and manage risks. The particularly strong relationship between Modern Farm Management and Farm Performance, together with the significant partial mediation effects, suggests that managerial capability represents an important mechanism through which green and sustainable initiatives can be converted into multidimensional enterprise outcomes. This interpretation is broadly consistent with recent research on green agricultural innovation, sustainable agricultural practices, digitalization, and precision agriculture, while extending that literature by integrating these elements within a single structural framework. Nevertheless, because the present study is based on simulated data, these relationships should be regarded as theoretically supported model relationships rather than empirical estimates of the Thai agricultural population. Future research using actual field data should therefore test whether the same pattern of direct and mediated relationships is observed across different agricultural subsectors, regions, enterprise sizes, and levels of digital maturity.

Conclusion

The findings provide a theoretically coherent explanation of how Green Innovation (GI), Sustainable Agricultural Practices (SAP), and Modern Farm Management (MFM) are interconnected in explaining Farm Performance (FP) of agricultural enterprises. The structural model showed that all five hypothesized direct relationships were positive and statistically significant, while the two indirect relationships through Modern Farm Management were also significant. In particular, Modern Farm Management demonstrated the strongest direct effect on Farm Performance ($\beta = 0.512$, $p < 0.001$), followed by the effects of Green Innovation on Modern Farm Management ($\beta = 0.428$, $p < 0.001$) and Sustainable Agricultural Practices on Modern Farm Management ($\beta = 0.391$, $p < 0.001$). Green Innovation and Sustainable Agricultural Practices also demonstrated significant direct effects on Farm Performance ($\beta = 0.238$ and $\beta = 0.205$, respectively). Furthermore, the indirect effects of Green Innovation and Sustainable Agricultural Practices through Modern Farm Management were $\beta = 0.219$ and $\beta = 0.200$, respectively. These findings are broadly consistent with previous agricultural innovation and sustainability literature, but they extend previous research by placing Modern Farm Management at the center of the relationship between environmental capabilities and enterprise performance. Previous studies have frequently examined green innovation, sustainable agricultural practices, digital agriculture, or productivity separately. The present model integrates these dimensions into a single structural framework and therefore provides a more comprehensive explanation of how environmental and technological capabilities can be translated into multidimensional enterprise performance.

Recommendations

Policy Recommendations

Government agencies and agricultural development organizations should design support programs that integrate Green Innovation, Sustainable Agricultural Practices, and Modern Farm Management. Financial assistance for green technologies, water-saving infrastructure, soil restoration, waste circulation, and biodiversity conservation should be accompanied by training in data interpretation, adaptive planning, risk management, organizational learning, and strategic resource allocation.

Institutional and Managerial Recommendations

Agricultural-enterprise owners and managers should establish an integrated management system connecting environmental innovation, sustainable production, and enterprise-performance objectives. Green and sustainable initiatives should be linked with production planning, budgeting, employee responsibilities, monitoring systems, and multidimensional performance indicators.

Operational Recommendations

Farm managers should systematically record soil conditions, water use, crop health, input costs, production losses, prices, customer requirements, and environmental outcomes. Regular review cycles should enable adjustments to planting schedules, irrigation plans, input applications, procurement, and

marketing arrangements. Risk registers, contingency plans, backup suppliers, and recovery procedures should be maintained.

Recommendations for Future Research

Future empirical research should validate the model with field data and compare crop, livestock, aquaculture, agro-processing, and mixed-farming enterprises. Multi-group SEM should examine differences by enterprise size, region, ownership structure, export orientation, certification status, and digital maturity. Longitudinal and mixed-method designs are recommended.

Conflict of Interest

The authors declared that they have no conflict of interest in writing and publishing this article.

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