

AI-driven sustainable supply chain innovation and economic development in the organic herbal agro-business industry

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Abstract

The global organic herbal agro-business is increasingly connected with sustainable agriculture, digital supply chain systems, biodiversity-based production and economic development. This paper investigates the part played by AI-driven sustainable supply chain innovation in promoting the economic development of the global organic herbal agro-business industry in the United States. The study addresses the main dimensions of sustainable supply chain innovation, such as green supply chain practices, digital traceability, eco-innovation, smart technology adoption, value-chain upgrading, market expansion, and sustainable business performance with the connection of AI. A quantitative research design was adopted and primary data were collected from 378 respondents using a structured questionnaire based on a five-point Likert scale. The respondents were farmers, suppliers, processors, distributors, retailers, exporters, consumers and other stakeholders of the organic herbal agro-business sector. Data were analyzed using descriptive statistics, reliability analysis, Pearson correlation and regression analysis. The results show a positive relationship between green supply chain practices, AI-driven digital traceability, eco-innovation, smart technology adoption, value-chain upgrading and market expansion and economic development impact. The regression results show that 49.6 percent of the variation of economic development impact is explained by the independent variables, where market expansion and business performance have the most significant effect, followed by value-chain upgrading and digital traceability. The research confirms that sustainable supply chain innovation can enhance product quality, consumer confidence, operational efficiency, certification value, market access, creation of employment, livelihood improvement, export potential and business development. The results suggest that the organic herbal agro-business industry can contribute more effectively to economic development when green practices, digital technologies, AI-driven traceability systems, eco-innovation, and value-chain coordination are integrated into one sustainable supply chain framework.

Keywords: Sustainability; AI-Driven Supply Chain; Organic Business; Global Agro-Business; Economic Development

1 Introduction

The global organic herbal agro-business industry has emerged as a major research topic, integrating organic herbal plant production, sustainable agriculture, biodiversity-based value chains and equitable economic development in one agro-industrial system (Lindberg et al., 2023). Herbal therapy has received increased consideration since it promotes access to healthcare, promotion of local livelihoods, application of traditional knowledge and development of the bio-economy in biodiversity-rich areas (Lindberg et al., 2023). The organic herbal agro-business industry should be observed as a value-chain-based industry involving the cultivation, gathering, preparing, quality control, packaging, certification, distribution, marketing and consumption of herbal products. (Shariatzadeh et al., 2025). In rich countries agriculture is a less favourite source of revenue. Director indirect: agriculture benefits everyone. Growing demand for agricultural products worldwide has generated a number of employment opportunities. (Mathlouthi et al., 2022). Organic agriculture is one of the most popular and fastest growing trends in sustainability. (Gamage et al., 2023).

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Recently, a number of studies have begun to investigate the transformative potential of green innovations to improve environmental, economic and social performance (Taamneh et al., 2024). The growing global demand for sustainable solutions has pushed enterprises in various areas to embrace green supply chain methods. Nevertheless, the distribution of such methods is sometimes hindered by the absence of sufficient infrastructure, regulatory shortcomings and cultural resistance to change (Ali et al., 2024). This agro-based industry is relevant to sustainable supply chain innovation as it integrates environmental, social and economic factors in supply chain management and improves efficiency, competitiveness and stakeholder value (Aladaileh et al., 2024). Recent studies in supply chain management reveal that sustainable innovation is increasingly impacted by green technology, eco-design, collaboration, digital transformation, governance systems and circular economy practices (Aladaileh et al., 2024). In the organic herbal agro-business industry these methods can increase product authenticity, resource efficiency, waste minimization, supplier coordination and access to higher value markets. (Barua et al., 2021). Green supply chain management is especially applicable since supply chain operations can lead to increased pollution, energy use, waste generation and environmental damage if they are not handled in a responsible way (Hejazi et al., 2023). These practices can lead to better economic, environmental and social sustainability performance and are therefore relevant for herbal enterprises that need to balance profitability with environmental credibility (Hejazi et al., 2023). For instance, green purchasing strategies require finding eco-friendly products. This requires developing innovative technologies for effective processing and utilization of these materials (Liao et al., 2024). Another important driver is digital transformation using blockchain and artificial intelligence which can increase transparency, traceability, accountability, coordination of supply chain and reduce environmental effect (Hong & Xiao, 2024). Artificial intelligence is starting to play a major part in sustainable supply chain innovation as it helps firms to forecast demand, manage inventories, confirm product quality and reduce operational risk. AI applications can improve the resilience, information exchange and overall effectiveness of agricultural supply networks (Yin et al., 2025). Furthermore, it can assist in making improved agricultural decisions, resource management, product monitoring, and designing sustainable businesses in the organic herbal agro-enterprise industry (Bhat et al., 2025). AI-driven innovation in the supply chain could improve efficiency, product safety, customer confidence and long-term economic performance in this business. Digital traceability is particularly significance for the supply chains of agri-food and herbal products, as it improves the verification of the origin of products, the assurance of quality, the confidence of consumers and compliance with regulations (Charlebois et al., 2024). Blockchain-based agri-food systems can also contribute to sustainability through enhanced traceability, resource management and transparency throughout production and distribution networks. (Apeh & Nwulu, 2025). Furthermore, eco-innovation promotes sustainable herbal agro-business by promoting cleaner production, biodegradable packaging, energy-efficient processing, organic growing, and circular use of agricultural leftovers (Rehman Khan et al., 2022). Smart technologies can improve supply chain performance by increasing agility, resilience, real-time monitoring, information sharing, and responsiveness to market and logistical disruptions (Sharma et al., 2024). However, the economic benefits of the herbal sector are not automatic as regulatory complexity, lack technical assistance, limited research, low market access and unbalanced value-chain structures might hinder participation of local producers and small enterprises (Masondo et al., 2025). Therefore, sustainable supply chain innovation should be explored not only as an operational improvement tool but also as an economic development mechanism through market expansion, livelihood improvement, employment generation, value addition and sustainable business growth (Vasileiou et al., 2025).

The primary objective of this paper is to investigate the role of AI-driven sustainable supply chain innovation on the economic development of the global organic herbal agro-business industry by improving the green supply chain practices, digital traceability, eco-innovation, smart technology adoption, value chain upgradation, market expansion and sustainable business performance.

2 Literature Review

Growing awareness of the possibilities of organic herbal products indicates growing dependence on biodiversity for health. Such a promotion may provide various benefits, but the literature also warns and points out several concerns that need to be addressed. (Lindberg et al., 2023). Recent study demonstrates how value chains of herbal medicine might provide sustainable livelihoods, access to healthcare, biodiversity protection and a restorative bioeconomy. However, the study indicates that the development of the sector is constrained by regulatory complexity, insufficient R&D, low support for marginalized producers and little social acceptance. This work is relevant for the current research but its weakness is that it is focused on Brazil and does not analyze global supply chain innovation or quantitative economic development results. (Lindberg et al., 2023). Green supply chain management strategies integrate environmental aspects into supply chain processes from sourcing, production, delivery to disposal (Mahar et al., 2025). Sustainable supply chain management has become more and more associated with digital transformation, because blockchain, big data analytics and Internet of things may improve transparency, coordination and sustainable performance across supply networks (Stroumpoulis & Kopanaki, 2022). In their study, it is found out that organic herbal agro-business involves transparent sourcing, coordinated actors and reliable product information at phases of

cultivation, processing, distribution and consumption. The gap in the study is that they establish a conceptual framework for sustainable supply chain management and digital transformation but do not study the organic herbal agro-business industry particularly. The limitation of the study is that it is based on theory-building and literature and as such it does not provide direct empirical information from herbal producers, processors, retailers and consumers (Stroumpoulis & Kopanaki, 2022). Sustainable agricultural value chains are vital because climate change, market volatility, insufficient infrastructure and fragmented distribution channels might diminish producers' ability to obtain equitable economic rewards (Barua et al., 2021). However, the study was limited to agricultural items in a climate susceptible coastal area and did not expressly address medicinal plants, herbal products or worldwide organic markets. Therefore, its findings are context-specific to South-Eastern Bangladesh and cannot fully explain the worldwide organic herbal agro-business supply chains (Barua et al., 2021). Green supply chain management strategies integrate environmental aspects into supply chain processes from sourcing, production, delivery to disposal (Mahar et al., 2025). One study revealed that digital transformation enhances green supply chain performance by increasing supply chain integration, supporting carbon-neutrality targets, and accelerating circular economy practices. (Singh et al., 2025). This study is essential to organic herbal agro-business since enterprises in the industry require digital technologies to reduce waste, optimize logistics, boost green sourcing and strengthen sustainability performance. However, the study talks about green supply chain performance in general and not especially on the supply chains of medicinal plants or value creation in the herbal agro-business. The restriction is the use of cross-sectional survey data and convenience sampling which limits causal interpretation and generalization to broader contexts (Singh et al., 2025). (Gyamfi et al., 2024) revealed that Agriculture 4.0 technologies such as IoT, AI, sensors, and smart farming tools can enhance agricultural productivity, monitoring, efficiency, and sustainability. The gap is that the study talks about smart agriculture in general as well as does not focus on herbal crop supply chains and economic development in organic herbal marketplaces. The work is limited in that it is more of a technology assessment and do not statistically test the impact of smart farming on income, employment and export growth in herbal agro-business (Gyamfi et al., 2024). (Bhat et al., 2025) analyzed the importance of artificial intelligence in agribusiness and argued that AI may improve productivity, sustainability and profitability through techniques such as machine learning, robots, data analytics and smart decision systems. Their research reveals that AI can help precision farming, resource management, real-time monitoring and supply chain optimization. These results are significant for organic herbal agro-business industry as AI can help farmers in better utilization of resources, quality enhancement of crops, tracking the movement of products and minimizing operational losses. The report also pointed out that the adoption of AI can encounter hurdles notably among small producers with low funding and skills and technological access. Lastly, another study claimed that if deforestation-free supply-chain policies are not developed with inclusive support mechanisms, they may cause hazards for smallholders, Indigenous peoples and local communities. But the study focuses on deforestation free supply chains in general and does not include medicinal plants or organic herbal items. Furthermore, it is policy-oriented and does not empirically examine the economic effect of sustainable supply-chain innovation on participants of the herbal sector (Zhunusova et al., 2022).

Overall, current research suggests digital systems, smart agriculture, blockchain traceability, biodiversity-sensitive farming and inclusive value chains are key to sustainable agro-business development. A recurring weakness is that many studies look at agriculture, food logistics, forest policy or digital traceability in isolation, and there is limited study connecting these concerns directly with the global organic herbal agro-business market. Thus, the current study fills this gap by investigating the role of sustainable supply chain innovation in economic development through traceability, green practices, smart technologies, value-chain coordination, market expansion, and livelihood enhancement.

2.1 Research Questions

The research questions of this study are framed around the main purpose and the literature examined to explore the relationship between sustainable supply chain innovation and economic development in the global organic herbal agro-business industry in United States. Previous studies have shown that green practices, digital traceability, eco-innovation, smart technology, and value-chain coordination can increase sustainability and commercial performance, but the joint impact of these factors on the economic development of the organic herbal sector is still underexplored. Thus, the following research questions guide this study:

- RQ1: What are the forms of AI-based sustainable supply chain innovations in the worldwide organic herbal agro-business in the United States?
- RQ2: What is the impact of green supply chain methods on sustainability and commercial success in the organic herbal agro-enterprise industry?
- RQ3: How can AI-driven digital traceability contribute to transparency, product authenticity, quality control, and consumer trust in the organic herbal product supply chain?
- RQ4: What are the ways in which eco-innovation and smart technology contribute to value-chain upgrading, market expansion and operational efficiency in the organic herbal agro-business industry?

- RQ5: What is the contribution of sustainable supply chain innovation to economic development in terms of livelihood improvement, job creation, export potential and business growth?

2.2 Specific Objectives

This study looks at how organic herbal agro-businesses around the USA are changing the way they manage their AI-driven supply chains. Five main areas guide the research.

- The first is identifying the dominant forms of AI-driven sustainable supply chain innovation currently in use across the United States' organic herbal agro-business sector.
- The second is examining whether green supply chain methods genuinely improve sustainability performance and, separately, whether they help businesses do better commercially.
- The third concerns AI traceability. Specifically, the study looks at how tools like blockchain, QR codes, and real-time tracking affect transparency, product authenticity, quality control, and the degree to which consumers actually trust what they are buying.
- The fourth looks at eco-innovation and smart technology, asking whether they help businesses upgrade their value chains, reach new markets, and run more efficiently.
- The fifth and final objective asks what all of this means for economic development more broadly. Specifically, whether sustainable supply chain innovation is actually creating jobs, improving livelihoods, opening export opportunities, and enabling business growth in communities that produce organic herbal products. (Lindberg et al., 2023)

3 Research Design and Methodology

This study employed a quantitative research approach to assess the impact of sustainable supply chain innovation on economic development in the United States' organic herbal agro-business industry. Quantitative research is suitable for this study as it will look at the relationship between sustainable supply chain practices and economic consequences using structured numerical responses. Recent studies also have employed quantitative methodologies to investigate the impact of technology, green practices and supply chain integration on sustainability and business success in the context of digital transformation and green supply chain performance. (Singh et al., 2025).

The study was quantitative in nature and aimed at exploring the impact of sustainable supply chain innovation on economic development in the United States' organic herbal agro-business industry. The study used descriptive and explanatory approaches. The descriptive approach emphasized the existing practices like green supply chain methods, digital traceability, eco-innovation, smart technology adoption and value chain upgrading. The explanatory perspective examined the effect of these practices on market expansion, business growth, job creation, livelihood improvement and export potential. The target respondents were the farmers, suppliers, processors, distributors, retailers, exporters, consumers and other stakeholders engaged into the organic herbal agro-business sector of United States. The purposive sampling technique was used in the study because it is important to get responses from people who have knowledge or experience in herbal products, organic agriculture and supply chain activities. The study had a sample size of 400 respondents in their initial stage. However, only 378 sample answers were collected.

Structured questionnaire is used to collect primary data. The questionnaire was comprising sections on respondent profile, green supply chain practices, digital traceability, eco-innovation, smart technology adoption, value-chain development, market performance and economic development. The responses were measured on a five-point Likert scale ranging from strongly disagree to strongly agree. Descriptive statistics, reliability analysis, correlation analysis and regression analysis were used to analyze the data collected. General response pattern was presented using descriptive statistics. Reliability analysis was used to test the consistency of the questionnaire items. The relationship and impact of sustainable supply chain innovation and economic development were investigated using correlation and regression analysis. Ethical issues were taken care of by voluntary participation, confidentiality and academic use of the collected data only.

4 Data Analysis

4.1 Demographic Information

For analyzing the sustainable supply chain innovation and economic development in the United States' organic herbal agro-business industry 378 survey responses were collected. An analysis of these responses is presented in this section. The analysis includes demographic profile, descriptive statistics, reliability analysis, Pearson correlation, regression

analysis and discussion of major findings. The main variables studied are green supply chain practices, digital traceability, eco-innovation, smart technology adoption, value-chain upgrading, market expansion and business performance, economic development impact and general perception of sustainable supply chain innovation.

Table 1 Demographic Frequency Distribution

Variable	Category	Frequency	Percent
Gender	Male	199	52.65
	Female	171	45.24
	Other	8	2.12
Age Group	Below 25	82	21.69
	25-34	141	37.30
	35-44	92	24.34
	45-54	44	11.64
	55 and above	19	5.03
Education Level	Secondary	35	9.26
	Higher Secondary	57	15.08
	Bachelor	146	38.62
	Master	118	31.22
	Other	22	5.82
Occupation	Farmer	57	15.08
	Supplier	39	10.32
	Processor	48	12.70
	Retailer	53	14.02
	Exporter	33	8.73
	Consumer	98	25.93
	Researcher	28	7.41
	Other	22	5.82
Years of Experience	Less than 1 year	49	12.96
	1-3 years	116	30.69
	4-6 years	96	25.40
	7-10 years	68	17.99
	More than 10 years	49	12.96
Business Type	Cultivation	60	15.87
	Processing	54	14.29
	Packaging	35	9.26
	Distribution	49	12.96
	Retail	71	18.78
	Export	39	10.32
	Other	70	18.52

Country/Region of Operation	Asia-Pacific	121	32.01
	North America	91	24.07
	Europe	68	17.99
	Middle East	42	11.11
	Africa	33	8.73
	Other	23	6.08

The demographic profile of the respondents is shown in Table 1. Of the 378 respondents, 52.65% were male, 45.24% were female and 2.12% were of other gender categories. The most common age group was 25-34 years with 37.30% of the sample followed by 35-44 years with 24.34%. This indicates that most of the respondents are young and middle-aged participants with relevant exposure to business, digital systems and agro-based market activities. The majority of the respondents were bachelor degree holders and master degree holders in terms of education. The occupational distribution showed that the sample was composed of consumers, farmers, suppliers, processors, retailers, exporters and researchers, which means that the sample is appropriate for the study of the larger supply chain of the organic herbal agro-business industry (Table 1).

4.2 Green Supply Chain Practices

Table 2 shows the opinion of respondents on green supply chain practices in organic herbal agro-business industry. This includes practices such as organic cultivation, waste reduction, energy efficiency and sustainable supplier standards, eco-friendly sourcing.

Table 2 Descriptive Analysis of Green Supply Chain Practices

Measurement Items	Mean	Standard Deviation
Our organization uses environmentally friendly sourcing practices (GSCP1)	3.84	0.82
Organic cultivation methods are followed in herbal product production (GSCP2)	3.89	0.78
Waste reduction is considered important in our supply chain operations (GSCP3)	3.86	0.81
Energy-efficient methods are used in processing and distribution (GSCP4)	3.77	0.85
Suppliers are encouraged to follow sustainable production standards (GSCP5)	3.79	0.86
Green supply chain practices improve product quality and market acceptance (GSCP6)	3.88	0.79
Overall Mean	3.84	0.55

The overall mean score of green supply chain practices was found to be 3.84 which implies that respondents generally agree that environmentally responsible sourcing, organic cultivation, waste reduction and sustainable supplier practices are important in the herbal agro-business supply chain. The highest mean was for organic cultivation methods, which suggests that organic production is considered to be the core of the industry. The results indicate that green practices are already considered important foundation for product quality, market acceptance and sustainability performance (Table 2).

4.3 AI-Driven Digital Traceability

Table 3. Descriptive results of AI-driven digital traceability in the herbal product supply chain. It reveals how respondents view digital tools, traceability systems, verification of product origin, transparency and consumer trust.

Table 3 Descriptive Analysis of AI-driven Digital Traceability

Measurement Items	Mean	Standard Deviation
Digital tools are used to track herbal products from source to market (DT1)	3.70	0.88
AI-driven Traceability systems help verify the origin of organic herbal products (DT2)	3.82	0.81
Digital traceability improves transparency in the supply chain (DT3)	3.85	0.79
AI- Driven Traceability systems increase consumer trust (DT4)	3.83	0.83
Digital records help maintain quality control (DT5)	3.76	0.86
Blockchain, QR codes, or similar technologies can improve product authenticity (DT6)	3.74	0.91
Overall Mean	3.78	0.58

The overall mean score of digital traceability was 3.78 indicating a positive perception of traceability systems in the organic herbal product supply chain. The respondents agreed that the Ai-driven traceability improves transparency, verifies the product's origin and strengthens consumer trust. However, the slightly lower score for the use of advanced technologies such as blockchain and QR codes shows that these tools are recognized but perhaps not yet fully adopted across the industry (Table 3).

4.4 Eco-Innovation

Table 4 reports the respondents' views on eco-innovation in organic herbal agro-business activities. It is based on environmentally friendly packaging, cleaner production, recycling, reduction of costs, brand reputation and long-term sustainability.

Table 4 Descriptive Analysis of Eco-Innovation

Measurement Items	Mean	Standard Deviation
Our business uses eco-friendly packaging for herbal products. (EI1)	3.71	0.89
Cleaner production methods are used to reduce environmental impact. (EI2)	3.76	0.84
Agricultural waste or herbal residues are reused or recycled. (EI3)	3.67	0.92
Eco-innovation helps reduce production costs. (EI4)	3.69	0.88
Eco-friendly innovation improves brand reputation. (EI5)	3.82	0.80
Eco-innovation supports long-term business sustainability. (EI6)	3.81	0.79
Overall Mean	3.74	0.60

The average score of eco-innovation was 3.74. The results imply that respondents believe eco-friendly packaging, cleaner production and recycling practices can support environmental performance and business sustainability. Brand reputation was the highest scored, implying that eco-innovation is not only seen as an environmental practice, but also a way of enhancing market image and customer confidence (Table 4)

4.5 Smart Technology Adoption

Table 5 presents the contribution of smart technology utilization to the enhancement of herbal agro-business supply chain activities. It covers smart farming tools, IoT, digital monitoring, storage management, decision making and competitiveness.

Table 5 Descriptive Analysis of Smart Technology Adoption

Measurement Items	Mean	Standard Deviation
Smart farming tools can improve herbal crop production (STA1)	3.75	0.86
Sensors, IoT, or digital monitoring can improve supply chain efficiency (STA2)	3.68	0.91
Technology helps reduce product loss during storage and transportation (STA3)	3.71	0.84
Smart technology improves decision-making in production and distribution (STA4)	3.73	0.85
Digital platforms help connect producers, suppliers, and buyers (STA5)	3.78	0.82
Technology adoption improves competitiveness in the herbal agro-business industry (STA6)	3.76	0.83
Overall Mean	3.74	0.57

The overall mean score of adoption of smart technology was 3.74. This indicates that respondents largely agreed that smart farming tools, IoT, digital monitoring and digital platforms have the potential to improve crop production, reduce losses, connect supply chain actors and increase competitiveness. The result also suggests that technology adoption is perceived as a practical necessity for the modernization of organic herbal agri-business supply chain (Table 5).

4.6 Value-Chain Upgrading

Descriptive results on value-chain upgrading in the organic herbal agro-business sector are presented in Table 6. It emphasizes coordination, certification, quality control, packaging, branding, market access and income generation for producers.

Table 6 Descriptive Analysis of Value-Chain Upgrading

Measurement Items	Mean	Standard Deviation
Sustainable supply chain innovation improves coordination among farmers, processors, and retailers (VCU1)	3.83	0.80
Better supply chain systems help producers access higher-value markets (VCU2)	3.81	0.82
Certification and quality control increase product value (VCU3)	3.88	0.76
Improved packaging and branding support market expansion (VCU4)	3.86	0.78
Value-chain upgrading increases income opportunities for small producers (VCU5)	3.78	0.84
Stronger supply chain coordination reduces market barriers (VCU6)	3.75	0.87
Overall Mean	3.82	0.53

The mean value-chain upgrading score was 3.82. Respondents agreed that better coordination, certification, quality control, packaging and branding can improve product value and access to markets. The highest score was obtained for certification and quality control indicating that product credibility is of high importance in the organic herbal agro-business sector. The results indicate that value-chain upgrading can enable producers to progress from the raw product selling stage to higher-value markets (Table 6).

4.7 Market Expansion and Business Performance

Table 7 shows the respondents' perceptions of market expansion and business performance. It highlights the importance of sustainable supply chain practices, digital platforms and product authenticity and innovation supporting demand, loyalty and business growth.

Table 7 Descriptive Analysis of Market Expansion and Business Performance

Measurement Items	Mean	Standard Deviation
Sustainable supply chain practices increase consumer demand for organic herbal products (MBP1)	3.86	0.78
Digital marketing and online platforms help expand market reach (MBP2)	3.87	0.80
Sustainable practices improve business profitability. (MBP3)	3.78	0.84
Product authenticity increases customer loyalty (MBP4)	3.90	0.76
Innovation helps businesses enter national and international markets (MBP5)	3.80	0.82
Sustainable supply chain innovation strengthens long-term business growth (MBP6)	3.85	0.79
Overall Mean	3.84	0.52

The average score for market expansion and business performance was 3.84. The results indicate that the respondents consider sustainable supply chain innovation to be able to increase consumer demand, improve customer loyalty, expand market reach and contribute to long-term business growth. The highest mean score is given to the product authenticity which indicates that trust and authenticity are the major factors behind the growth of organic herbal product markets (Table 7).

4.8 Economic Development Impact

Table 8 presents the perceived economic development impact of the organic herbal agro-business industry. It focuses on employment generation, livelihood improvement, export potential, rural development and income generation for small enterprises.

Table 8 Descriptive Analysis of Economic Development Impact

Measurement Items	Mean	Standard Deviation
Organic herbal agro-business creates employment opportunities (EDI1)	3.87	0.79
Sustainable supply chain innovation improves livelihoods of local producers (EDI2)	3.85	0.81
The herbal agro-business sector has strong export potential (EDI3)	3.89	0.77
Innovation in the supply chain contributes to rural economic development (EDI4)	3.82	0.83
Sustainable herbal agro-business supports income generation for small enterprises (EDI5)	3.88	0.78
The sector can contribute to broader economic development if supported by technology, certification, and market access (EDI6)	3.91	0.75
Overall Mean	3.87	0.51

The average score of economic development impact was 3.87 indicating that respondents highly acknowledged the development potential of the organic herbal agro-business industry. The findings highlight the potential of the sector to contribute to job creation, improved livelihoods, exports, rural economic development and income generation for small enterprises. The highest mean score was for the broad economic development through technology, certification and market access, confirming the importance of institutional and technological support (Table 8)

4.9 Overall Perception

Table 9 shows the general perception of the respondents on sustainable supply chain innovation. It highlights the significance of green practices, AI-driven traceability, smart technology, institutional support and producer training.

Table 9 Descriptive Analysis of Overall Perception

Measurement Items	Mean	Standard Deviation
Sustainable supply chain innovation is essential for the future growth of the organic herbal agro-business industry (OP1)	4.03	0.72
AI driven digital traceability, green practices, and smart technology should be integrated together (OP2)	4.01	0.73
Government and institutional support are necessary for AI- driven sustainable herbal agro-business development (OP3)	4.08	0.70
Small producers need training and technical support to benefit from sustainable supply chain systems (OP4)	4.05	0.71
The global organic herbal agro-business industry can grow faster through sustainable innovation (OP5)	4.00	0.74
Overall Mean	4.03	0.47

The overall perception score was 4.03 which shows a high level of agreement among the respondents. Findings: The study reveals that respondents consider sustainable supply chain innovation is critical for the future growth of organic herbal agro-business industry. The results also emphasize the need for the integration of digital traceability, green practices and smart technology, together with governmental support and technical training for small producers (Table 9).

4.10 Reliability Analysis

The reliability results of the measurement scales used in this study are presented in Table 10. Cronbach's alpha values are reported to evaluate internal consistency of each variable and total questionnaire.

Table 10 Reliability Analysis

Variable	No. of Items	Cronbach's Alpha
Green Supply Chain Practices	6	0.812
AI- driven Digital Traceability	6	0.826
Eco-Innovation	6	0.801
Smart Technology Adoption	6	0.818
Value-Chain Upgrading	6	0.835
Market Expansion and Business Performance	6	0.841
Economic Development Impact	6	0.854
Overall Perception	5	0.796
Overall Scale	47	0.914

The reliability results indicate that all the variables have Cronbach's alpha values above the acceptable level. The overall scale had a Cronbach's alpha value of 0.914, which indicated high internal consistency among the items of the questionnaire. Thus, the questionnaire was a reliable instrument to assess sustainable supply chain innovation and economic development in the organic herbal agro-business industry (Table 10).

4.11 Pearson Correlation Analysis

Table 11 presents the Pearson correlation results of the major study variables. It shows the strength and direction of links between green supply chain practices, digital traceability, eco-innovation, smart technology, value-chain upgrading, market expansion and economic development impact.

Table 11 Pearson Correlation Analysis

Variable	GSCP	DT	EI	STA	VCU	MBP	EDI
GSCP	1.000	0.482**	0.456**	0.438**	0.511**	0.498**	0.522**
DT	0.482**	1.000	0.431**	0.506**	0.489**	0.517**	0.548**
EI	0.456**	0.431**	1.000	0.443**	0.472**	0.486**	0.501**
STA	0.438**	0.506**	0.443**	1.000	0.463**	0.492**	0.516**
VCU	0.511**	0.489**	0.472**	0.463**	1.000	0.536**	0.581**
MBP	0.498**	0.517**	0.486**	0.492**	0.536**	1.000	0.568**
EDI	0.522**	0.548**	0.501**	0.516**	0.581**	0.568**	1.000

Note: ** Correlation is significant at the 0.01 level.

Pearson correlation results indicate that all the major variables are positively and significantly correlated. Green supply chain practices, digital traceability, eco-innovation, smart technology adoption, upgrading of the value-chain and expansion of markets were all positively associated with impact on economic development. The strongest association was found between value-chain upgrading and economic development impact, followed by market expansion and business performance with economic development impact. This suggests that better coordination, certification, value addition to products, marketing and business performance are closely related to livelihood improvement, employment generation, export potential and sustainable economic development (Table 11).

4.12 Regression Analysis

Table 12. Summary of regression model for the effect of sustainable supply chain innovation on economic development impact. It shows the model strength with R, R Square, Adjusted R Square, F-value and significance level.

Table 12 Model Summary

Model Indicator	Value
R	0.704
R Square	0.496
Adjusted R Square	0.486
F-value	48.10
Sig.	<0.001

The regression coefficients of the predictor variables used in this study are shown in Table 13. This paper demonstrates the individual effect of green supply chain practices, AI-driven digital traceability, eco-innovation, smart technology adoption, value-chain upgrading and market expansion on economic development impact.

The regression analysis shows that sustainable supply chain innovation significantly affects economic development impact. The R Square value of 0.496 shows that the independent variables explain 49.6 per cent of the variation in economic development impact. Among predictors, market expansion and business performance had the strongest effect, followed by value-chain upgrading and digital traceability. This implies that the organic herbal agro-business industry's economic development depends not only on green practices but also on market access, product authenticity, certification, digital transparency and stronger coordination among supply chain actors (Table 12 & 13)

Table 13 Regression Coefficients

Predictor Variable	Standardized Beta	Sig.
Green Supply Chain Practices	0.154	0.008
AI Driven Digital Traceability	0.176	0.003
Eco-Innovation	0.132	0.021
Smart Technology Adoption	0.119	0.034
Value-Chain Upgrading	0.208	<0.001
Market Expansion and Business Performance	0.249	<0.001

5 Discussion

The findings show that sustainable supply chain innovation has a favorable relationship with economic development in the United States' organic herbal agro-business industry. Green supply chain practices were proven to improve product quality, market acceptability and environmental responsibility that should be link with AI-driven supply chain system. AI-driven digital traceability was also vital, boosting transparency, verification of the product's origin, quality control and consumer trust. These results imply that consumers and corporate operators in the organic herbal sector are increasingly concerned about authenticity and sustainability. The findings also demonstrate that eco-innovation and smart technology can help enhance operational efficiency, reduce waste, facilitate better decision making and promote competitiveness. Value-chain upgrading was intimately related to economic growth, and demonstrated how certification, branding, packaging and co-ordination between farmers, processors and merchants could help producers to reach higher-value markets. Market expansion and business performance had also a strong impact on economic development, which means that sustainable innovation can contribute to business growth, employment creation, export potential, income generation and rural economic development. In general, the analysis validates the crucial role of sustainable supply chain innovation in the expansion of the organic herbal agro-business industry.

5.1 Limitations

There are certain limitations in this study. The study was first based on 378 responses and may not fully represent the whole global organic herbal agro-business industry. The sector includes different countries, producers, processors, exporters, retailers and consumers and so the findings may vary across regions and market conditions. Second, the study was conducted using the quantitative questionnaire method. The results therefore are based on perceptions of the respondents and may not fully represent actual business practices or financial performance. Third, the study was a cross-sectional study because data were collected at one-time point. Hence, it cannot explain long-term variation in sustainable supply chain innovation and economic development. Finally, the research was based on specific variables such as green supply chain practices, digital traceability, eco-innovation, smart technology, upgrading of value-chain and market expansion. To provide a more thorough knowledge of sustainability adoption, future study should look more closely at these issues. (Mahar et al., 2025)

6 Conclusions

This study was concerned with the role of sustainable supply chain innovation on the economic development of the United States' organic herbal agro-business industry. The findings indicate that green supply chain practices, AI-driven digital traceability, eco-innovation, smart technology adoption and value-chain upgrading result in product quality, transparency, consumer trust, and market access and business growth. The results also point to the fact that AI-driven sustainable supply chain innovation can support job creation, improved livelihoods, increased exports, rural development and income generation for small enterprises. The study says that herbal business companies in the USA need to focus on sourcing. They should also look into farming reducing waste using eco-friendly packaging and setting up systems to track their products. Companies need to improve how they work with their suppliers digitally. They should get certified, control their product quality create brands and make their supply chains more market-focused as well. This will help producers sell their products in markets both in the USA and internationally. Small producers need help to join supply chains. This support will allow them to participate in sustainable supply chains. In order to support sustainability, social justice, and economic growth, future research should create adaptable, technology-driven supply

chain strategies that enhance productivity, resilience, safety, product quality, market stabilization, resource allocation, oversight, and evaluation while attending to the needs of farmers and consumers (Wang et al., 2024).

Overall, the study concludes that sustainable supply chain innovation is an environmental and economic development tool. The organic herbal agro-business industry can be further developed if businesses invest in green practices, technology, traceability system and market-oriented value-chain development. Small producers also need government support, technical training, certification assistance and financing to take advantage of this change.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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