Green Supply Chain Management Enhances Competitiveness and Accelerates Economic Growth in India's Agro-Food Sector

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ABSTRACT

This study argues that green supply chain management (GSCM) significantly boosts competitiveness and economic growth in India's agro-food sector. It analyzes how Indian agro-food companies adopt GSCM practices. As a part of the GSCM approach, eco-friendly packaging, reverse logistics, and energy-efficient transportation are considered to maintain their product quality. Apart from the GSCM approach, there is the impact these practices have on the competitiveness and financial performance of the rest of the mode of production. In this study, quantitative methods and secondary data from government and industry sources are used. The research demonstrates how these GSCM elements strengthen company performance and contribute to the agro industry's sectoral growth. Using descriptive statistics and core hypotheses, the study identifies prevalent practices in the agro-industry. Through this study, we review relevant policy frameworks, identify the obstacles in this sector, and recommend strategies for broader GSCM adoption. The investigation further connects green logistics, sustainable sourcing of agro-green products, and identifies emerging technologies for operational cost reductions and market expansion. The expected outcome of this study is that technological advancements, such as hybrid seeds and modern irrigation, will drive higher productivity and economic growth in Indian agriculture. Practical recommendations are provided to help policymakers, industry leaders, and academics build effective, sustainable, and competitive green agri-food supply chains in India.

Keywords: Green Supply Chain Management, Economic Growth, Agro-food Industry Sustainability, Eco-friendly Practices

INTRODUCTION

Green Supply Chain Management (GSCM) is now central to competitiveness and economic value creation across all sectors of the economy. GSCM integrates environmental priorities directly into product supply chain processes. Intended for the sale of goods and services, it distinguishes between product origin, operational supply chain management, and product sustainability throughout the product lifecycle. This connection to core economic principles: consumption, production, distribution, exchange, and revenue drives both consumption's utility and producer profits. Through implementing green practices, GSCM can advance sustainable and responsible business operations. Economic sustainability shapes both business strategy and market expectations. GSCM emerges as a fundamental approach that links economic growth to ecological sustainability. This introduction outlines how applying GSCM across the supply chain creates value and reduces environmental harm, reinforcing its importance in today's competitive agency environment.

Needs of green supply chain management

Supply chain management is essential for economic development, connecting producers and consumers while supporting marketing and sales. Efficient systems are critical when the number of producers is less than the number of consumers, and an effective market is equalized by a distribution system. Product markets are shaped by product features, production scale, product differentiation, supply chain optimization, and infrastructure, all of which influence green supply chain management. Efficiency focuses on reducing costs and streamlining processes, while effectiveness addresses stakeholder interests throughout the product lifecycle. Economic theory

simplifies these dynamics, but real-world complexities require adaptive management to address market changes. The entry and exit of companies influence market dynamics, affecting prices, production, and distribution. Green supply chain management leverages new technologies to modernize traditional supply chains. For instance, tools such as blockchain for tracking, artificial intelligence for demand forecasting, and the Internet of Things (IoT) for real-time inventory management enhance efficiency and resilience. At the same time, globalization has increased complexity, requiring companies to navigate international trade regulations and diverse legal environments. Therefore, businesses must address these challenges while controlling costs, managing risks, and meeting rising expectations for ethical and sustainable practices.

The circular economy in supply chain management aims to minimize waste, improve resource efficiency, and promote sustainability through the product lifecycle. This approach replaces linear models and prompts businesses to revisit production, packaging, and end-of-life processes. Management studies bridge economic theory and practical challenges to support adaptive, sustainable strategies. As a market mechanism, supply chain management remains vital for economic development, innovation, and growth. In agro-food, GSCM applies sustainability at every stage, starting with eco-friendly farming: selecting sustainable seeds, using organic fertilizers, and implementing integrated pest management to reduce chemical use and support biodiversity. Water conservation methods, such as drip irrigation and rainwater harvesting, and energy-efficient equipment, enhance resource efficiency and reduce emissions.

Sustainability initiatives extend to processing plants, where energy-efficient equipment and renewable energy sources are increasingly used. Moreover, companies are implementing waste treatment to reduce food waste and reuse byproducts, supporting a circular economy. Packaging is also shifting toward biodegradable or recyclable materials to minimize plastic waste. Transportation and logistics improvements, such as optimized routes, efficient vehicles, and alternative fuels, help lower carbon emissions. While sustainable technologies often require significant upfront investment, they can yield long-term savings. As a result, companies are exploring financing options like green bonds and sustainability-linked loans. Furthermore, the COVID-19 pandemic has heightened consumer interest in food origins and production methods, increasing demand for supply chain transparency. Consequently, agro-food companies are adopting more eco-friendly practices and enhancing traceability to meet consumer expectations for sustainability information.

Green supply chain management (GSCM) delivers measurable economic and environmental benefits by improving resource efficiency, reducing waste, and strengthening brand reputation. Environmental, social, and governance (ESG) is a business model that prioritizes eco-friendly practices achieve higher efficiency, cost savings, and stronger customer loyalty, thereby directly enhancing competitiveness. These strategies also reduce risks from climate change, resource scarcity, and regulatory changes. The Indian agro-food industry's wider adoption of GSCM is driven by enduring consumer demand and clear long-term financial value. Technologies such as blockchain, IoT, and artificial intelligence are essential tools that support transparency, real-time monitoring, and resource optimization. Business sustainability at a large scale requires active partnership among all supply chain actors. While industry standards, farmer-producer organizations (FPOs), and NGO involvement indirectly enhance production capacity. This approach accelerates the adoption of consistent best practices, which directly support India's economic growth. Adopting green supply chain management in the agro-food industry presents challenges, including high costs, complex technologies, and difficulties in measuring sustainability outcomes. However, increasing government pressure and consumer demand for eco-friendly products make these practices essential for long-term success in the agro-food industry. Additionally, the sector faces negative perceptions of packaged food due to concerns about chemicals and the environmental impact of packaging, which extend to broader issues such as soil degradation, water pollution, and carbon emissions.

This study provides actionable strategies for producers, emphasizing that effective green supply chain management (GSCM) is essential for overcoming industry challenges. And responding to consumer priorities, and supporting rapid sector growth. GSCM focuses on eco-friendly practices across production, processing, packaging, and distribution, and companies can strengthen competitiveness and meet the rising demand for sustainable food. While large firms have greater resources to manage green supply chains, small producers need targeted support due to limited access to technology, funding, and markets, as well as high certification expenses. Despite these barriers, the fast-growing Indian agro-food industry stands to gain significantly from GSCM,

capturing greater market share and delivering greater value. The industry's path forward hinges on adopting sustainable production techniques, reducing chemicals, choosing eco-friendly packaging, and implementing a coordinated green strategy across the supply chain to achieve an enduring competitive edge. Implementing green supply chain management offers benefits such as reduced environmental impact, improved resource efficiency, higher product quality, and increased customer trust. Organic farming, for example, prevents soil and water damage while producing healthier food. Innovative packaging made from renewable materials or that uses less plastic attracts eco-conscious consumers and benefits the environment. Sustainable strategies can open new markets, particularly in countries with strict environmental standards. to boost exports and support India's economic growth. However, transitioning to green supply chains requires significant investment, stakeholder collaboration, and support from government, industry, and research organizations. Policies that promote eco-friendly practices, assist small producers, and raise consumer awareness are essential. Despite the challenges, the potential rewards in market growth, customer satisfaction, and environmental protection are substantial. By embracing innovation, India's agro-food industry can lead in sustainable food production, meet evolving consumer demands, and advance broader environmental and social objectives.

How to create a green supply chain management

Green supply chain management (GSCM) is an integrated approach that considers environmental factors throughout the supply chain. It encourages sustainability in raw material sourcing, manufacturing, distribution, and end-of-life disposal. GSCM addresses both economic and sustainability issues, aiming to reduce environmental impact and improve resource efficiency throughout a product's life cycle. Key elements include reverse-engineering products and supply chains, planning production to use fewer resources and generate less waste, and carefully selecting suppliers and materials. Logistics and marketing strategies also focus on cutting transportation emissions and encouraging sustainable consumption. Companies that use GSCM can gain a competitive edge through cost savings, reduced waste, and improved energy efficiency. The push for eco-friendly products also leads to innovation and new market opportunities. Improved efficiency and supply chain management further boost business performance, which is important as consumers and stakeholders increasingly focus on environmental responsibility. Policies and emissions regulations strongly influence the adoption and success of GSCM initiatives. Hariyani et al. (2024) proposed a framework highlighting sustainable sourcing and distribution as key components of GSCM. Sustainable sourcing focuses on selecting environmentally and socially responsible suppliers and materials, assessing suppliers' environmental performance, promoting recycled or renewable materials, and considering the lifecycle impact of sourced goods. Sustainable distribution aims to reduce the environmental impacts of logistics and warehousing by optimizing transportation routes, using low-emission vehicles, adopting energy-efficient warehousing practices, and exploring alternative delivery methods. The implementation of GSCM is supported by several conceptual models: 1. Triple Bottom Line Theory stresses balancing economic, social, and environmental performance. 2. Stakeholder Theory highlights the need to address the concerns of various stakeholders, not just shareholders. 3. Resource-Based View Theory suggests firms can gain an advantage by developing unique, sustainable practices or technologies. 4. Circular Economy models promote closed-loop systems that minimize waste and boost resource efficiency. Together, these models provide a comprehensive approach to implementing GSCM, emphasizing the need to consider environmental and social impacts alongside economic performance, engage with stakeholders, develop sustainable capabilities, and move from linear to circular production models.

When companies use Green Supply Chain Management (GSCM) practices, they can reduce their environmental impact, operate more efficiently, improve their reputation, and create lasting value for both businesses and society. As environmental concerns grow worldwide, GSCM is becoming an increasingly important part of business strategy across many industries. New technologies have made GSCM more effective, changing how companies approach sustainability. Advances like blockchain, IoT, artificial intelligence, and big data analytics help make supply chains more transparent, efficient, and resource-friendly. For example, blockchain enables secure tracking of products from start to finish, ensuring that sustainability claims are genuine. IoT devices let companies monitor conditions and resource use in real time, enabling them to quickly cut waste and save energy. AI helps with route planning and inventory, reducing emissions and avoiding overproduction. Big data analytics helps companies spot trends and make better sustainability decisions. New materials, such as bioplastics and recycled materials, support a circular economy by reducing the need for new raw materials and cutting waste.

These changes not only help the environment but can also lower costs and improve products. Working closely with suppliers is also important. Companies are training suppliers in green practices, offering incentives like better contracts or shared savings, and setting joint goals to build a shared commitment to sustainability across the supply chain.

Despite these improvements, organizations still face significant challenges in implementing GSCM. High upfront costs for green technologies and materials can be a major barrier, especially for smaller companies with limited funds. The long-term benefits of GSCM, such as lower costs and a better reputation, may not be clear right away, making it hard to justify the initial investment. Technology and infrastructure can also pose obstacles, as many organizations, especially in developing countries, may lack access to the latest tools or need to upgrade outdated systems. Regulations add another layer of complexity, especially for companies operating across regions with varying rules and standards. This can lead to higher costs and operational issues as companies try to meet different requirements. Cultural and organizational resistance is another challenge. If employees and stakeholders are unaware of the benefits of sustainable supply chains, they may be slow to adopt them or prefer old methods. Overcoming this resistance often requires strong leadership and careful change management. Addressing these barriers is essential for organizations to get the full benefits of GSCM and help build a sustainable economy. When done well, GSCM can improve environmental performance, increase efficiency, reduce costs, and boost brand value. As more consumers want eco-friendly products, companies that overcome these challenges and adopt GSCM are likely to stand out.

REVIEW OF LITERATURE

The literature emphasizes the key role of green supply chain management in fostering economic growth, particularly amid challenges such as global warming, climate change, and public health issues. To further explore this topic, a research goal was formulated to extend the investigation. Research on green supply chain management (GSCM) in the agro food sector highlights several recurring themes: the role of digital technologies, waste management, climate change, organizational willingness, policy frameworks, and consumer trust. Together, these studies provide a comprehensive picture of how sustainability practices are reshaping green supply chains in India and beyond. The conceptual framework for this study is built upon six interrelated thematic pillars derived from the literature on Green Supply Chain Management (GSCM) in the agro-food sector. These themes converge to shape a holistic understanding of how sustainability practices enhance competitiveness and drive economic growth in India's agricultural sector.

Digital Transformation and Green Technologies: This theme captures the role of emerging technologies, such as blockchain, IoT, and AI, in improving transparency, resource efficiency, and traceability across the supply chain. These innovations enable real-time monitoring and predictive analytics, which are essential for optimizing logistics and reducing environmental impact.

Waste Management and Resource Efficiency: Studies emphasize minimizing waste at the earliest stages of production and distribution. Efficient resource use, biodegradable packaging, and circular economy principles are central to reducing ecological footprints and improving operational performance.

Organizational and Structural Factors: Internal willingness, green human capital, and supply chain control are critical enablers of GSCM. Organizational commitment, training, and stakeholder engagement determine the success of sustainability initiatives, especially among SMEs and marginal producers.

Policy, Regulation, and Market Dynamics: Government incentives, net-zero policies, and certification mechanisms influence the adoption of green practices. Market dynamics, such as consumer demand for sustainable products and international competitiveness, further motivate firms to align with environmental standards.

Analytical and Modeling Approaches: Quantitative models and simulation techniques help assess uncertainty, trade-offs, and performance outcomes in green supply chains. These tools support evidence-based decision-making and strategic planning for business sustainability.

Artificial Intelligence and Machine Learning: AI-ML technologies offer high-accuracy assessments of sustainability metrics, enabling companies to automate evaluations and improve compliance. These tools are especially valuable in scaling GSCM across diverse and complex supply networks. At the center of this framework is Green Supply Chain Management in the Agro-Food Sector. This integrates these six themes to guide empirical analysis and strategic recommendations. The framework reflects a systems-oriented approach, recognizing that sustainable transformation requires technological innovation, institutional support, organizational capacity, and collaborative action across the supply chain. In this paper, we incorporate the previous study and examine its relevance.

Digital Transformation and Technology: A growing body of work emphasizes the importance of digital technologies in strengthening GSCM. Singh et al. (2025) examined how digital transformation supports carbon neutrality and encourages circular economy practices. Kumar et al. (2023) found that integrating IoT and blockchain into food supply chains reduces waste and emissions while improving food quality and security. Similarly, Yu et al. (2025) identified clusters of digital transformation in agri food supply chains, including sustainability, operations, performance, and risk management. Industry 4.0 and 5.0 technologies—such as AI, robotics, smart sensors, and big data—are increasingly linked to sustainability outcomes. Hassoun et al. (2022) connected these technologies to the Sustainable Development Goals, while Singh et al. (2025) highlighted how Industry 5.0 integrates human collaboration with advanced digital tools to promote sustainable food production. Despite these advances, challenges remain. Narwane et al. (2022) highlighted interoperability, trust, and security issues in IoT adoption, while Halder et al. (2025) noted persistent risks, including cyberattacks and concerns about data validity.

Waste Management and Circular Economy: Waste reduction is another central theme. Kharola et al. (2022) stressed that preventing waste early in the supply chain is more effective than addressing it later. Kumar and Agrawal (2023) revealed that inefficient supply chains account for nearly one-third of India's annual waste of fresh agricultural products, underscoring the need for restructuring. Panpatil and Kant (2022) analyzed green supply chain practices and found that deliberate sustainability drivers are critical to performance. Circular economy approaches are widely recommended. Gardas et al. (2018) identified environmental management and regulatory pressure as key drivers of performance in India's agro sector. Packaging innovations, recycling, and reuse of byproducts are seen as essential strategies for minimizing waste and improving efficiency.

AI and Machine Learning Applications: Artificial intelligence and machine learning are emerging as powerful enablers of GSCM. Saha et al. (2025) demonstrated that AI/ML technologies achieve up to 99% accuracy, compared with 80–90% for manual assessments, reducing downtime and labor costs while strengthening supply chains. Andika et al. (2025) integrated AI and ML with Life Cycle Assessment to improve predictive capabilities. Nath et al. (2024) further showed that AI can enhance crop yield prediction, quality control, and supply chain optimization, contributing to both sustainability and food security.

Climate Change and Food Security: Climate change poses significant risks to agro-food supply chains. Tchonkouang et al. (2024) reviewed over 1,500 publications and concluded that extreme weather conditions weaken food supply chains by affecting agricultural output, prices, and food safety. Sridhar et al. (2023) highlighted that pandemics and climate change threaten food security, leaving 30% of the population without adequate access to food. Trivedi et al. (2021) emphasized the importance of climate-resilient supply chains in Uttarakhand. Policy responses are also critical. Singh (2025) found that net-zero policies improve supply chain sustainability and agility, while Sharma et al. (2024) identified international pressure as a key driver of the adoption of decarbonized technologies in India's food supply chains.

Green Human Capital and Organizational Readiness: Organizational willingness and human capital are decisive factors in GSCM adoption. Tjahjadi et al. (2022) showed that green human capital readiness influences SME performance, with market orientation and supply chain practices mediating this effect. Chakraborty et al. (2023b) highlighted internal factors such as top management commitment, reverse logistics, and material management as critical drivers. Sharma et al. (2016) used AHP analysis to rank performance indicators, identifying internal environmental management and regulatory pressure as the most significant. Resistance to change remains a barrier. Studies note that cultural and organizational inertia can slow adoption, requiring strong leadership and effective change management.

Policy, Regulation, and Stakeholder Engagement: Policy frameworks and stakeholder engagement are consistently identified as enablers of GSCM. Gardas et al. (2018) emphasized regulatory pressure as a major driver of performance. Rueda et al. (2016) argued that private investment is essential for ecological sustainability, suggesting that relocating firms without sustainable technologies is not sustainable. Sharma et al. (2024) developed a consensus model to assess suppliers' ability to track sustainable performance, highlighting financial strength as a key factor. Cooperative models also play a role. Gu et al. (2024) showed that contract farming and subsidies encourage technology adoption and increase farmer participation, while Sargani et al. (2025) linked digital technology adoption to improved resilience and productivity in China's farming sector.

Food Quality, Safety, and Consumer Trust: Finally, food quality and consumer trust are central to competitiveness. Song et al. (2017) demonstrated that certification and reputation improve safety, quality, and international competitiveness. Yadav et al. (2020) noted that blockchain adoption in India's food supply chains addresses contamination scandals and enhances traceability. Innovative packaging and preservation technologies also contribute. Chaudhary et al. (2024) reviewed the use of ionizing radiation to extend shelf life while preserving nutrients, and Joshi et al. (2024) analyzed osmotic dehydration as a method to improve supply chain quality in India's fruit industry. Further, its extension, we are incorporating all intext citation in the tabular form given below:

Author & Year	Methodology	RESULTS & Findings	Connection to Current Study
Abad et al. (2023).	RNRAMSSP modeling validated with EVPI & VSS	Effective in managing supply uncertainty	Provides methodological insights for uncertainty in agro-food supply chains
Agarwal et al. (2025).	Quantitative analysis	Green infrastructure drives supply chain circularity via digital adoption	Aligns with eco-friendly technology adoption in India
Anand et al. (2024).	Grey DEMATEL & ANP	Barriers to collaborative practices identified	Provides insights into waste reduction
Andika et al. (2025).	AI + Life Cycle Assessment	Enhanced predictive capabilities for sustainability	Suggests integrating AI with LCA for agro-food chains
Ashaolu & Ashaolu (2020).	Review	Industrialization increases food fraud	Highlights the need for green & organic products
Birasnav et al. (2022).	Theoretical framework & research model	Identified antecedents & outcomes of GSCM practices	Provides foundational attributes for evaluating Indian agro-food firms
Chakraborty et al. (2023).	Interpretive Structural Modeling (ISM)	Identified internal GSCM factors; highlighted top management commitment, reverse logistics, and material management as critical drivers	Reinforces organizational readiness and leadership as key enablers of GSCM adoption in India's agro-food sector
Chaudhary et al. (2024).	Review	Irradiation extends the shelf life of food	Suggests tech for reducing waste
Das et al. (2022).	Game-theoretic comparison	Profits, greening levels, and prices vary across structures	Highlight's role of small retailers in sustainable development
Das et al. (2025).	Game-theoretic modeling	Manufacturer cooperation boosts greening but raises prices; competition lowers	Demonstrates trade-offs relevant to Indian agro-food markets

		prices but undermines sustainability	
Fu et al. (2025).	Empirical study	Farmers' livelihood risks linked to green transformation	Connects socio-economic risks to GSCM adoption
Gardas et al. (2018a).	DEMATEL analysis	Environmental management and regulatory pressure are key drivers	Identifies causal factors for India's agro-sector
Gardas, B., Raut, R., Jagtap, A. H., & Narkhede, B. (2018)	Modeling & KPI analysis	Explored key performance indicators (KPIs) of GSCM in the agro-industry — waste reduction, energy efficiency, and eco-friendly packaging	Provides a performance measurement framework directly relevant to evaluating GSCM adoption in India's agro-food sector
Gu et al. (2024).	Modeling	Subsidies & cooperatives boost green tech adoption	Suggests policy incentives for India
Halder et al. (2025).	Survey on AI & IoT	AI & SIIoT improve agri-food security but face cyber risks	Highlights digital security challenges
Hassoun et al. (2022).	Industry 4.0 analysis	Linked AI, IoT, blockchain to SDGs in food systems	Shows tech-enabled ecological transition
Hassoun et al. (2024).	Industry 4.0 review	Smart sensors, AI, and blockchain improve sustainability	Shows tech-enabled transformation
Joshi et al. (2024).	Review	Osmotic dehydration improves supply chain quality	Provides food preservation insights
Khan et al. (2023).	Survey	IoT adoption barriers: cost, infrastructure	Highlights adoption challenges
Kharola et al. (2022).	Case-based analysis	Waste prevention is most effective at the early stages	Supports resource efficiency focus in agro-food GSCM
Kumar & Agrawal (2023).	Case study	Identified 34 challenges in AFSCs	Provides insights into restructuring Indian supply chains
Kumar et al. (2023).	Empirical study using IoT & blockchain	Reduced waste, improved food quality, enhanced food security	Demonstrates tech-enabled transparency in food supply chains
Le (2023)	Empirical study	CSR & GSCM promote sustainable consumption	Connects CSR to agro-food sustainability
Narwane et al. (2022).	IoT adoption study	Challenges: interoperability, trust, security	Highlights barriers to tech adoption in India
Nath et al. (2024).	Review	AI enhances sustainability & food security	Supports AI integration in agro-food chains
Panpatil & Kant (2022).	Analytical modeling of GSCPs	Driver GSCPs are strategic; dependent GSCPs are performance-focused	Offers categorization useful for Indian agro-food firms
Phiri et al. (2023).	Review	Farming practices linked to soil degradation	Suggests sustainable farming solutions

Rajan & Radhakrishnan (2022).	Review	Ohmic heating improves seed germination	Suggests sustainable post-harvest methods
Rajesh (2020)	Decision-making model	SSCM offers a competitive advantage	Provides an integrative model for India
Raut et al. (2019).	Fuzzy multi-criteria approach	Cold logistics reduces food losses	Suggests logistics solutions for India
Rueda et al. (2016).	Empirical study	Private investment drives ecological sustainability	Suggests investment strategies for Indian agro-food firms
Saha et al. (2025).	AI-ML application	AI-ML achieves 99% accuracy vs. 80–90% manual	Demonstrates the potential of AI for monitoring GSCM outcomes
Sargani et al. (2025).	Empirical study	Digital adoption improves resilience & productivity	Reinforces tech adoption benefits
Sazvar et al. (2018).	Modelling sustainable supply chains	Hybrid organic-conventional model reduces costs & environmental risks	Balances sustainability with economic growth
Sharma et al. (2016).	AHP analysis	Internal environmental management & regulatory pressure key	Identifies performance indicators relevant to India
Sharma et al. (2024a).	Policy analysis	International pressure drives decarbonization	Connects global policy to Indian food chains
Sharma et al. (2024b).	Delphi method	Financial strength key for supplier evaluation	Offers evaluation framework for Indian agro-food suppliers
Shetty & Bhat (2021).	Review	Globalization intensifies competition	Reinforces need for GSCM in India
Singh (2025)	Policy analysis	Net-zero policies enhance agility & sustainability	Connects policy frameworks to competitiveness in agro-food sector
Singh et al. (2023).	Grey causal modelling	Digital twins enhance resilience	Supports resilience-building in Indian food chains
Singh et al. (2025a).	Conceptual & empirical analysis	Digital transformation supports carbon neutrality & circular economy	Highlights tech adoption relevance for India's agro-food GSCM
Singh et al. (2025b).	Systematic review	Industry 5.0 integrates AI, IoT, robotics	Shows future direction for sustainable food production
Song et al. (2017).	Empirical study	Certification improves safety, quality, and competitiveness	Supports the role of standards in export competitiveness
Sridhar et al. (2023).	Review	Climate change & pandemics threaten food security	Supports resilience-building in agro-food GSCM
Sreedharan & Raju (2018).	Green Lean Six Sigma model	Improved public-sector services	Suggests lean integration for the Indian agro-food
Tchonkouang et al. (2024).	LITERATURE REVIEW	Climate change weakens food supply chains	Highlights resilience needs in India

Tjahjadi et al. (2022).	Survey of 182 SMEs	Green human capital readiness improves performance via market orientation	Suggests that workforce readiness is critical for Indian SMEs
Trivedi et al. (2021).	Case study	A climate-resilient supply chain is essential in Uttarakhand	Regional insights for resilience
Yadav et al. (2020).	ISM-DEMATTEL & fuzzy-MICMAC	Blockchain adoption barriers identified	Highlights early-stage blockchain challenges
Yadav et al. (2024a).	SEM & ANN analysis	Digital technologies positively affect green integration & innovation	Reinforces role of digital tools in sustainable food chains
Yadav et al. (2024b).	SEM analysis	Digital technologies positively affect green innovation	Reinforces tech-driven sustainability
Yu et al. (2025).	Empirical clustering	Identified 5 clusters in digital agri-food supply chains	Provides theoretical grounding for digital adoption

The **research objectives** are as follows:

1. To identify and classify green supply chain management practices adopted by agro-food companies in India.

2. This study examines the roles of policy mechanisms and institutional support in facilitating green supply chain transitions in the agro-food sector.

3. To assess the barriers and enablers influencing the implementation of green supply chain management practices throughout various stages of the agro-food value chain–procurement, processing, packaging, and distribution.

This study adopts a conceptual framework grounded in multiple theoretical perspectives: Triple Bottom Line, Stakeholder Theory, Resource-Based View, and Circular Economy models, to examine the impact of Green Supply Chain Management (GSCM) practices on competitiveness and economic growth in India's agro-food sector. The framework identifies five core GSCM practices: sustainable farming, green processing, eco-friendly packaging, green logistics, and reverse logistics. These practices serve as independent variables that influence three mediating factors: operational efficiency, innovation capacity, and brand reputation & consumer trust. These mediators, in turn, affect key outcomes such as firm competitiveness, economic growth indicators, and environmental sustainability. The framework also incorporates four moderating variables: policy and institutional support, technological infrastructure, firm size and resources, and global market standards, which shape the strength and direction of the relationships between mediators and outcomes. This structure enables a nuanced understanding of how GSCM practices contribute to performance improvements and strategic advantages in the agro-food sector. The conceptual model guided data collection, variable categorization, and hypothesis formulation. A research methodology was adopted to address the stated objectives, relying on a systematic analysis of secondary data. Data sources included government reports from the Ministry of Agriculture and the FSSAI, as well as industry publications and trade databases such as APEDA and NABARD. Due to limited data availability. Descriptive statistics were used to summarize adoption levels and firm characteristics. The lack of primary data limited the application of advanced statistical tools to analyze green supply chain management performance in India's agro-industry. Research questions were developed to guide the classification and analysis phases, thereby supporting the achievement of the **research questions**, which are as follows:

1. What is the relationship between green supply chain management and economic growth in India's agro-food sector?

2. How do green supply chain practices affect the competitiveness of agro-food companies in India?

3. How much do green logistics and sustainable sourcing contribute toward cost savings and market development?

Data analysis and interpretation:

This conceptual framework illustrates the dynamic interplay between GSCM practices and their impact on competitiveness and economic growth in India's agro-food sector. It begins with five core sustainable practices: sustainable farming, green processing, eco-friendly packaging, green logistics, and reverse logistics, which serve as independent variables. These practices influence three mediating factors: operational efficiency, innovation capacity, and brand reputation & consumer trust. These mediators, in turn, drive key outcomes such as firm competitiveness, economic growth indicators, and environmental sustainability. The strength and direction of these relationships are moderated by policy and institutional support, technological infrastructure, firm size and resources, and global market standards. This framework integrates theoretical insights from the Triple Bottom Line, Stakeholder Theory, Resource-Based View, and Circular Economy models, offering a holistic lens to understand how GSCM can transform India's agro-food supply chains into sustainable engines of growth. In this study, we are incorporating five tables to present the study for two primary reasons: first, the unavailability of data directly related to the research topic; second, the premise that production and consumption patterns are reflected in import and export data. In each country, certain products and services exhibit surpluses or deficits, leading to imports or exports to support the national economy. Table 1 provides insights into commercial agricultural products. Indian tea is renowned worldwide, and coffee also contributes significantly to the country's gross domestic product. Analysis of Table 1 indicates that Indian tea and coffee make substantial contributions to national income and influence both production and employment sectors.

Table 1: Tea and Coffee import and export by India, Quantity in Thousand Tons and Value in Rupees in Crore

Year	Tea				Coffee			
	Import		Export		Import		Export	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore
2014-15	28.39	388.66	234.39	4171.25	74.88	930.47	463.55	4973.25
2015-16	23.72	377.47	245.7	4719	65.61	801.83	255.74	5125.45
2016-17	24.89	338.35	243.43	4905.64	78.04	926.81	288.61	5646.43
2017-18	24.94	356.99	272.89	5396.65	77.22	996.5	317.83	6245.36
2018-19	28.851378	417.96492	270.3064	5828.3383	82.772392	958.5876	282.8399	5721.9754
2019-20	21.935219	411.06209	254.80066	5851.1078	88.087665	962.15896	257.03245	5236.7626

2020-21	38.585218	658.87394	212.68766	5603.5017	78.496484	900.56498	245.2098	5339.6467
2021-22	30.343053	475.68166	208.61416	559.66748	84.722607	1054.299	333.09894	761.36208
2022-23P	26.824153	427.1851	206.29666	5629.5923	93.0621	1509.263	250.15391	7251.4788

Sources: Environment Statistics–Vol. I, National Statistical Office, Ministry of Statistics and Programme Implementation, Government of India

Table 2 presents data on pulses and spices concerning India's imports and exports. The data suggest that Indian pulses currently experience a deficit, while spices exhibit a surplus within the Indian economy. Regarding branding, India possesses an opportunity to develop the spices sector and faces a challenge in the pulses sector. Green supply chain management offers an opportunity to expand the supply side of the economy and potentially gain a competitive advantage in global markets.

Table 2: Pulses and Spices import and export by India, Quantity in Thousand Tons and Value in Rupees in Crore

Year	Pulses				Spices			
	Import		Export		Import		Export	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore
2014-15	4584.85	17062.94	222.14	1218.31	163.09	4393.25	939.01	14847.74
2015-16	5797.71	25619.06	255.72	1655.9	197.06	5399.95	831.68	16630.14
2016-17	6609.49	28523.18	136.72	1277.7	242.29	5760.25	1014.45	19111.25
2017-18	5607.53	18748.57	179.6	1469.63	222.33	6385.26	1096.32	20084.91
2018-19	2527.875	8035.2953	287.131	1801.512	240.55522	7932.7034	1133.8894	23217.773
2019-20	2898.078	10221.448	232.081	1511.7996	320.93534	10186.934	1193.4409	25642.041
2020-21	2466.156	11937.589	276.927	1977.6267	344.21135	8070.5311	1607.0585	29529.393
2021-22	2.699694	16627.582	0.387208	268.29044	364.06763	9684.7405	1427.7181	2903.9266
2022-23P	1.998006	12705.154	0.539763	3783.7773	343.24891	9073.6945	1026.4139	24195.979

Sources: Environment Statistics - Vol. I, National Statistical Office, Ministry of Statistics and Programme Implementation, Government of India

Table 3 presents data on India's imports and exports of sugar, fruit, and vegetable seeds. Sugar and vegetable seeds serve as key ingredients in numerous agricultural products available in the market. The data indicate that India benefits from positive externalities from expanding and improving product quality through green supply chain management.

Table 3: Sugar and Fruits/Vegetable Seeds import and export by India, Quantity in Thousand Tons and Value in Rupees in Crore

Year	Sugar				Fruits / Vegetable Seeds			
	Import		Export		Import		Export	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore
2014-15	1538.64	3668.21	1955.19	5328.83	14.01	611.53	12.5	427.04
2015-16	1943.13	4037.86	3844.45	9824.52	14.33	703.03	13.1	529.19
2016-17	2146.15	6868.61	2544.01	8659.54	14.07	653.33	11.29	522.75
2017-18	2402.98	6035.84	1757.93	5225.6	16.05	768.26	14.47	670.91
2018-19	1490.605	3175.3881	3989.661	9523.1367	19.725768	835.80749	17.5324	866.31258
2019-20	1117.726	2473.2455	5798.534	13981.556	17.775563	851.78724	19.221693	771.66033
2020-21	1963.998	4720.0118	7517.923	20668.566	24.983614	1060.2374	32.285421	929.62867
2021-22	0.359615	1263.188	10.45708	3434.4685	19.761889	1043.1247	20.989493	84.382432
2022-23	0.495093	2049.2526	9.655156	37397.858	25.721448	1047.3258	14.488531	802.4929

Sources: Environment Statistics - Vol. I, National Statistical Office, Ministry of Statistics and Programme Implementation, Government of India

Table 4 presents data on India's imports and exports of fresh fruits and vegetables. As an agriculture-based economy, India possesses significant opportunities to develop agricultural products and services. The data suggest that India has an abundance of vegetable products but limited fresh fruit production. This disparity may be attributed to underdeveloped agricultural infrastructure, particularly the lack of cold storage and silos needed to preserve fresh fruits and vegetables. Green supply chain management could facilitate extended storage and maintain food quality, thereby improving consumption patterns.

Table 4: Fresh Fruits and Vegetables import and export by India, Quantity in Thousand Tons and Value in Rupees in Crore

Year	Fresh Fruits		Fresh Vegetables	
	Import	Export	Import	Export

	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore
2014-15	900.98	9566.81	539.23	3160.08	8.24	11.14	2081.8	4666.45
2015-16	857.9	11071.57	654.66	4191.24	140.73	394.45	2104.36	5237.1
2016-17	1057.51	11290.62	817.06	4974.21	8.55	11.12	3404.07	5790.71
2017-18	994.7	12524.55	714	4913.28	15.66	25.64	2448.02	5297.72
2018-19	1124.178	13931.655	823.085	5538.1527	14.749	24.217712	3192.493	5679.1043
2019-20	993.73	14137.085	834.835	5496.381	150.097	594.81645	1930.511	4617.3407
2020-21	1211.833	15764.8662	973.177	5668.74996	72.898	225.56568	2339.675	5388.0263
2021-22	1.552494	18342.085	1.16644	656.5838	0.045989	138.1123	2.468404	607.58254
2022-23P	1.213848	16584.036	0.745419	4229.8532	0.017693	35.452796	2.678521	6005.7955

Sources: Environment Statistics - Vol. I, National Statistical Office, Ministry of Statistics and Programme Implementation, Government of India

Table 5 presents India's imports and exports of processed vegetables, processed fruits, and juices. In India, a significant proportion of the working class has adopted processed foods and increased consumption of fruit and juice. The table details the progress in processing vegetables, fruits, and juices from 2014–15 to 2022–23, providing insight into the positive impact on these sectors. Numerous agricultural producer organizations have been established in India to cooperate with local farmers and organize markets, thereby facilitating the production of high-quality goods and services. Green supply chain management offers an opportunity to improve product quality, promote eco-friendly agricultural practices, and address health concerns through technology and certification of agricultural products, eventually improving perceptions, strengthening the agricultural sector, and increasing the GDP ratio across other sectors of the economy.

Table 5: Processed Vegetables, Fruits, and Juices import and export by India, Quantity in Thousand Tons and Value in Rupees in Crore

Year	Processed Vegetables				Processed Fruits and Juices			
	Import		Export		Import		Export	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore	Thousand Tones	Rupees in Crore
2014-15	10.96	104.45	186.04	1721.89	33.55	499.54	588.38	3626.86
2015-16	15.38	120.33	174.43	1697.22	40.49	526.49	532.29	3767.08

2016-17	13.32	115.26	192.86	1765.75	42.99	548.1	533.15	3921.08
2017-18	15.34	134.83	212.2	1823.36	53.59	803.81	573.28	4169.13
2018-19	18.097792	161.83124	228.967	2055.411	59.123888	909.33669	594.48733	4481.2512
2019-20	33.62182	253.67528	223.30825	2212.0319	54.10236	771.22033	568.88301	4590.964
2020-21	18.265594	163.52327	367.09892	3150.056	44.436756	662.91635	532.87072	5150.8031
2021-22	20.714024	209.09094	308.27531	307.27685	63.163835	997.78281	629.70418	580.25321
2022-23P	19.179833	217.65874	293.25412	3216.9372	50.419526	1008.6341	514.48357	5969.5776

Sources: Environment Statistics - Vol. I, National Statistical Office, Ministry of Statistics and Programme Implementation, Government of India

DISCUSSION

The data suggest that many people in India still face malnutrition, even though markets and the government focus on public health and morale. Although India has the largest working population in the world, its energy levels are lower than those of developed countries. Green supply chain management could help maintain value and encourage more environmentally friendly practices.

The study finds that Green Supply Chain Management (GSCM) practices, like eco-friendly packaging, reverse logistics, and energy-efficient transport, make India's agro-food sector more competitive. These practices help reduce inefficiencies, improve product quality, and build stronger brands, creating long-term value for companies. Similar findings by Kumar et al. (2023) show that green supply chain management cuts waste and emissions while improving food quality. However, there are still barriers to wider adoption, such as high initial costs, certification fees, and infrastructure challenges, which especially affect small producers. Panpatil and Kant (2022) point out that while some GSCM practices are essential, others focus more on performance, making it hard to balance sustainability and profits. Different regulations across regions also make compliance harder, especially for multinational companies. The results highlight the need for supportive policies and collaboration. Government incentives, green loans, and bonds can help lower financial barriers. Industry groups and NGOs are important for setting standards and offering technical help. As Das et al. (2025) note, working together in the supply chain helps with greening but requires careful cost and pricing management. In India, it's especially important to support small producers so they can be part of the move to sustainable supply chains. The findings also support several key models: the Triple Bottom Line (balancing economic, social, and environmental goals), **Stakeholder Theory** (addressing the needs of all stakeholders), the **Resource-Based View** (using unique sustainable strengths for advantage), and Circular Economy models (reducing waste through closed-loop systems). Together, these models help explain GSCM adoption in the agro-food sector.

CONCLUSION

This study shows that Green and Sustainable Supply Chain Management (GSCM) is both an environmental responsibility and an economic need for India's agro-food industry. Making sustainability part of every step— from farming to packaging and distribution—can help companies reduce their environmental impact, operate more efficiently, and identify new market opportunities. Using advanced technologies also helps Indian agriculture become a leader in eco-innovation. While there are challenges such as financial constraints, infrastructure gaps, and regulatory differences, the long-term benefits of GSCM outweigh the costs.

Companies that lead in adopting green practices will be better able to manage climate risks, government demands, and changing consumer preferences. Small producers, especially, need targeted support, such as subsidies, training, and assistance with certification, to ensure everyone can take part. On a policy level, GSCM not only helps companies compete but also supports national economic growth and environmental protection. By working together and adhering to global sustainability standards, India's agro-food sector can strengthen its position in world markets and address urgent environmental challenges. Overall, GSCM gives India a real chance to combine growth with sustainability, helping the agro-food industry stay competitive and resilient while supporting broader environmental and social goals.

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