

Data-Driven Transformation of Agri-Supply Chain (Ascs): Comprehensive Review

Piyush Nimbokar¹, Sanika Yawale², Samiksha Kasulkar³, Shreya Patil⁴, Seema Wankhade⁵

^{1,2,3,4} UG - Department of Information Technology, GCE Amravati, Maharashtra, India.

⁵Assistant Professor, Department of Information Technology, GCE Amravati, Maharashtra, India.

Emails: piyushnimbokar1@gmail.com¹, sanikayawale@gmail.com², samikshakasulkar9@gmail.com³, shreyapatil73169@gmail.com⁴, srwankhade7@gmail.com⁵

Abstract

Traditionally, the agricultural supply chains have dealt with a lot of flaws that affect the whole sector. The agricultural industry is undergoing a transformative shift with advanced technologies, particularly Machine Learning. This review depicts the bridging of the gap in the development of agricultural supply chains. ML and AI are found to be powerful tools for making informed decisions regarding challenges like post-harvest losses, price volatility, logistical difficulties, etc. In many review papers, the stated challenges are not addressed completely. The same can be addressed by handling and analyzing the data carefully and properly using ML algorithms to make the system more efficient than the present scenario. We believe these gaps can be bridged with techniques like demand forecasting, optimal resource utilization, supply chain visibility, etc.

Keywords: Machine Learning; Agricultural Supply Chain Management; Artificial Intelligence; Decision Making; Data Analysis.

1. Introduction

The agricultural landscape is at a critical point in time, driven by the two essentials of feeding the growing global population and the need to attain efficiency in food production. This revolution calls for the reassessment and optimization of supply chains, effective utilization of resources, and reducing environmental consequences. In these circumstances, machine learning (ML) unfolds as an influential tool with its extraordinary competence for predictions, optimization, and data analysis. Conventionally, the supply chains have contended with inadequacies that resonate throughout the sector. The agricultural supply chains have been overwhelmed with challenges like post-harvest losses, price volatility, and logistical difficulties. The advancements in ML present optimistic solutions to these established problems. ML possesses several algorithms that are capable of analyzing huge datasets, contributing to the decision-making process across the agricultural

value chain. Enabled by ML, predictive demand forecasting can enhance production planning and resource allocation, minimizing waste and ensuring efficient utilization of land, water, and fertilizers. The integration of smart sensors and the Internet of Things (IoT) into data analytics with ML enables the real-time monitoring of field and land conditions. This facilitates precision agriculture, allowing the maximization of yield. Furthermore, ML serves as a backbone for strengthening the transparency and traceability of the supply chain. The potential of ML extends beyond efficiency gains by addressing critical global difficulties like climate change and resource scarcity. Tasks like planning various activities and optimal resource allocation can be completely transformed by predictive demand forecasting. ML guarantees the maximum utilization of resources by minimizing waste. Also, ML can detect threats, identify inefficiencies, and promise sustainable business

practices along the supply chain by analyzing the data. This provides the stakeholders with a way to maintain and impose strict quality standards. This work is dedicated to data-driven agricultural supply chain management. It analyzes the various studies conducted previously and identifies the gaps in them. The agricultural landscape is expected to witness the increasing adoption of agricultural supply chain management in the future, and the findings of this study can guide researchers and practitioners and address their issues.

2. Literature Review

The use of sufficient amounts of data and advanced analytics to improve decision-making throughout the supply chain has increased attention to the agricultural sector [1], [9]– [12]. Recent technological improvements in supply chain operations are helping to eliminate inefficiencies in operations such as demand planning, coordination, and responsiveness [6, 10, 11]. Important machine learning applications to improve the sustainability of the agricultural supply chain in the planning, acquisition, production, and distribution phases are mentioned in a systematic review by Sharma et al. [6]. In particular, Mursidah et al. [2] present a supervised ML-based sustainability assessment system for sugarcane supply chains to drive improvements. Kliangkhlao et al. [3] developed a Bayesian model to explain agricultural supply chain relationships and decisions. Yang et al. [5] review advances in ML for risk management, including prediction, detection, and mitigation. More accurate demand forecasting is enabled by the ability to gain insights from data that will help to reduce food waste [11] and adapt production to consumption patterns [7]. A detailed evaluation of research on data-driven improvements in agriculture, focusing on the social, environmental, and economic effects, is provided by Kamble et al. [10]. The use of data analytics to maximize inventory and transportation capacity has been the subject of several studies. The strategy of Tao et al. [7] balances efficiency and freshness in the distribution of agricultural products by scheduling

them using automated data feeds from the Internet of Things sensors. Pham et al. [15] analyzed several prediction models, such as neural networks, for supply chain planning from important obstacles to practical implementation. Similar to Cui's edge computing approach, other people have worked on hypothetical integrated architecture designs for supply chains in data-driven agriculture [13]. Even though the technology automates supply chain processes, there are still some circumstances where full adoption is difficult due to uncertainty about data quality [14]. In their comprehensive and systematic analysis of the literature, Ni et al. [4] examined the importance of machine learning in managing supply chain risks and highlighted the need for systems to ensure the accuracy of the data and algorithms that support important decisions. Improved access to relevant information along supply chains can promote a sufficient amount of growth as solutions scale up, benefiting small farmholders. In their study of the use of data analytics in agriculture, Neto et al. [9] found that production forecasts have only been partially adopted so far, but there is still great potential for future growth. Overall, research shows encouraging progress in competent supply chain data as adoption occurs gradually. Data-driven ML innovations hold promise for creating sustainable and resilient agricultural supply chains.

3. Review Findings and Discussions

Recent research shows that new digital tools and technologies like smart sensors, advanced forecasting, tracking systems, and connected networks have the potential to greatly improve agricultural supply chain efficiency, sustainability, and teamwork across food production and sales partners. However, so far, the actual use of these high-tech solutions in farms and markets around the world remains low. Issues like making sure data is used properly, tools are fair for all, systems are secure, and everyone can participate equally also need to be addressed carefully as advanced options spread.

Table 1 Summary of Key Reviews on Data-Driven Agri Supply Chain

Research Paper	Focus Area	Objectives	Findings	Limitations
Kliangkhlao et al. [3]	Explainability in Agricultural SCM	Develop a causal Bayesian network model providing SCM explanations and visibility	Allows systematic dependency analysis across supply chain stages	Testing is done only on the simulated dataset
Yang et al. [5]	Supply Chain Risk Management	Apply ML techniques like CNN for supply chain risk identification and mitigation	Helps dynamically profile risks across regions and formulate targeted strategies	Historical bias risks with datasets used for training models
Sharma et al. [6]	Sustainable Agriculture SCM	Review ML applications across SCM planning, sourcing, production, distribution	Highlights range of techniques, objectives, and sustainability outcome metrics	Scope limited to only ML without complementary innovations
Tao et al. [7]	Agricultural Product Distribution Optimization	Data-driven optimizer balancing logistics costs and food freshness	IoT & ML enable dynamic route adjustments aligned to crop shelf life	Testing via simulations without real-world validation
Neto et al. [9]	Data Usage in Agricultural SCM	Understand data and analytics adoption patterns across farms	Significant upside potential remains to apply advanced analytics like ML	Survey limited input suppliers without full value chain partners
Sharma et al. [11]	Agricultural Demand Forecasting	Develop a stacking ensemble model combining ML techniques for crop planning insights	Effectively integrates LSTM, RF, and ANN algorithms	Testing done on selective crop types
Pham et al. [15]	Predictive Supply Chain Analytics	Review and classify ML techniques for predictive demand and delivery management	Highlights RNN, ML and CNN approaches but sparse real-world testing exists	Significant gaps in commercial adoption

Some key questions that drive the review work of this paper in terms of social economic and feasibility study were discussed. As technological innovations rapidly transform the global agricultural supply chain.

- What is the significant level of data-oriented analytics and automation adoption across

agricultural networks today? Review discussion revealed that some factors of high complexity remain in AI/ML with fragmentation limiting data flows and infrastructure connectivity [3, 4, 9].

- What magnitude of transformation is possible from enabling efficiency potentials using

data-driven technologies? The analysis estimates over 25% optimizations in crop yield, post-harvest loss reductions, and lead time compressions demonstrating sizable transformative potential from precision agriculture systems [1, 6, 7].

- How can environmental and social prosperity be integrated alongside productivity advances with emerging innovations? Frameworks to assess smallholder engagement, community participation and environmental drivers will enable comprehensive measurement [8-10, 14].

In this section, we have reviewed and analyzed the most comprehensive survey papers. The reviewed papers are listed in Table 1 with certain findings and objectives.

Conclusion

In the global scenario, the agricultural supply chain is of prime importance. Machine learning and artificial intelligence play a vital role in data-driven decision-making due to their powerful capabilities for working with vast amounts of data. For the betterment of producers and consumers, an efficient management system is necessary. Though ML and AI are in use for ASCM, they still have some gaps that need to be bridged. After reviewing the existing work, it was learned that some works are restricted to a particular region, have gaps in commercial adoption, have been tested on specific crop types, and so on. In this context, the integration of various technologies with the existing landscape of ASCM can direct producers and decision-makers to make informed decisions that will ultimately benefit producers as well as consumers. The inferences or patterns extracted from the analysis of data, predictions, or optimizing methods will improve the outcomes. Sustainable and resilient agricultural supply chains can be achieved through innovations in ML and other emerging technologies.

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