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Leveraging AI For Enhancing Agricultural Supply Chain Efficiency: Reducing Waste And Improving Distribution

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Abstract:
Artificial intelligence (AI) is increasingly transforming agricultural supply chains by improving forecasting, reducing waste, and enhancing distribution efficiency. This study reviews how AI-driven tools such as predictive analytics, smart inventory systems, route optimization, and decision support systems address persistent supply chain challenges, including post-harvest losses, demand uncertainty, weak logistics, and limited traceability. The study also examines the complementary role of IoT, blockchain, and business intelligence in strengthening visibility, transparency, and responsiveness across the supply chain. The review finds that AI improves coordination, minimizes spoilage, supports sustainability, and enhances food security by enabling more data-driven and adaptive supply chain operations. The study concludes that AI is a strategic enabler of agricultural supply chain transformation, although its effectiveness depends on infrastructure, digital capability, and institutional support, particularly in developing and emerging markets.

Keywords: Artificial intelligence, agricultural supply chain, food waste reduction, predictive analytics, logistics optimization, sustainability.

1.0 INTRODUCTION

1.1 Background to the Study

Agriculture remains a foundational sector in the global economy because it supports food production, employment generation, rural livelihoods, industrial input supply, and international trade. Yet, the performance of agriculture is not determined by production alone. It also depends on how efficiently products move from farms to processors, warehouses, transport networks, retailers, and final consumers. This broader movement of goods, information, and value constitutes the agricultural supply chain. In practical terms, the agricultural supply chain links input procurement, cultivation, harvesting, storage, processing, packaging, distribution, and retail delivery into one interconnected system whose efficiency directly influences profitability, food quality, and consumer access (Ganeshkumar et al., 2023; Trabelsi et al., 2023).

Agricultural supply chains are especially sensitive to inefficiency because they manage products that are often perishable, seasonal, and highly vulnerable to environmental and market fluctuations. Unlike durable industrial goods, many agricultural commodities deteriorate rapidly when storage conditions, transport timing, and market coordination are weak. This means that delays, poor visibility, and inaccurate planning can quickly translate into spoilage, revenue loss, and reduced supply chain performance. Trabelsi et al. (2023) note that the growing value of artificial intelligence in the agri-food sector is tied to this very challenge: the sector requires technologies capable of improving information flow, responsiveness, and operational precision. Similarly, Ganeshkumar et al. (2023) argue that the agricultural value chain is becoming increasingly data-intensive, making intelligent systems more relevant to both short-term operational decisions and long-term strategic planning.

In many developing and emerging markets, agricultural supply chains continue to experience deep structural inefficiencies. Farmers often operate with limited access to real-time market information, weak storage infrastructure, poor road networks, fragmented buyer-seller coordination, and limited visibility into downstream demand. As a result, products may be harvested without clear market alignment, transported through inefficient channels, and stored under conditions that accelerate deterioration. These constraints contribute to post-harvest losses, unstable prices, reduced farmer income, and inconsistent market supply. Hassan et al. (2023) show that food waste across agricultural and retail chains is closely related to poor information systems and weak business intelligence, while Onyeaka et al. (2023) emphasize that food waste reduction now requires more intelligent, predictive, and circular approaches to resource use.

Beyond economic loss, inefficiencies in agricultural supply chains also have environmental and social consequences. Wasted food represents wasted land, water, labor, fertilizer, fuel, and energy. When agricultural products spoil before reaching markets, the result is not merely lower business performance, but also reduced resource efficiency and a weaker contribution to food security. Ahmed (2023) argues that technological innovation is central to building more sustainable systems, while Oyeboade and Olagoke-Komolafe (2023) stress that data-driven solutions are increasingly necessary for sustainable agricultural development and productivity. These arguments position digital transformation not as an optional modernization strategy, but as a necessary response to persistent inefficiencies in agricultural systems.

Against this background, artificial intelligence has emerged as one of the most promising technologies for transforming agricultural supply chains. AI refers broadly to computational systems capable of learning from data, identifying patterns, making predictions, and supporting decisions that would traditionally require human judgment. Within supply chain contexts, AI is used to forecast demand, optimize inventory levels, predict spoilage risks, improve route planning, enhance warehouse management, and support real-time logistics coordination (Anwar et al., 2023; Ganeshkumar et al., 2023). Its relevance to agriculture is particularly strong because agricultural supply chains generate diverse forms of data, ranging from weather conditions and harvest volumes to transport times, market demand, storage conditions, and retail behavior. When this data is intelligently processed, supply chain actors can move from reactive management to predictive and proactive coordination.

Anwar et al. (2023) demonstrate that AI-driven optimization can improve farm-to-consumer supply systems by strengthening planning accuracy, reducing process inefficiencies, and enhancing business performance. Likewise, Trabelsi et al. (2023) contend that the value of AI in agri-food systems lies in its ability to support both operational optimization and strategic transformation. These insights suggest that AI is not limited to on-farm automation or crop analytics; it is also a powerful tool for coordinating the movement, timing, and quality management of agricultural products across the entire chain.

Table 1- Selected Traditional Inefficiencies in Agricultural Supply Chains

Inefficiency	Practical Effect	Outcome
Poor demand visibility	Production not aligned with market need	Overstocking or shortages
Weak storage systems	Faster deterioration of produce	Post-harvest losses
Logistics delays	Slower movement to markets	Reduced freshness and lower value
Low traceability	Poor monitoring across chain stages	Weak accountability and decision-making

One of the strongest arguments for AI adoption in agricultural supply chains is its potential to reduce food waste. Food waste remains a major challenge across agricultural systems, particularly where perishability is high and supply chain coordination is weak. AI can help predict spoilage, prioritize shipments, optimize warehouse turnover, and improve timing in distribution networks. Onyeaka et al. (2023) link AI-enabled waste reduction to broader circular economy objectives by showing how intelligent systems can maximize resource efficiency and minimize environmental harm. Hassan et al. (2023) similarly show that better information systems and business intelligence can help reduce food waste across agricultural and retail chains by improving inventory decisions and demand matching. In this sense, AI supports not only efficiency, but also sustainability and resilience.

Another important issue is uncertainty in agricultural markets. Demand patterns can change quickly because of seasonality, consumer preferences, weather events, trade disruptions, and broader economic volatility. Traditional planning methods that rely heavily on historical averages or manual judgment may be too slow or too simplistic for such an environment. AI improves this condition by enabling more dynamic and data-responsive forecasting. Nayal et al. (2023), in their examination of agriculture supply chains under COVID-19-related stress, show that artificial intelligence and machine learning can improve adaptability and decision-making during periods of disruption. Uzozie et al. (2023) further argue that AI-driven predictive analytics can strengthen supply chain resilience in emerging markets by supporting risk mitigation, forecasting, and more agile responses to operational uncertainty.

AI also becomes more valuable when integrated with complementary digital technologies. Internet of Things systems can provide real-time sensor data from farms, warehouses, transport vehicles, and retail nodes. Blockchain can improve traceability, transparency, and trust by creating verifiable records of movement and transactions across the chain. Business intelligence platforms can transform large data streams into dashboards and decision-support tools for managers. Tsolakis et al. (2023) argue that the joint implementation of AI and blockchain can promote sustainability, improve supply chain visibility, and create new opportunities for data-driven value creation. Arogundade and Njoku (2024) likewise highlight the role of blockchain in improving agricultural supply chain efficiency, profitability, and accountability. Taken together, these technologies create the foundation for a more responsive, transparent, and intelligent supply network.

1.2 Problem Statement

Despite the growing recognition of digital transformation in agriculture, many agricultural supply chains still operate with low efficiency, limited visibility, and weak data-driven coordination. In many cases, supply chain actors continue to rely on fragmented information systems, manual decision processes, and delayed market signals. This contributes to poor production-market alignment, high post-harvest losses, weak logistics performance, and reduced profitability. Products may be available in one part of the chain but not where and when they are most needed, leading to both waste and scarcity. These challenges are particularly severe in developing and emerging markets, where infrastructure deficits and institutional constraints can intensify existing inefficiencies (Hassan et al., 2023; Uzozie et al., 2023).

Although the literature increasingly recognizes the value of AI in agriculture, much of that discussion has focused either on production-side applications or on broad digital innovation without fully integrating waste reduction, distribution optimization, and supply chain coordination into one framework. Ganeshkumar et al. (2023) review AI in agricultural value chains from a broad perspective, while Trabelsi et al. (2023) examine the wider value of AI in the agri-food sector. Onyeaka et al. (2023) emphasize AI for food waste and circular economy outcomes, and Tsolakis et al. (2023) focus on AI and blockchain in sustainable supply chains. While these studies are highly relevant, there remains a need for a more focused examination of how AI can simultaneously reduce waste and improve distribution efficiency across agricultural supply chains, especially in contexts where inefficiencies have direct implications for food security and agribusiness performance.

Table 2- Selected AI Functions and Their Supply Chain Relevance

AI Function	Supply Chain Use	Expected Benefit
Predictive analytics	Anticipating demand and spoilage	Better planning and less waste
Smart inventory control	Monitoring stock movement and shelf life	Lower overstocking and spoilage
Route optimization	Improving delivery schedules and routing	Faster distribution and lower cost
Decision support systems	Supporting real-time managerial decisions	Greater responsiveness and coordination

1.3 Rationale for the Study

The rationale for this study is based on the need to understand AI not merely as a technological trend, but as a strategic mechanism for agricultural supply chain transformation. Agricultural systems today face increasing pressure to deliver food more efficiently, sustainably, and reliably under conditions of climate uncertainty, population growth, and volatile markets. Traditional supply chain practices are often too reactive to address these pressures effectively. AI offers an alternative by enabling predictive analysis, early risk detection, intelligent resource allocation, and better operational coordination (Anwar et al., 2023; Nayal et al., 2023).

This study is also justified by the practical value of combining multiple strands of the literature. Studies such as Anwar et al. (2023), Ganeshkumar et al. (2023), and Trabelsi et al. (2023) show the strategic and operational potential of AI in agri-food systems. Hassan et al. (2023) and Onyeaka et al. (2023) highlight its value for reducing waste and promoting sustainability. Tsolakis et al. (2023), Uzozie et al. (2023), and Arogundade and Njoku (2024) further show that integration with blockchain, resilience analytics, and emerging-market realities is increasingly important. However, a consolidated discussion that directly links these themes to agricultural supply chain efficiency, waste reduction, and improved distribution remains limited. This study therefore responds to a real conceptual and practical need.

1.4 Aim and Objectives of the Study

The main aim of this study is to examine how artificial intelligence can be leveraged to enhance agricultural supply chain efficiency by reducing waste and improving distribution. To achieve this aim, the study considers the role of AI-driven forecasting, predictive analytics, smart inventory systems, route optimization, and decision support mechanisms in strengthening the movement of agricultural products from farm to consumer.

More specifically, the study seeks to explain the major inefficiencies affecting traditional agricultural supply chains, assess how AI addresses waste and distribution challenges, examine the role of complementary technologies such as IoT, blockchain, and business intelligence, and show how these digital interventions contribute to sustainability, resilience, and food security outcomes (Onyeaka et al., 2023; Tsolakis et al., 2023; Oyeboade & Olagoke-Komolafe, 2023).

1.5 Significance of the Study

This study is significant for both theory and practice. Academically, it contributes to the growing literature on AI in agriculture by placing supply chain efficiency, waste reduction, and distribution optimization within a single analytical discussion. Practically, it offers insight for agribusiness managers, food distributors, technology developers, and policymakers seeking ways to improve coordination, reduce losses, and strengthen market responsiveness. In contexts where agricultural inefficiency leads directly to income loss, environmental waste, and limited food access, such insight is particularly valuable (Ahmed, 2023; Uzozie et al., 2023).

Overall, the introduction establishes that agricultural supply chains face persistent inefficiencies that limit performance and increase waste, but AI provides a credible pathway toward improvement. By supporting predictive planning, smart inventory control, logistics optimization, and integrated digital visibility, AI can help transform agricultural supply chains into more efficient, resilient, and sustainable systems (Anwar et al., 2023; Ganeshkumar et al., 2023; Tsolakis et al., 2023).

2. LITERATURE REVIEW

2.1 Concept and Importance of Agricultural Supply Chain Efficiency

An agricultural supply chain refers to the sequence of interrelated activities through which agricultural products move from input sourcing and farm production to storage, processing, transportation, retailing, and final consumption. This chain is more vulnerable than many industrial supply systems because it is shaped by perishability, biological variability, seasonality, infrastructure limitations, and uncertain market demand. As a result, efficiency in agricultural supply chains is critical not only for reducing costs and preserving product quality, but also for improving delivery speed, market responsiveness, and customer satisfaction (Ganeshkumar et al., 2023; Trabelsi et al., 2023). When supply chain efficiency is weak, the outcomes often include higher spoilage rates, delayed market access, reduced profitability, and unstable food availability.

The growing importance of efficient agricultural supply chains is closely linked to broader concerns about sustainability, food security, and agribusiness competitiveness. Agricultural products that fail to move efficiently through the chain often lose economic value before reaching final markets. This creates a dual challenge: businesses lose income, while societies lose food and productive resources. Ahmed (2023) argues that technology-driven systems are increasingly necessary for creating sustainable production and distribution structures, while Oyeboade and Olagoke-Komolafe (2023) emphasize the value of innovative data-driven solutions in improving agricultural productivity and development outcomes. These perspectives support the view that agricultural supply chain efficiency has become a strategic concern that extends beyond logistics into sustainability and development policy.

2.2 Traditional Challenges in Agricultural Supply Chains

Despite their importance, agricultural supply chains continue to experience persistent operational challenges. One of the most widely discussed is post-harvest loss, which results from poor handling, weak storage infrastructure, delayed transportation, and inadequate cold-chain systems. These losses are especially severe for highly perishable commodities and can significantly reduce returns to farmers and distributors. Onyeaka et al. (2023) observe that food waste reduction now requires intelligent and systematic interventions capable of predicting deterioration and optimizing resource allocation.

Demand uncertainty is another major challenge. In many agricultural markets, producers and distributors make decisions using incomplete or delayed market information, which often leads to mismatch between supply and actual demand. This mismatch contributes to overproduction in some areas, shortages in others, unstable pricing, and avoidable spoilage. Hassan et al. (2023) show that food waste across agricultural and retail supply systems is strongly associated with weak information use, limited forecasting capacity, and inadequate coordination among decision-makers.

Distribution and logistics constraints further compound these problems. Poor transport infrastructure, routing inefficiencies, delivery delays, and fragmented coordination reduce the speed and reliability with which products move to markets. Limited traceability and weak transparency also hinder performance, since stakeholders may lack real-time visibility into product movement, storage conditions, and points of loss across the chain. Nayal et al. (2023) and Uzozie et al. (2023) suggest that these vulnerabilities reduce resilience and make agricultural supply chains highly exposed to both routine inefficiencies and unexpected disruptions.

2.3 Artificial Intelligence in Agricultural Supply Chains

Artificial intelligence refers to computational systems capable of learning from data, identifying patterns, generating predictions, and supporting decision-making. Within agricultural supply chains, AI enables a transition from reactive, manual decision processes to predictive and data-driven coordination. Relevant AI applications include machine learning, predictive analytics, optimization algorithms, intelligent decision support systems, and smart monitoring tools (Ganeshkumar et al., 2023; Trabelsi et al., 2023). These technologies are increasingly important because agricultural supply chains generate complex and time-sensitive data related to production volumes, storage conditions, transport timing, and market demand.

A major strength of AI lies in its ability to reduce waste. Predictive analytics can estimate spoilage risk and product shelf-life by analyzing variables such as temperature, humidity, storage duration, and transport conditions. Smart inventory systems improve stock control by reducing overstocking and understocking, while AI-based monitoring tools can identify specific points where waste is likely to occur. Onyeaka et al. (2023) connect these capabilities to circular economy objectives, arguing that AI supports more efficient use of resources and reduces the environmental burden associated with food loss. AI also contributes significantly to distribution efficiency. Demand forecasting tools support better alignment between production output and market needs, thereby reducing mismatch and improving planning. Route optimization models help minimize delays, transport costs, and product deterioration during movement. Real-time decision support systems enable managers to respond more quickly to disruptions, changing demand conditions, or logistics bottlenecks. According to Anwar et al. (2023), AI-driven optimization improves farm-to-consumer supply systems by enhancing coordination, reducing inefficiencies, and strengthening overall business performance.

2.4 Integration with Complementary Digital Technologies

The value of AI in agricultural supply chains becomes more significant when combined with complementary digital technologies. IoT systems provide real-time data through sensors used in production sites, warehouses, and transportation networks. These data streams improve visibility and strengthen the predictive power of AI systems. Blockchain enhances trust, transparency, and accountability by creating secure and verifiable records of transactions and product movement. Business intelligence systems support interpretation by converting operational data into dashboards, reports, and decision-support visuals for managers. Tsolakis et al. (2023) argue that the integration of AI and blockchain can create more sustainable and transparent supply chains, while Arogundade and Njoku (2024) show that digital traceability tools can improve agricultural efficiency, profitability, and coordination.

Figure 1. Conceptual Relationship Between AI and Agricultural Supply Chain Performance

Traditional Agricultural Supply Chain Challenges
(post-harvest loss, demand uncertainty, poor logistics, weak traceability)

↓

AI-Based Interventions
(predictive analytics, smart inventory, demand forecasting,
route optimization, intelligent decision support systems)

↓

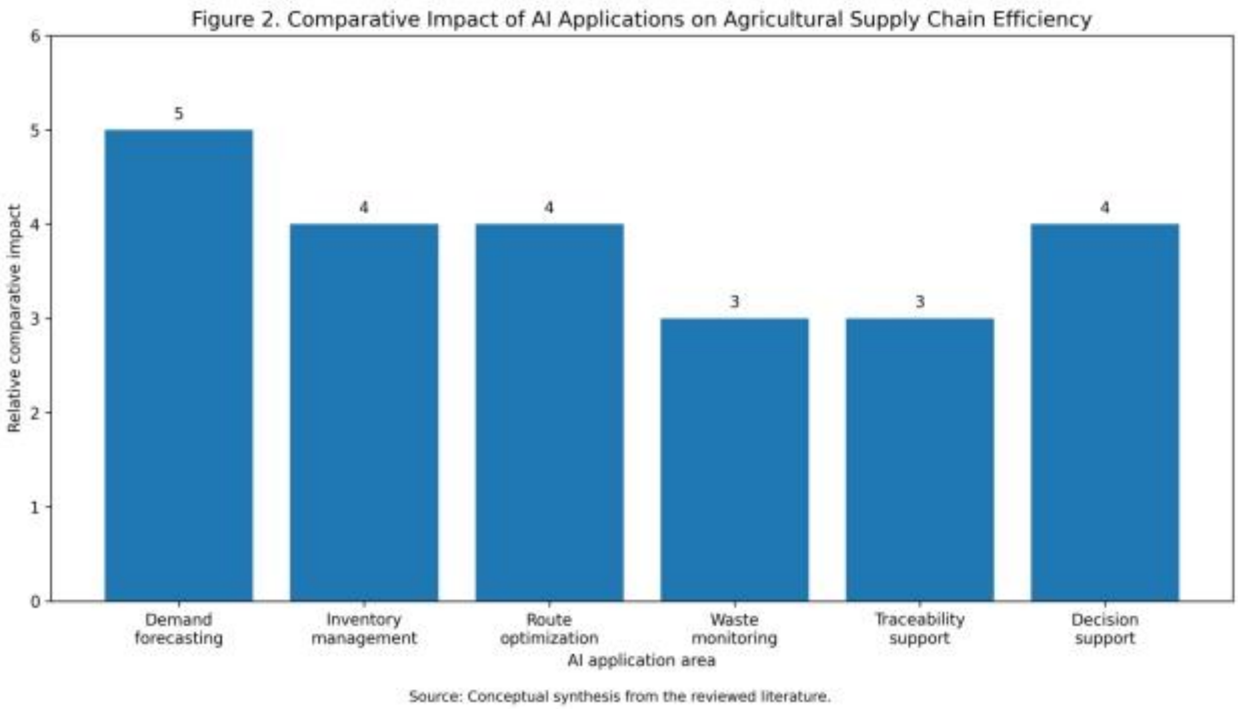
Complementary Digital Technologies
(IoT, blockchain, business intelligence)

↓

Improved Supply Chain Outcomes
(reduced waste, improved distribution, higher transparency,
stronger sustainability, better food security)

2.5 Empirical Review and Research Gap

Recent studies consistently show that AI is becoming central to agricultural supply chain modernization. Ganeshkumar et al. (2023) and Trabelsi et al. (2023) demonstrate that AI is increasingly relevant to agricultural value chain transformation and operational performance. Anwar et al. (2023) specifically connect AI-driven optimization with improved coordination and stronger farm-to-consumer efficiency. Hassan et al. (2023) and Onyeaka et al. (2023) establish the value of intelligent systems in reducing food waste and supporting sustainability objectives. In addition, Tsolakis et al. (2023), Uzozie et al. (2023), and Arogundade and Njoku (2024) highlight the roles of resilience, blockchain integration, and emerging-market relevance in digital agricultural supply chains.



However, an important gap remains in the literature. Many studies discuss AI in agriculture broadly, but fewer integrate waste reduction, smart distribution, and the joint role of IoT, blockchain, and business intelligence within a single agricultural supply chain framework. There is also comparatively limited discussion of how these integrated solutions operate in developing and emerging market settings, where infrastructure gaps, weak digital systems, and limited institutional support may shape adoption outcomes. This study addresses that gap by examining AI as a multidimensional tool for reducing waste and improving distribution efficiency across agricultural supply chains.

3. METHODOLOGY

3.1 Research Design

This study adopted a conceptual, narrative review design to examine how artificial intelligence can enhance agricultural supply chain efficiency through waste reduction and improved distribution. This design was appropriate because the study was not based on primary field data or experimental investigation, but on the synthesis and interpretation of existing scholarly literature. A review-based methodology is particularly suitable for emerging interdisciplinary topics where knowledge is distributed across several studies and where the main objective is to integrate ideas, identify common themes, and clarify conceptual relationships (Ganeshkumar et al., 2023; Trabelsi et al., 2023).

The design enabled the study to bring together key strands of literature on agricultural supply chain inefficiencies, AI-driven forecasting, inventory management, logistics optimization, traceability, and sustainability. It also supported a more integrated analysis of how AI interacts with complementary technologies such as IoT, blockchain, and business intelligence to improve supply chain performance (Anwar et al., 2023; Tsolakis et al., 2023).

3.2 Sources of Data

The study relied exclusively on secondary data obtained from academic and professional literature relevant to artificial intelligence in agriculture and supply chain management. The main sources included peer-reviewed journal articles, review papers, conceptual studies, and technology-focused publications that addressed agri-food logistics, predictive analytics, waste reduction, resilience, and sustainable digital transformation (Hassan et al., 2023; Onyeaka et al., 2023). These sources were selected because they provide both theoretical and applied insight into how AI is being used to improve agricultural supply chain systems.

The evidence base for the study was drawn from selected references focusing on farm-to-consumer optimization, food waste reduction through business intelligence, AI in agricultural value chains, digital sustainability pathways, blockchain-based traceability, and predictive risk management in emerging markets (Anwar et al., 2023; Ganeshkumar et al., 2023; Uzozie et al., 2023; Arogundade & Njoku, 2024). Collectively, these studies offered a relevant foundation for evaluating the strategic and operational role of AI in agricultural supply chain transformation.

3.3 Criteria for Selection of Literature

To ensure relevance and consistency, the reviewed literature was selected using clear inclusion criteria. First, each source had to address at least one of the major themes of the study, namely artificial intelligence, agricultural supply chains, food waste reduction, logistics optimization, predictive analytics, digital traceability, or sustainability in agribusiness. Second, the source had to provide conceptual, empirical, or practical insight directly relevant to supply chain efficiency. Third, more recent studies were prioritized to reflect the rapidly changing nature of AI applications in agriculture and logistics (Trabelsi et al., 2023; Nayal et al., 2023).

Studies that discussed agriculture in very general terms without meaningful relevance to supply chain operations were not emphasized. Likewise, sources that referred broadly to digital innovation without clearly connecting it to efficiency, waste reduction, or distribution performance were given less priority. This helped maintain analytical focus and ensured that the review remained aligned with the central objective of the study (Oyeboade & Olagoke-Komolafe, 2023; Bayeroju, 2023).

3.4 Method of Data Collection

Data collection involved the systematic reading and extraction of relevant concepts, arguments, and findings from the selected literature. The reviewed sources were examined in order to identify how they defined agricultural supply chain challenges, the AI tools they discussed, the outcomes of those tools, and the broader implications for sustainability and food system performance. Particular attention was given to recurring discussions around post-harvest losses, demand uncertainty, inventory control, route optimization, predictive analytics, and technological integration (Anwar et al., 2023; Hassan et al., 2023).

The extracted information was organized around major conceptual areas, including traditional inefficiencies in agricultural supply chains, AI-enabled waste reduction, AI-supported distribution improvement, integration with complementary digital systems, and implications for sustainability and resilience. This approach enabled the study to capture both operational and strategic dimensions of AI use in agriculture (Onyeaka et al., 2023; Tsolakis et al., 2023).

3.5 Method of Data Analysis

The study employed thematic analysis as its primary method of data analysis. This involved grouping the selected literature into major themes and synthesizing the arguments and findings within those themes. Thematic analysis was appropriate because the study sought interpretive understanding rather than statistical measurement, and because the selected sources included conceptual, empirical, and applied discussions that required structured synthesis (Ganeshkumar et al., 2023; Uzozie et al., 2023).

The analysis was organized under key themes that appeared consistently across the literature. These included the concept and importance of agricultural supply chain efficiency, traditional supply chain challenges, AI applications in predictive analytics and logistics, AI-driven waste reduction, and the integration of AI with blockchain, IoT, and business intelligence systems (Trabelsi et al., 2023; Arogundade & Njoku, 2024). This structure made it possible to compare viewpoints across studies, identify areas of agreement, and clarify the role of AI as an integrated tool for improving agricultural supply chain performance.

3.6 Analytical Framework

The analytical framework of the study was based on the assumption that inefficiencies in agricultural supply chains can be reduced when decision-making becomes more predictive, intelligent, and data-driven. Within this framework, traditional problems such as spoilage, poor market matching, transport delays, and limited transparency were treated as the key constraints affecting supply chain performance. AI-based interventions, including predictive analytics, machine learning models, intelligent inventory systems, and route optimization tools, were then examined as responses to these inefficiencies (Anwar et al., 2023; Nayal et al., 2023).

The framework also recognized that AI is most effective when used alongside complementary technologies. IoT enhances the flow of real-time operational data, blockchain improves traceability and accountability, and business intelligence tools strengthen interpretation and managerial action. Together, these systems create a more visible and responsive agricultural supply chain capable of reducing waste, improving distribution, strengthening resilience, and supporting food security outcomes (Tsolakis et al., 2023; Arogundade & Njoku, 2024; Onyeaka et al., 2023).

3.7 Reliability and Limitations of the Method

The reliability of the study was strengthened by the use of recent and topic-specific literature drawn from multiple relevant perspectives. By synthesizing evidence across studies on AI, supply chain management, food waste, sustainability, and digital integration, the review reduced dependence on a single viewpoint and improved the breadth of interpretation (Ganeshkumar et al., 2023; Trabelsi et al., 2023). The use of peer-reviewed and thematically relevant literature also enhanced the academic credibility of the analysis.

However, the study is subject to the limitations of secondary-data research. Its conclusions depend on the quality, scope, and contextual relevance of the reviewed sources. It does not include primary empirical testing in a specific commodity chain or geographical setting. Moreover, because AI adoption varies across countries, infrastructure environments, and institutional conditions, some findings may be more applicable to certain contexts than others (Uzozie et al., 2023; Nayal et al., 2023). Despite these limitations, the methodology remains suitable for building an integrated understanding of how AI can reduce waste and improve distribution efficiency in agricultural supply chains.

4. RESULTS AND DISCUSSION

4.1 Overview of Findings

The review shows that artificial intelligence is increasingly positioned as a strategic enabler of agricultural supply chain efficiency. Across the literature, the major findings converge around three broad areas. First, AI improves forecasting and planning by helping supply chain actors anticipate demand, identify risk patterns, and respond more effectively to uncertainty. Second, AI reduces waste by improving spoilage prediction, inventory management, and supply chain monitoring. Third, AI strengthens distribution by enabling better logistics coordination, route optimization, and real-time

decision support. When combined with complementary technologies such as IoT, blockchain, and business intelligence, these capabilities contribute to improved visibility, transparency, sustainability, and food security outcomes (Anwar et al., 2023; Ganeshkumar et al., 2023; Tsolakis et al., 2023).
These findings suggest that AI should not be viewed as a narrow technological tool limited to farm production. Rather, it functions as a cross-cutting system that can improve how agricultural goods are planned, moved, monitored, and delivered across the entire supply chain. This makes AI particularly relevant to agricultural systems where inefficiencies are caused not only by production constraints, but also by weak coordination and delayed decisions.

4.2 AI-Driven Forecasting and Better Supply Chain Planning

One of the clearest findings from the reviewed literature is that AI improves agricultural supply chain efficiency by strengthening demand forecasting and planning accuracy. Traditional agricultural planning often depends on historical averages, manual judgment, or delayed market information, which are frequently inadequate in volatile environments. Because agricultural markets are shaped by seasonality, climate effects, changing consumer preferences, and transport disruptions, supply chain actors require more adaptive planning tools. AI provides this advantage by analyzing large and diverse datasets to generate more accurate demand estimates and operational projections (Anwar et al., 2023; Nayal et al., 2023).

Improved forecasting contributes directly to waste reduction and better distribution. When producers and distributors can better predict demand, they are more likely to align harvest volumes, storage allocation, and transport schedules with market requirements. This reduces the chance of oversupply, understocking, or delayed product movement. Anwar et al. (2023) show that AI-driven optimization improves farm-to-consumer systems by enhancing planning accuracy and business performance, while Uzozie et al. (2023) emphasize the role of predictive analytics in strengthening resilience and decision-making in emerging market supply chains. These findings indicate that forecasting is not merely a technical function; it is a foundational element of supply chain efficiency.

4.3 AI and the Reduction of Post-Harvest Waste

The review further reveals that AI plays a significant role in reducing post-harvest losses and broader food waste within agricultural supply chains. Post-harvest loss remains one of the most persistent challenges in agri-food systems, especially where storage conditions are poor, transport is delayed, and quality monitoring is weak. AI addresses this issue by supporting predictive spoilage management, smart inventory control, and waste hotspot identification. These capabilities allow supply chain actors to intervene earlier and allocate products more efficiently before deterioration becomes irreversible (Onyeaka et al., 2023; Hassan et al., 2023).

Predictive analytics is especially important in this regard. By analyzing data on temperature, humidity, storage duration, movement history, and market timing, AI systems can estimate shelf-life and detect likely spoilage risks. This supports proactive decisions such as prioritizing certain deliveries, adjusting storage conditions, or redirecting products to alternative markets. Smart inventory systems also improve stock turnover by reducing overstocking and understocking. Hassan et al. (2023) demonstrate that better information use and business intelligence can reduce food waste across agricultural and retail supply chains, while Onyeaka et al. (2023) connect AI-driven waste reduction to circular economy principles and more efficient resource utilization.

This means that the value of AI extends beyond preserving product quality. It also contributes to environmental sustainability by reducing the waste of land, water, labor, fuel, and energy embedded in food production and distribution. In that sense, AI supports a more sustainable agricultural supply system by helping ensure that more of what is produced is actually consumed rather than lost across the chain.

4.4 AI for Improving Distribution Efficiency

Another central finding of the review is that AI improves distribution efficiency by optimizing transport decisions, enhancing route planning, and supporting faster responses to operational disruptions. Agricultural products often lose value when delivery is delayed, poorly coordinated, or disconnected from real-time market conditions. In many traditional agricultural systems, transport decisions are made without adequate use of live operational data, resulting in inefficient routing, higher logistics costs, and reduced product freshness. AI helps correct these inefficiencies by enabling data-driven logistics planning (Ganeshkumar et al., 2023; Trabelsi et al., 2023).

Route optimization is one of the most practical applications of AI in this area. By considering traffic conditions, distance, delivery priority, storage needs, and demand location, AI can recommend more efficient transport paths and schedules. This improves delivery speed and reduces fuel consumption, cost, and spoilage risk. In addition, real-time decision support systems make it easier for managers to adjust quickly to weather disruptions, infrastructure failures, or sudden changes in market demand. Nayal et al. (2023) show that AI and machine learning are useful in addressing supply chain disruptions, while Anwar et al. (2023) link AI-supported coordination directly to better supply chain outcomes. These studies reinforce the conclusion that distribution efficiency is one of the strongest practical advantages of AI adoption in agriculture.

4.5 Integration with IoT, Blockchain, and Business Intelligence

The review also finds that the effectiveness of AI is significantly enhanced when it is integrated with complementary digital technologies. AI depends on timely and accurate data, and this requirement is best met when IoT systems, blockchain infrastructure, and business intelligence tools are embedded within the supply chain. IoT devices provide real-time data from farms, warehouses, cold storage systems, and transport vehicles. These inputs improve the predictive capacity of AI systems by increasing visibility into product condition and movement across the chain (Tsolakis et al., 2023).

Blockchain contributes by improving traceability, accountability, and transparency. In agricultural supply chains, traceability is especially important because it helps stakeholders verify product origin, monitor transactions, and reduce information asymmetry. Arogundade and Njoku (2024) argue that blockchain enhances yield, profitability, and supply chain coordination by improving transparency and trust. Tsolakis et al. (2023) likewise show that AI and blockchain together create pathways toward sustainability and data-driven supply chain management. Business intelligence systems add another layer of value by transforming large data streams into dashboards, reports, and visual decision tools for managers. As a result, the combination of AI with these supporting technologies creates a more visible and responsive supply chain ecosystem.

4.6 Sustainability, Resilience, and Food Security Implications

An important discussion emerging from the review is that AI-driven supply chain efficiency has implications far beyond business performance. More efficient agricultural supply chains support sustainability by reducing spoilage, cutting unnecessary transport, lowering resource waste, and improving the productivity of existing systems. Ahmed (2023) and Oyeboade and Olagoke-Komolafe (2023) both suggest that digital innovation is central to sustainable agricultural development. In this context, AI supports sustainability not only by improving individual business operations, but also by reducing environmental pressure associated with waste and inefficiency.

The literature also indicates that AI strengthens resilience. Agricultural supply chains are increasingly exposed to climate variability, disease outbreaks, transport disruption, and sudden market changes. Predictive systems, intelligent monitoring, and data-driven planning improve the ability of supply chain actors to anticipate and adapt to these risks. Uzozie et al. (2023) frame AI-driven predictive analytics as a basis for resilience and risk mitigation in emerging markets, while Nayal et al. (2023) show that AI can help agricultural supply chains respond more effectively to crisis-related disturbances.

These improvements also affect food security. When waste is reduced and distribution becomes more efficient, food becomes more available, accessible, and stable across markets. This is especially important in developing and emerging economies where supply chain inefficiencies often translate directly into food scarcity, price instability, and lower producer incomes. Therefore, AI contributes not only to agribusiness performance, but also to broader social and developmental goals.

4.7 Persistent Challenges and Implementation Constraints

Despite these benefits, the review also reveals that AI adoption in agricultural supply chains is not without constraints. High implementation costs, limited digital infrastructure, poor data quality, low technical capacity, and weak institutional support remain significant barriers, particularly in developing and emerging markets (Uzozie et al., 2023; Arogundade & Njoku, 2024). Even where AI tools are available, their effectiveness may be limited if real-time data collection systems are weak or if supply chain actors lack the skills needed to interpret and apply digital insights.

This suggests that successful AI adoption requires more than technology acquisition. It also requires investment in infrastructure, training, governance, and ecosystem-wide coordination. Without these supporting conditions, AI may remain underutilized or unevenly distributed across supply chain participants. Thus, while the literature strongly supports the value of AI, it also makes clear that technological potential must be matched by institutional readiness and practical implementation capacity.

4.8 Discussion of the Study's Central Argument

Overall, the reviewed evidence supports the central argument of this study: artificial intelligence enhances agricultural supply chain efficiency by reducing waste and improving distribution. The findings show that AI improves planning through forecasting, reduces losses through predictive spoilage and inventory control, strengthens logistics through route optimization, and enhances transparency through integration with IoT, blockchain, and business intelligence systems. These combined effects position AI as a multidimensional tool for transforming agricultural supply chains into more efficient, resilient, and sustainable systems (Anwar et al., 2023; Onyeaka et al., 2023; Tsolakis et al., 2023).

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study examined how artificial intelligence can be leveraged to enhance agricultural supply chain efficiency by reducing waste and improving distribution. The review of relevant literature shows that agricultural supply chains continue to face persistent challenges, including post-harvest losses, demand uncertainty, weak logistics coordination, poor traceability, and limited real-time decision-making capacity. These inefficiencies reduce profitability, increase resource waste, and weaken the contribution of agriculture to food security and sustainable development (Hassan et al., 2023; Onyeaka et al., 2023).

The study found that AI offers a practical and increasingly strategic response to these challenges. Through predictive analytics, machine learning, smart inventory systems, route optimization, and intelligent decision support, AI helps supply chain actors anticipate demand, reduce spoilage risk, improve distribution speed, and respond more effectively to disruptions. These capabilities move agricultural supply chains away from reactive and fragmented operations toward more predictive, coordinated, and data-driven systems (Anwar et al., 2023; Ganeshkumar et al., 2023; Trabelsi et al., 2023).

The findings also show that the value of AI becomes stronger when integrated with complementary technologies such as IoT, blockchain, and business intelligence. IoT improves data collection and real-time monitoring, blockchain strengthens traceability and transparency, and business intelligence systems enhance managerial interpretation and action. Together, these technologies create a more visible, accountable, and responsive agricultural supply chain ecosystem that supports not only operational efficiency, but also sustainability and resilience (Tsolakis et al., 2023; Arogundade & Njoku, 2024).

Overall, the study concludes that AI is not simply a technological innovation for modern agriculture, but a strategic enabler of smarter supply chain management. By reducing food waste, improving product movement, strengthening planning accuracy, and enhancing transparency, AI can contribute significantly to agribusiness performance, environmental sustainability, and food security. However, the realization of these benefits depends on supportive infrastructure, data availability, digital capability, and institutional readiness, especially in developing and emerging markets (Uzozie et al., 2023; Nayal et al., 2023).

5.2 Recommendations

Based on the findings of the study, the following recommendations are proposed.

5.2.1 Adoption of AI-Based Forecasting Systems

Agribusiness firms, cooperatives, and distributors should adopt AI-based demand forecasting systems to improve alignment between production output and market needs. More accurate forecasting will reduce oversupply, prevent understocking, and improve planning across harvesting, storage, and delivery stages. This is particularly important in agricultural systems where demand fluctuations and perishability make manual planning highly inefficient (Anwar et al., 2023; Nayal et al., 2023).

5.2.2 Investment in Smart Inventory and Waste Monitoring Tools

Agricultural supply chain actors should invest in smart inventory management systems and predictive spoilage monitoring tools. These technologies can improve stock control, reduce deterioration, and identify waste hotspots before losses become severe. Such systems are especially valuable for perishable goods that require strict timing and quality preservation across storage and transport stages (Onyeaka et al., 2023; Hassan et al., 2023).

5.2.3 Strengthening Logistics and Distribution Intelligence

Supply chain managers should deploy AI-driven route optimization and real-time logistics coordination tools to improve delivery efficiency. Better transport planning can reduce delay, lower fuel consumption, preserve product freshness, and improve customer satisfaction. In regions with infrastructure constraints, this recommendation is essential for minimizing the operational losses associated with inefficient movement of goods (Ganeshkumar et al., 2023; Trabelsi et al., 2023).

5.2.4 Integration with IoT, Blockchain, and Business Intelligence

Organizations should not treat AI as a stand-alone solution. Greater value can be achieved when AI is integrated with IoT sensors, blockchain systems, and business intelligence platforms. IoT can support real-time monitoring, blockchain can improve traceability and trust, and business intelligence can help managers interpret operational data more effectively. This integrated approach will strengthen visibility, accountability, and strategic decision-making across the supply chain (Tsolakis et al., 2023; Arogundade & Njoku, 2024).

5.2.5 Policy Support and Digital Infrastructure Development

Governments and development agencies should support the digital transformation of agricultural supply chains by investing in infrastructure, connectivity, and enabling policy frameworks. AI adoption is unlikely to succeed at scale where road systems, electricity supply, storage facilities, internet access, and digital governance structures remain weak. Policy support is therefore essential for creating the conditions under which intelligent supply chain systems can function effectively, especially in developing and emerging economies (Oyeboade & Olagoke-Komolafe, 2023; Uzozie et al., 2023).

5.2.6 Capacity Building and Stakeholder Training

Training should be provided to farmers, supply chain managers, warehouse operators, and logistics personnel on the use of AI-enabled tools and digital decision systems. The success of AI depends not only on the availability of technology, but also on the ability of users to understand, trust, and apply it effectively. Capacity building will therefore be necessary to ensure broader adoption and more consistent operational benefits across the supply chain (Ahmed, 2023; Uzozie et al., 2023).

5.2.7 Future Research Direction

Future studies should focus on empirical testing of AI applications in specific agricultural commodities, regions, or value chains. There is also a need for comparative studies that examine how AI performs in different institutional and infrastructural environments. Such research would deepen understanding of the practical conditions under which AI can most effectively reduce waste and improve distribution in agricultural supply chains (Ganeshkumar et al., 2023; Tsolakis et al., 2023)

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