SUPPLY CHAIN OPTIMIZATION IN AGRICULTURE USING ARTIFICIAL INTELLIGENCE

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ABSTRACT

Agriculture is vital to nation's economy as it fulfills the food demand of increasing population .The demand for sustainable practices increases and supply chain optimization using Artificial Intelligence (AI) is the most promising technology in agriculture sector. This article reviews the recent research done in the field of supply chain based on various AI techniques. The process of supply chain in agriculture is discussed and various AI tools are discussed which helps in mitigating the problems of supply chain. The research gaps in the current scenario are also discussed.

KEYWORDS: Supply Chain Optimization, Artificial Intelligence, IoT.

INTRODUCTION

Since the awake of COVID-19 pandemic, the area of supply chain optimization in agriculture is gaining popularity The agricultural sector, facing the dual challenges of meeting the rising food demands of a expanding global population and adapting to the complexities of climate change. The demand for sustainable farming practices increases.AI has been used in farming extensively (Oluwafunmi Adijat Elufioye et al., 2024). It helps farmers to select optimum crop according to certain weather condition. AI is transforming the agricultural supply chain by enhancing efficiency, reducing waste, and improving overall productivity AI offers a wide range of tools and methodologies that improve the agriculture supply chain from production, transportation and distribution. The new techniques play a vital role in optimizing the complex agriculture supply chain.AI algorithms can assist in influential the best packing materials and designs to enhance product quality and extend shelf life by evaluating data on environmental factors, product attributes, and other variables.

Furthermore, by increasing openness and visibility into the supply chain and logistical process, AI can contribute to better food safety. Retailers can detect and resolve possible food safety concerns before they become an issue by following items from farm to table. To achieve the objective of an enlarged agri-food supply chain that incorporates more stakeholders and the whole supply chain lifecycle, more contributions that utilize a range of data sources will be required. A notable development in the agricultural industry is the shift from conventional farming methods to real-time data-driven agriculture, which reflects the incorporation of technological innovations to satisfy the growing demands for sustainable farming methods and food production (Olabimpe Banke Akintuyi, 2024)

ROLE OF AI IN AGRICULTURE

AI is transforming agriculture, making it more efficient, sustainable, and productive. The food industry has always been dependent on agriculture (Taneja et al., 2023). The agriculture sector can address several issues affecting crop production and enhance the quality and quantity of raw materials accessible to the food industry by implementing AI and ML in crop management and utilizing sophisticated automated systems. Manual grain inspection is a time consuming task and is exposed to human error.ML algorithms are used to examine images of grains and identify defects and impurities. They are also used to identify pests and weed management. The selection of crop according to weather condition is the most promising application of AI in agriculture. AI systems analyze soil data to provide insights on nutrient levels, moisture content, and other factors affecting crop health. This helps in making informed decisions about fertilization and irrigation.
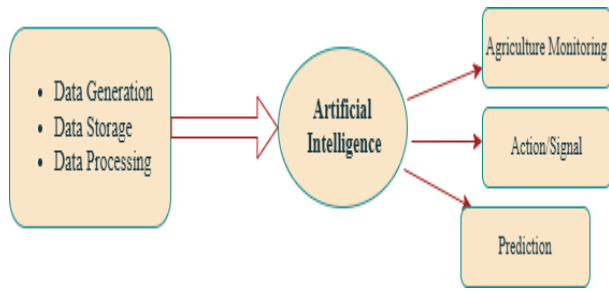
Figure 1: Process of Artificial Intelligence Adoption in Agriculture
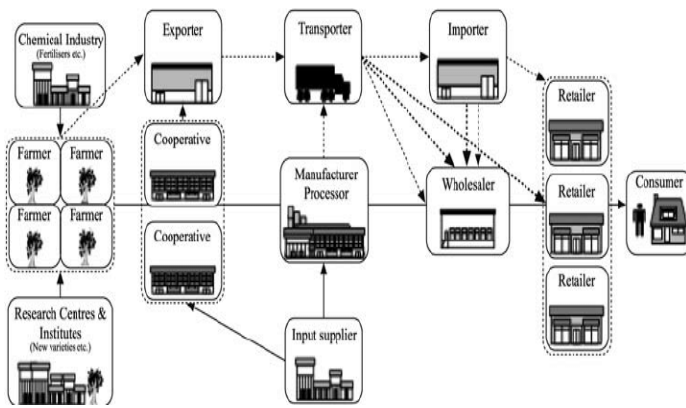
Figure 2: Process of Supply Chain in Agriculture

PROCESS OF SUPPLY CHAIN IN AGRICULTURE

Many functions engaging with various, sometimes conflicting goals and a multitude of linkages between material and information flows make supply-chain operations intrinsically complicated across industries. Disjointed inbound and outgoing networks significantly complicate the agriculture supply chain. The agricultural supply chain typically consists of three stages: farmers to third-party silos, silos to transformation facilities, and transformation plants to consumers. At each level, a number of decisions must be made. Multiple decisions has to be taken at every step to maximize the profit from supply chain and to ensure that overall process of supply chain is optimized. With the integration of AI, the burden of workers has reduced to a great extent and overall productivity is increased. Various tools and techniques of AI are used to automate the process of agriculture. IoT sensors and ML algorithms also play a pivotal role in finding the hidden patterns.

RELATED WORK

This section highlights the various techniques used so far in supply chain optimization in agriculture using AI and ML and how it helps farmers and suppliers. It helps farmers in selection of crops according to suitable weather condition and the overall productivity in agriculture sector is improved with the integration of AI.

The researcher in paper (Javaid et al., 2023) identifies the various applications of AI in the field of agriculture and how it helps farmers. It also discusses how it helps in increasing productivity by minimizing negative impacts of environment. The paper also discuss the process of AI adoption in agriculture and various parameters of agriculture are also monitored by AI such as soil management, pest protection, intelligent spraying, weather prediction etc.AI robots can be implemented in agriculture which can reduce the work of labor as future direction.

(Bai et al., 2023) discusses the key issues of how to make green investments and how to coordinate supply chain. Game Theory and Optimization Technique is developed in which agriculture supply chain consist of risk averse farmer and a risk neutral retailer. the result revealed that farmer and retailer maximize green investment level. In addition, the supportive decision increases the marginal revenue, sales price, and the expected utility of the retailer and decreases the expectations of farmers.

Using the Vehicle Routing Problem (VRP) model, (Rahim et al., 2023a) examines the specific food safety system within the context of the green supply chain, concentrating on the logistical aspects. Transportation distance, vehicle capacity, supplier quantity, and stakeholder location are all taken into consideration when developing the model. Distance optimization and organic farming are both studied. The outcome demonstrates an enhanced food safety system with goals focused on the environment.

(Mishra et al.) presents promising AI breakthroughs in agriculture. Agriculture is becoming more resilient and sustainable thanks to supply chain efficiency, automation, precision farming, and predictive analytics. Numerous AI applications in agriculture are also investigated. Some of the obstacles that will be addressed in the future include managing bias, interdisciplinary cooperation, accessibility and cost issues, and data privacy and security issues.

In order to examine the application of AI in supply chain management within the context of Industry 5.0, (Vatin et al., 2024) carried out an experimental investigation. Significant cost savings in transportation logistics, enhancements in supplier cost efficiency, and notable decreases in excess inventory were demonstrated by a study of fake data that represented product inventories, supplier details, customer orders, and transportation details.

A prototype for the multi-period deterministic inventory routing problem (MP-DIRP) in supply chains with an emphasis on the agricultural sector is developed by (Rahim et al., 2023b). A simulation technique is used to optimize the cost and transportation problem, and an algebraic modeling language called a mathematical programming language (AMPL) is designed to find the best solution in the allotted time. It is anticipated that by using this approach, industries will be able to optimize their operations by reducing their overall inventory expenses.

SUPPLY CHAIN OPTIMIZATION TOOLS

The agricultural supply chain is being optimized through the application of a number of AI techniques and technologies. A more robust, sustainable, and effective agricultural supply chain is being developed with the aid of these instruments and technology.

Table 1. AI tools for agriculture

Technique	Problem	AI Solution	Tool
Predictive Analytics and Demand Forecasting	Demand Fluctuations due to which there is shortage of products.	ML models can be used to predict data, patterns, market trends to help farmers maximize their profits	Time series forecasting, Deep Learning models, data analytics platform
Supply Chain Visibility and Tracking	The supply chain is fragmented due to which there is inefficiency, delay and shortage of food.	End to end visibility of supply chain is provided by AI using real time IoT devices, Blockchain technologies	Blockchain, AI powered Logistics, route optimization tools, RFID-enabled tracking
Supply Farming and Precision Agriculture	Inefficient farming practices leads to wastage of resources such as pesticides, water	Drones IoT Sensors and satellite imagery are some solutions that help farmers to monitor soil, crop growth and environment conditions in real time	Computer Vision, ML models, autonomous tractors and smart irrigation system
Inventory Management and Distribution Optimization	Quantity of goods cannot be measured in advance which leads to wastage or shortage of goods	AI can track and measure environment factors, optimize quantity of inputs and reduce waste	Inventory Management and Distribution Optimization
Risk Management and climate Adaption	Natural conditions of weather leads to widespread loss	Potential risks are predicted, AI can simulate what if plan to help contingency plan in adverse conditions	ML, NLP, Predictive analysis
Automated Quality Control	Defected products, intensive labor work required	AI can inspect and sort products based on shape, color, size , quality. It also detects defect or spoilage in products.	Computer Vision, Deep Learning, Image Recognition
Digital Twins	Agriculture produces tremendous amount of data which is difficult to handle	Virtual simulations and optimizations are created that include all elements of supply chain and its interfaces	Big data analytics

GENERAL METHODOLOGY

Supply chain management in agriculture involves the coordination of various activities to ensure that agricultural products more efficiently from farms to

consumers. Figure 1 depicts a general framework which needs to be followed for executing supply chain. The steps are described below:

1. Planning

Predictive analytics is used to forecast market demands based on historical data and trends and crop production schedule is planned accordingly considering factors such as planting time, growth cycle and harvest dates.

2. Sourcing

Necessary inputs such as seeds, fertilizers and equipments are identified and contract management is done to ensure timely and cost effectiveness procurements of inputs.

3. Farming Operations

Precision farming techniques are used to optimize resource usage. IoT sensors and AI tools are used to monitor crop health, soil usage, weather patterns in real time.

4. Harvesting and Post Harvesting Handling

The optimal time for harvesting crops to maximize yield and quality is determined .Proper storage facilities are used to maintain the freshness and quality of the crops that include cleaning, sorting and packaging.

5. Distribution and Marketing

Transportation routes and schedules are optimized using AI that ensures timely delivery of products and market trends are analyzed and appropriate distribution channels are selected.

6. Consumer Feedback

The final step involves the feedback mechanism which is necessary for continuous improvement and provide details about what must be changed next time to increase the production. This involves improvement in farming practices, product quality and supply chain process.

DISCUSSION

There still are certain areas where these supply chain practices need to improve. Some of them are listed below:

- **Data Privacy and Security Issues-** Privacy and security concerns hamper agricultural AI.AI is gathering and evaluating data on environmental conditions, agricultural output, and farm management. Concerns about misuse, data ownership, and privacy are brought up by this data collection and sharing. Farmers and stakeholders need to establish robust data governance procedures in order to protect sensitive data.
- **Ethical Considerations–**Automation and AI driven solutions can lead to job displacement in labor - intensive agriculture sector.
- **Connectivity Issues–** Many agricultural sector lacks reliable internet connection which is essential for real time data transmission and AI integration.
- **Technical Expertise–** There is a significant gap in the availability of skilled professionals who can develop, implement and maintain AI systems in agriculture.

Figure 3. General Methodology

CONCLUSION & FUTURE SCOPE

Significant changes have been brought about by the incorporation of AI into agricultural supply chains, affecting technological, economic, and environmental aspects among other elements. This article presents a review about the recent articles proposed for the execution of supply chain in agriculture. It involves usage of predictive analytics for detecting the soil moisture content, environmental factors, growth of the crop, market trends etc. Various predictions models are used for making decisions about which route to be followed , end to end visibility of supply chain is done by integrating AI. Various simulations and optimization techniques are embedded and future directions will lead to improving usage of such technologies to improve the overall production.

REFERENCES

Bai, S., Wang, Y., Zheng, S., & He, H. (2023). Green Investment Decisions and Coordination in a Green Agri-Product Supply Chain considering Risk Aversion and Bargaining Power under Different Channel Power Structures. *Complexity*, *2023*. https://doi.org/10.1155/2023/6401962

Javaid, M., Haleem, A., Khan, I. H., & Suman, R. (2023). Understanding the potential applications of Artificial Intelligence in Agriculture Sector. *Advanced Agrochem*, *2*(1), 15–30. https://doi.org/10.1016/j.aac.2022.10.001

Mishra, A. C., Das, J., & Awtar, R. (n.d.). *An Emerging Era Of Research In Agriculture Using AI*. www.jsrtjournal.com

Olabimpe Banke Akintuyi. (2024). Adaptive AI in precision agriculture: A review: Investigating the use of self-learning algorithms in optimizing farm operations based on real-time data. *Open Access Research Journal of Multidisciplinary Studies*, *7*(2), 016–030. https://doi.org/10.53022/oarjms.2024.7.2.0023

Oluwafunmi Adijat Elufioye, Chinedu Ugochukwu Ike, Olubusola Odeyemi, Favour Oluwadamilare Usman, & Noluthando Zamanjomane Mhlongo. (2024). AI-Driven Predictive Analytics in Agricultural Supply Chains: A Review: Assessing The Benefits And Challenges Of AI In Forecasting Demand And Optimizing Supply In Agriculture.*Computer Science & IT Research Journal*, *5*(2), 473–497. https://doi.org/10.51594/csitrj.v5i2.817

Rahim, M. K. I. A., Harahap, A. Z. M. K., Bolaji, B. H., & Ahmad, A. N. A. (2023a). Optimizing a Multi Period Deterministic Inventory Routing Problem in Agriculture Industries. *Paper Asia*, *39*(5), 40–47. https://doi.org/10.59953/comp.by.paperasia.v39i5(b).35

Rahim, M. K. I. A., Harahap, A. Z. M. K., Bolaji, B. H., & Ahmad, A. N. A. (2023b). Optimizing a Multi Period Deterministic Inventory Routing Problem in Agriculture Industries. *Paper Asia*, *39*(5), 40–47. https://doi.org/10.59953/comp.by.paperasia.v39i5(b).35

Taneja, A., Nair, G., Joshi, M., Sharma, S., Sharma, S., Jambrak, A. R., Roselló-Soto, E., Barba, F. J., Castagnini, J. M., Leksawasdi, N., & Phimolsiripol, Y. (2023). Artificial Intelligence: Implications for the Agri-Food Sector. In *Agronomy* (Vol. 13, Issue 5). MDPI. https://doi.org/10.3390/agronomy13051397

Vatin, N. I., John, V., Nangia, R., Kumar, M., & Prasanna, Y. L. (2024). Supply Chain Optimization in Industry 5.0: An Experimental Investigation Using AI. *BIO Web of Conferences*, *86*. https://doi.org/10.1051/bioconf/20248601093