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Role of Big Data and IoT in Optimizing Post-Harvest Management

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ABSTRACT-

Post-harvest management is a crucial stage in the agricultural value chain, involving processes like transportation, storage, and preservation, which significantly affect the quality, quantity, and cost of crops. The introduction of modern technologies such as Big Data and the Internet of Things (IoT) has transformed this phase, offering innovative solutions to optimize these processes. Big Data involves analyzing vast amounts of structured and unstructured data to derive insights, while IoT connects devices that monitor environmental parameters in real-time. These technologies enhance decision-making, enable predictive maintenance, and improve real-time monitoring, thereby reducing post-harvest losses. IoT sensors installed in storage and transportation facilities help maintain optimal environmental conditions, preventing spoilage. Predictive analytics derived from Big Data allows stakeholders to anticipate risks, like equipment failure, and take proactive measures. Additionally, data-driven decision-making helps farmers and supply chain managers optimize resource use, inventory management, and transportation logistics. However, the high cost of implementing these technologies and concerns over data privacy remain barriers, especially for small-scale farmers in developing regions. Despite these challenges, Big Data and IoT offer a promising future for post-harvest management, enhancing sustainability, profitability, and food security across the agricultural supply chain.

Keywords- Post-harvest management, Big Data, Internet of Things (IoT), real-time monitoring, predictive maintenance, supply chain optimization, agricultural technology, post-harvest losses.

1. Introduction

A crucial stage in the agricultural value chain, post-harvest management includes all operations carried out from the time crops are harvested until they are consumed. During this time, procedures including transportation, storage, and preservation take place, all of which have a big impact on the quantity, quality, and cost of the crop. The agricultural landscape has changed because of the integration of contemporary technologies like the Internet of Things (IoT) and Big Data, which provide creative ways to improve post-harvest management. IoT and Big Data improve decision-making and resource utilization, which lowers post-harvest losses by enhancing data collecting, processing, and real-time monitoring. The optimization of post-harvest management using Big Data and IoT is examined in this article, along with the consequences for the agriculture sector.

2. The Importance of Post-Harvest Management

Post-harvest handling entails several intricate procedures, including as cleaning, grading, drying, packing, and storing. The Food and Agriculture Organization (FAO) estimates that 14% of the food produced worldwide is wasted between harvest and retail, resulting in a substantial loss of revenue and resource wastage. (FAO, 2019). Several things can lead to post-harvest losses, such as poor supply chain logistics, insufficient storage conditions, and careless monitoring of environmental parameters including moisture, humidity, and temperature. Consequently, enhancing post-harvest procedures is essential for boosting food security, farmer profitability, and food system sustainability.

3. Big Data and IoT: An Overview

The term "big data" describes the enormous volume of both structured and unstructured data produced by numerous sources, including mobile devices, satellites, and sensors. Due to the huge amount, variety, and velocity of this data, analysis using conventional data processing techniques is not possible. Big Data can be analyzed to provide insightful information that helps with decision-making using sophisticated analytics tools and machine learning algorithms (Hashem *et al.,* 2015).

For example, the IoT means devices connected that collect data and share it over the internet; it usually comprises products fitted with sensors to measure any environmental and operational factors such as temperature and humidity or location. Using real-time data from the stakeholders, IoT has progressively been applied in agriculture for crop monitoring, livestock management, and equipment maintenance. Deployed on post-harvest management, the IoT provides the opportunity for remote monitoring and process control in a way that ensures an optimal condition during produce preservation. (Jayashree *et al.,* 2020).

4. Big Data and IoT in Post-Harvest Management

4.1 Real-Time Monitoring and Control

Real-time monitoring of conditions will be another prominent advantage of using post-harvest integration with Big Data and IoT, because of the presence of environmental sensors from IoT installed in the facilities used in storage, transportation vehicles, and warehouses to measure conditions like temperature, humidity, and carbon dioxide, which directly affect the quality of produce. (Mohapatra *et al.,* 2021). For example, perishables, such as fruits and vegetables, need tightly controlled temperatures to prevent degradation. IoT technology does this because it continuously monitors the environmental conditions in storage space, and if the measured parameter remains outside of the optimal value, the system can send alarm notifications or mechanically adjust the space for better preservation of produce.

Big Data analytics tools process and analyze data collected from IoT devices transmitted to the central system. Thus, using predictive analytics, risk can be foreseen and prevention can be done in time. For instance, historical data about fluctuations in temperature can predict spoilage during transport time and make companies alter routes or change storage conditions. (Zhang *et al.,* 2019).

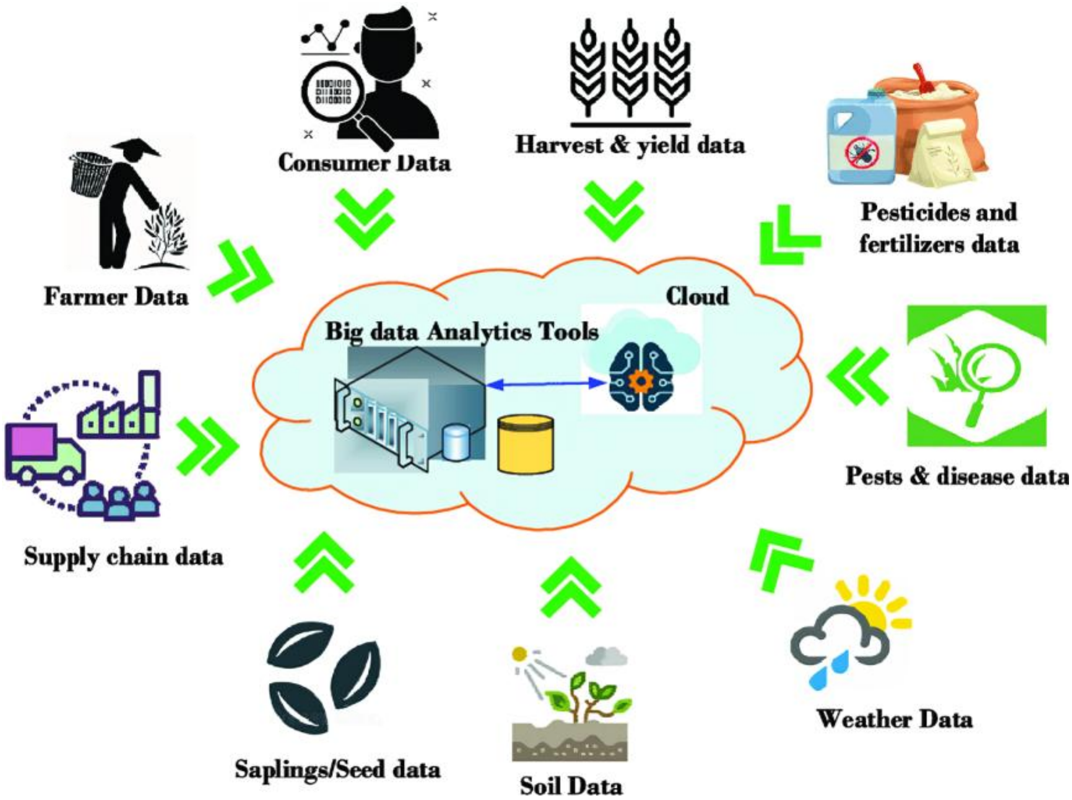

Fig No. 1

4.2 Predictive Maintenance of Storage and Transportation Systems

Big Data and IoT technologies are revolutionizing post-harvest management by enabling predictive maintenance. Through the deployment of IoT sensors on storage equipment like refrigeration units, it is possible to continuously monitor their performance and detect early signs of malfunction. By analyzing the vast amount of sensor data collected over time, Big Data algorithms can predict with remarkable accuracy when equipment is likely to fail. This predictive capability empowers stakeholders to schedule timely repairs or replacements, preventing breakdowns that could lead to significant post-harvest losses. This proactive approach not only minimizes spoilage due to equipment failure but also ensures that the produce maintains its freshness and quality throughout the storage and transportation process. (Abdel-Basset *et al.,* 2020).

4.3 Data-Driven Decision Making

In that respect, data-driven decision making is the most important post-harvest management as it can optimize resource use and make operations more efficient. Big Data analytics will enable the farmer and supply chain manager to make informed decisions on storage conditions, routes taken in transporting produce, and inventory control. For example, the advanced algorithms analyze historical weather-related data, transportation-related delays, or market-related orders to determine if produce should be harvested, stored, or shipped. (Maheshwari *et al.,* 2019).

One more key aspect of Big Data is its use to best optimize inventory through predicting demand fluctuations so that perishable items are not overstuffed or understocked. This prevents the loss from waste while helping ensure that consumers get fresh produce and increasing profitability for farmers and retailers alike.

4.4 Reducing Post-Harvest Losses

The agricultural industry faces a real threat in the form of Wastage at various levels of production. The WB estimates that Level wastages account for almost 30 percent of food loss. (World Bank, 2021). Post-harvest management can be adjusted to lower these losses by combining Big Data and IoT. Produce may be stored under ideal circumstances thanks to the ability of IoT-enabled technologies to monitor the environment throughout transportation and storage. Furthermore, by enabling prompt reactions to possible dangers like temperature spikes or equipment failures, real-time data collection and analysis help prevent spoiling.

Big Data and IoT together also improve supply chain traceability by giving stakeholders comprehensive information about the produce's path from farm to plate. Because of its traceability, which increases accountability and transparency, post-harvest losses can be prevented and quality control can be improved. (Bakker *et al.,* 2018).

5. Challenges and Future Directions

Apart from these potential benefits of Big Data and IoT for the optimization of post-harvest management, many challenges remain. It may become economically unaffordable to small-scale farmers, especially in newly emerging regions, mainly because the costs incurred from the implantation of IoT infrastructure and platforms for data analytics are very high. This is probably because the massive volume of data attained from IoT devices demands advanced processing capabilities that may not readily be available in most agricultural contexts. Other challenges include privacy and security issues surrounding the sharing and storage of data as related to the widespread adoption of these technologies. (Li *et al.,* 2020).

6. Conclusion

Big Data and IoT have become effective instruments for improving real-time monitoring, predictive maintenance, and data-driven decision-making, which in turn optimizes post-harvest management. Using these technologies, stakeholders may enhance resource efficiency, lower post-harvest losses, and boost profitability across the whole agricultural supply chain. Future food security and sustainability will depend more and more on the use of Big Data and IoT in post-harvest management as the agriculture sector continues to embrace digital revolution.

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