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Sustainable Agriculture Leveraging Artificial Intelligence Systems in Kenya's Agri-food Supply Chain

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ABSTRACT

The Agro-food supply chain is crucial for achieving Sustainable Development Goal No. 2 of zero hunger and sustainable agriculture. However, Kenya faces significant post-harvest losses, mainly attributed to challenges in first and last-mile logistics. In the era of technological advancements, this research paper explores the potential of Artificial Intelligence (AI) to enhance the Kenyan agri-food supply chain. Building on existing information, the study focuses on AI's role in monitoring and controlling farmland outputs, optimizing supply chain logistics, and addressing fraud and counterfeiting. The research objectives include assessing AI's utility in monitoring and controlling outputs in farmlands improving supply chain efficiency, and combating fraud in agricultural inputs. Research methods involve a comprehensive literature review, analyzing case studies such as Project FARM and FAO's Fall Armyworm Monitoring and Early Warning System, and reviewing scholarly articles on AI applications in agriculture. The research results highlight the benefits of leveraging AI in farmland monitoring, climate change adaptation, supply chain logistics, and fraud prevention. AI technologies can enhance agricultural productivity, reduce transportation costs, and eliminate corruption in the supply chain. The findings suggest that integrating AI systems into the agri-food supply chain is vital for achieving sustainable agriculture in Kenya. The study concludes that AI offers innovative solutions to address the challenges faced by smallholder farmers, enhance supply chain efficiency, and contribute to achieving zero hunger and sustainable agricultural practices.

Keywords: Climate, Fraud, Logistics, Post-Harvest, Supply chain efficiency, Zero Hunger

1. INTRODUCTION

Sustainable agriculture has become a critical component in addressing global food security and environmental concerns. In the context of Kenya, where agriculture plays a significant role in the economy, the integration of artificial intelligence (AI) systems holds promise for enhancing efficiency, productivity, and environmental sustainability in the agri-food supply chain (Kipkoge et al., 2021). Kenya's agricultural sector is characterized by smallholder farmers who face challenges such as limited access to modern technology, fluctuating weather patterns, and inefficient supply chain management (World Bank, 2019). These challenges contribute to food insecurity and hinder the sector's overall sustainability. Therefore, the convergence of sustainable agriculture and artificial intelligence holds great potential for transforming Kenya's agri-food supply chain. By addressing current challenges and leveraging AI technologies, the country can



enhance food security, increase farmers' incomes, and contribute to the overall sustainability of its agricultural sector.

According to the Kenya-country commercial guide (2021), Agriculture accounts for 40% of the overall workforce and about 25% of the annual workforce. Given the Arable land and suitable climatic conditions, the country can export agricultural products such as tea, coffee, vegetables, and cut flowers. Indeed, Kenya is reportedly the world's leading exporter of cut flowers and black tea (Onjala, 2020). Consequently, the agri-food supply chain that encompasses farmers, suppliers, processors, distributors, consumers, and other stakeholders plays a critical role in the production, movement, and distribution of agricultural and food products and, by extension, sustainable agricultural production systems.

Despite these successes, Kenya faces a persistent challenge in the form of post-harvest losses within its agri-food supply chain. According to the Food and Agriculture Organization (FAO), approximately 1.3 billion tonnes of food globally go to waste due to post-harvest losses (Bhargar, 2021). The financial implications are staggering, with developed nations losing nearly 680 billion dollars and developing countries, including Kenya, losing around 310 billion US dollars. The intricate nature of the Kenyan agricultural ecosystem, characterized by unorganized practices and multiple intermediaries, impedes farmers' ability to maximize profits (World Bank, 2020). However, the advent of digital technologies, particularly Artificial Intelligence (AI), presents an opportunity to revolutionize field operations and enhance overall agricultural productivity and efficiency (Ngugi et al., 2019).

The genesis of Kenya's post-harvest losses can be traced to the complex and unorganized nature of the agri-food supply chain (Mwangi, 2018). Multiple intermediaries involved in different stages of the supply chain create inefficiencies and opportunities for losses (Ndung'u et al., 2019). Farmers, often smallholders, face challenges in monitoring and controlling farmland outputs, leading to suboptimal yields (Kinyanjui & Mwanarusi, 2020). Furthermore, the lack of transparency and traceability in the supply chain contributes to fraud and counterfeiting, eroding trust and adding additional layers of complexity (Odhiambo et al., 2021).

Additionally, climate change poses a significant threat to agricultural sustainability in Kenya (Ochieng et al., 2017). Fluctuations in weather patterns, unpredictable rainfall, and the increasing frequency of extreme events impact crop yields and exacerbate the vulnerability of smallholder farmers (Mugendi et al., 2016). Adaptation to these changing climatic conditions is crucial for ensuring food security and the sustainability of agriculture in the region (Njenga et al., 2022). Integrating climate-smart agricultural practices and technologies is essential for mitigating

the adverse effects of climate change on crop production and reducing post-harvest losses (FAO, 2018).

Therefore, this research paper examines the viability of leveraging Artificial Intelligence (AI) to reduce post-harvest losses in the Kenyan agri-food supply chain. The paper focuses on how AI can enable farmers to monitor and control the outputs of farmlands, optimize supply chain logistics, and eliminate fraud and counterfeiting in the agri-food supply chain. The study is centered on exploring the multifaceted applications of AI in the Kenyan agri-food supply chain and investigates how AI can empower farmers, optimize logistics, and enhance overall transparency, with the ultimate goal of significantly reducing post-harvest losses and promoting sustainability in the agricultural sector.

Artificial Intelligence

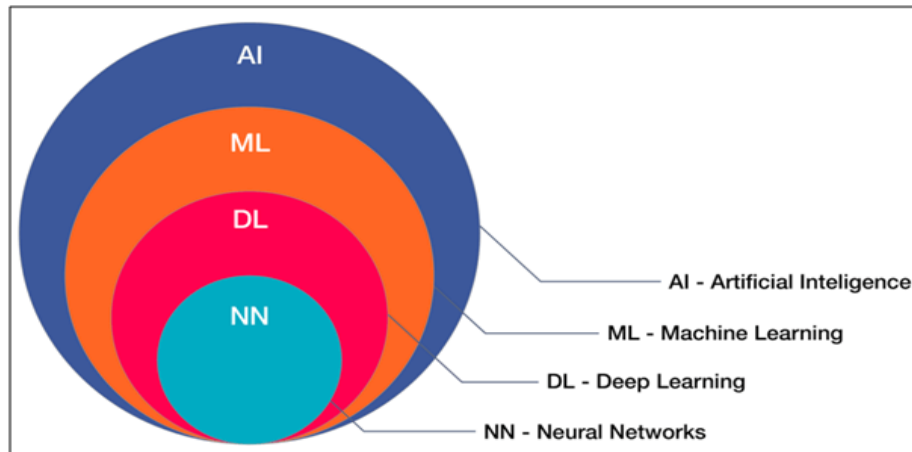
Artificial Intelligence (AI), also known as machine intelligence, is the simulation of human intelligence processes by machines, especially computer systems (Burns, Laskowsky & Tucci, 2022). According to McCarthy (2004), AI is the science and engineering of developing intelligent machines, particularly intelligent computer programs. It involves designing systems capable of reasoning, discovering meaning, generalizing, and building on previous knowledge. AI systems ingest bulk-labeled training data and analyze such data to determine correlations and patterns that inform future forecasts (Burns et al., 2022).

AI provides a framework through which enterprises gain insight into previously unknown operations and brings efficiency to performing tasks, especially tasks that may be detail-oriented and repetitive. For instance, AI has been leveraged to improve efficiency in digital breast tomosynthesis (Conant et al., 2019), University efficiency (Vinichenko, Melnichuk & Karacsony, 2020), radiographic fracture recognition (Guermazi et al., 2021), production efficiency in furniture manufacture (Long et al., 2020), and agricultural productivity (Lakshmi & Corbett, 2020).

Artificial Intelligence (AI) has emerged as a transformative force across various industries, and its applications in agriculture are gaining increasing attention for their potential to address sustainability challenges. In the context of agriculture, AI refers to the utilization of advanced technologies, including machine learning, data analytics, and automation, to enhance efficiency, productivity, and sustainability throughout the entire agricultural value chain (Kamilaris et al., 2017). Therefore the intersection of Artificial Intelligence (AI) and agriculture has gained prominence as a transformative force with the potential to address sustainability challenges in the agri-food sector. The integration of AI technologies into agricultural practices holds promise for optimizing resource use, mitigating environmental impact, and enhancing overall sustainability.



Therefore, Artificial Intelligence (AI) is a technological field that replicates human intelligence through three main components: Neural networks, Machine learning, and Deep Learning. Unlike AI, Robotic Process Automation (RPA) focuses on automating production processes without requiring human intervention.



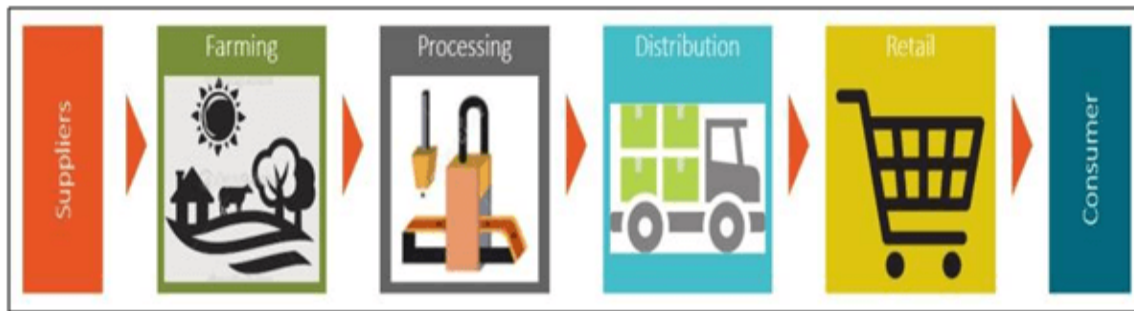
Source: <https://www.abetasquare.com/understanding-artificial-intelligence/>

The Role of Artificial Intelligence in Agri-food supply chain

Artificial Intelligence (AI) plays a pivotal role in revolutionizing the agricultural sector, contributing to the development and implementation of sustainable practices. AI technologies offer innovative solutions for addressing various challenges in agriculture, ranging from resource optimization to crop management. The global population is projected to increase from 7.7 billion to 9.7 billion by 2050, as reported by the United Nations. Simultaneously, the ongoing impact of global warming is anticipated to lead to a scarcity in agricultural production in the coming decades. Addressing this challenge requires leveraging the advancements in digital technologies, with a particular focus on incorporating Artificial Intelligence (AI) solutions into the agricultural supply chain. (FAO,2018).

Industry 4.0 represents a technological endeavor focused on transforming manufacturing by digitally reshaping both processes and products. This initiative anticipates a comprehensive evolution of the industrial supply chain, envisioning increased autonomy and intelligence throughout (Liu et al,2021). Agri-food supply chains are encountering comparable challenges in embracing technological advancements, including the integration of the Internet of Things (IoT), robotics, artificial intelligence (AI), big data and analytics, and blockchain. Nevertheless, within the realm of essential cross-industry technologies, artificial intelligence (AI) is just starting to surface as a viable solution to address various challenges encountered by the agricultural sector in

the extended agri-food supply chain (José Monteiro & João Barata, 2021). Numerous farmers lack an adequate understanding of the agricultural supply chain. The agri-food supply chain encompasses various phases, starting from the farm and extending to the consumer's plate. This involves every step, such as sourcing, cultivation, processing, distribution, retail, and consumption, as illustrated in the diagram below.



Source: <https://www.precisionag.com/in-field-technologies/connectivity/iot-will-transform-the-agriculture-supply-chain-get-on-board/>

The study primarily concentrates on the adoption of artificial intelligence (AI) in the agricultural supply chain, specifically in post-harvest phases (Processing, Distribution, Retail, and Consumption), due to the transformative potential and consequential benefits it offers to the agricultural industry. The post-harvest stages are critical in ensuring the quality and efficiency of crop handling, storage, processing, and distribution. AI technology enhances decision-making processes, optimizes resource utilization, and minimizes post-harvest losses. By leveraging AI in this context, we aim to contribute to the development of intelligent systems that improve supply chain resilience, reduce waste, enhance traceability, and ultimately promote sustainable agricultural practices, addressing crucial challenges in food security and resource management.

Placing a strong emphasis on sustainability within the food lifecycles requires an exploration of how AI is utilized in the agricultural and food supply chain. This exploration serves as the inspiration for defining the following research objectives (RO).

RO1: Assessing AI's utility in monitoring and control of outputs.

RO2: Improving supply chain efficiency.

RO3: Combating fraud in agricultural inputs.

2. MATERIALS AND METHODS

The research methods adopted in this study combined literature exploration, case study analysis, and a focus on empirical evidence to build a comprehensive understanding of the potential impact of AI in Kenya's agri-food supply chain particularly addressing the challenges

such as monitoring and control of farm inputs, supply chain efficiency, and fraud prevention in agricultural inputs.

AI and the monitoring and control of outputs of farmlands

Although agriculture is the backbone of Kenya's economy, agricultural productivity stagnates due to a lack of proper monitoring and control of production. Besides, the country lacks the required technology to predict climate change and provide soil and crop dynamics knowledge. Considering that most farmers in Kenya are smallholder farmers between 5 million and 9 million (Wight, 2019), the agri-food supply chain is highly vulnerable to climate change and soil and crop dynamics. Consequently, digital technology such as AI could offer an innovative approach to solving such uncertainty in climate change and crop and soil dynamics. Artificial Intelligence (AI) plays a crucial role in the monitoring and control of outputs in farmlands, contributing to precision agriculture and sustainable farming practices. This integration of AI in agriculture involves the use of advanced technologies such as sensors, drones, machine learning, and data analytics to optimize various farming processes. Evidence mainly from developed nations supports the continuing importance of AI in the agricultural supply chain, as seen in Table 1 in the following reviewed studies.

Table 1. Importance of artificial intelligence in monitoring and control of outputs in farmlands

Author(s)	Context	AI Utility
Dayal, Deo & Apan (2017)	Climate change impacts	Drought modeling based on AI and Neural Network (ANN) Algorithms predicts the Standardized Precipitation-Evapotranspiration Index (SPEI) for drought.
Pampouchidou et al. (2017)	Weed and Pest Control	Drones equipped with cameras and machine learning algorithms can identify and target specific areas for treatment.
Khaliq et al. (2018)	Farm monitoring	Providing real-time information about crop conditions, helping farmers make data-driven decisions for improved productivity.
Liakos et al. (2018)	Crop yield prediction	Emphasizes the potential of AI in providing accurate forecasts to optimize farming operations
Zaman et al. (2019)	Resource Optimization	Optimize the use of resources such as water, fertilizers, and energy by providing real-time insights into crop needs.
Adikari et al. (2021)	Disaster management in Arid and tropical regions	AI enables modeling of flood and drought occurrence, thus allowing for forecasting of the same
Luccioni et al. (2021)	Climate change impacts	Developing an AI climate impact visualizer that allows for an AI-imagined visualization of the future.
Kumar et al. (2021)	Risk Management	AI systems provide a framework for risk assessment and resilience for critical infrastructure
Mikhailov et al. (2021)	Profitability of agro-industrial production	AI enables the development and distribution of precision farming systems capable of supporting decisions companies make regarding risk and disease prediction



Note: The table summarizes the diverse applications of artificial intelligence in farmlands, showcasing its role in climate change adaptation, resource optimization, disaster management, and enhancing overall agricultural productivity.

Another group of scholars demonstrates the importance of AI in controlling productivity, pollution, and irrigation in the agri-food supply chain as demonstrated in Table 2.

Table 2. Importance of Artificial intelligence

Author(s)	Context	AI Utility
Sundmaeker et al. (2016)	Pollution control	The use of AI in crop monitoring and pest control can reduce the need for excessive use of pesticides and fertilizers, thus mitigating pollution.
Lobell et al. (2017),	Productivity	AI-driven precision agriculture helps optimize inputs such as water, fertilizers, and pesticides, leading to increased crop yields.
Jha et al. (2019)	Agricultural automation	Automation allows farmers to decipher harmful pesticides, control irrigation, and control pollution
Li et al. (2019)		AI is instrumental in improving irrigation practices through real-time data analysis. AI-based systems can assess soil moisture levels, weather conditions, and crop water requirements.
Abukhader & Kakoore (2021)	Food production control	AI for vertical farming to monitor and control food productivity
Talaviya (2020)	Agricultural automation	Optimization of irrigation and application of herbicides and pesticides. Besides, using AI systems maintains soil fertility and efficiently uses human resources. This improves quality and elevates productivity.
Lakshmi & Corbett (2020)	dynamic capabilities	Primarily, AI increases agricultural efficiency and productivity. Moreover, AI can address environmental sustainability concerns and labor shortages.
Songol, Awuor & Maake (2021)	Productivity in developing nations	AI systems can provide timely, accurate, and relevant information for decision-making

Note: The table summarizes the importance of Artificial Intelligence in agriculture, highlighting specific contexts and the utility of AI as reported by various authors.

AI and supply chain logistics

Logistics remains a central term in the supply chain. According to the Council of Supply Chain Management Professionals (CSCMP), logistics is a domain of the supply chain process. It plans, implements, and controls the forward and reverse flow and shortage of goods, services, and the related flow of information efficiently and effectively between the source point and the point of consumption to meet the customer's needs (CSCMP, 2018). Meanwhile, professors of Michigan State University define logistics as activities such as packaging, transportation, warehousing, and others that move and position inventory while acknowledging its role in supply chain synchronization.





Whatever the definition, logistics is deemed fundamental to supply chain performance. It is argued that in less than two decades, logistics management has influenced product movement to meet or exceed consumer demand (Yusuf, Nurhilalia & Putra, 2019). The logistics of getting products to consumers are improved through automated systems, partnerships with suppliers, warehousing efficiency, and enhanced shipping services, culminating in faster delivery and reduced overhead costs. Yet in Kenya, poor infrastructure, low aggregation volumes, poor-quality vehicles, sparse distribution of farmers, and poor storage options remain major challenges raising per unit cost at every stage of the chain.

Despite the first and last-mile logistics being core to rural supply chains and crucial for smallholder livelihoods, they remain inefficient and expensive. For instance, research shows that approximately 62 percent of farmers use manual forms of transport, thereby consuming more time (AFCAP, 2014). Moreover, the Rural Transport and Agriculture Fact Sheet, 2015 documents that transportation costs make up 28% of Kenya's final market prices, significant in the value chain (Olwande et al., 2015). How then can AI be leveraged to lead to notable savings in the Agri-supply chain?

Research documents evidence of the importance of AI in supply chain logistics as demonstrated in the following reviewed studies in Table 3

Table 3. Importance of Artificial Intelligence in Supply Chain Logistics

Author(s)	Context	AI Utility
Modgil, Singh & Hannibal (2021)	Supply chain resilience	AI contributes to enhanced transparency, enhanced last-mile delivery, personalized solutions to upstream and downstream stakeholders, and facilitates an agile procurement strategy
Pandian (2019)	Warehousing efficiency	Enhancing logistics, coordination, and management potentials, i.e., creating a smart warehousing environment.
Klumpp, M (2018)	Logistics automation	Motivated by the scarcity in high-skilled personnel – AI allows for automated truck driving in logistics which is important for the design of autonomous driving supervision
Han & Zhu (2017)	Warehousing management	AI optimizes the production process and streamlines the warehouse management system.
Klumpp et al. (2019)	Optimization of supply chain logistics	Automation systems such as AI enable keeping the required quality and quantity and sequencing and scheduling profiles. Moreover, fully automated processes secure transportation and safeguard workers from the monotonous repetition of activities.
Rymarczyk & Klosowski (2018)	Autonomy in supply chain logistics	Through AI, Semi-autonomous transport vehicles can be used such that a control system informs the driver of the most optimal route.
Cavallo et al. (2018)	Supply chain visibility	AI via computer vision systems (CVSs) allows a non-destructive evaluation of quality levels in vegetables. Has the capability to monitor quality level regardless of packaging.



Note: The table provides a summary of studies exploring the importance of Artificial Intelligence in various aspects of supply chain logistics. Each entry includes the author(s), the context of the study, and the specific utility of AI in that context.

AI and Agri-food supply chain Fraud and Counterfeiting

Fraud and counterfeiting are major challenges in the agri-food supply chain in Kenya. Right from counterfeit Agro-inputs such as seeds and fertilizer to fraudulent pesticides, the chain is bedeviled by fraudulent activities at all stages. Although quality agricultural inputs, including fertilizer, seeds, and pesticides, are critical to agricultural productivity, access to high-quality inputs remains challenging in rural African markets. For instance, a previous study in Kenya determined that only close to 77 percent of hybrid maize seeds germinated or grew into maize crops, even though the Kenyan government requires a minimum of 90 percent for certification (Miguel, Hsu & Wambugu, 2020).

A report titled Counterfeiting in African Agriculture Inputs—challenges & Solutions (de Boef et al., 2019) paints a grim picture of counterfeit inputs in rural African markets. According to CropLife Middle East Africa (2011), 30 percent of pesticides on sale in Ghana by 2011 were unlicensed or smuggled. On the other hand, the Kenya Agricultural Research Institute (2012) indicated that as of 2012, there were 40 percent fake seed packets in Kenya, and by 2014 there were 30 percent counterfeit hybrid high-yielding variety seeds in the Ugandan market. According to Kenya's Anti-Counterfeit Authority (ACA), there has been an upsurge in reported cases of counterfeit targeting the grain-basket counties. Such cases involve counterfeit fertilizers and seeds, fraudulent labeling, trademark infringements, and theft of labels and packaging materials (ACA, 2021).

The question then is how to leverage systems that eliminate fraud and counterfeiting in Kenya's agri-food supply chain. A large body of research demonstrates in Table 4 the viability of AI to act as an anti-corruption tool in developed settings.

Table 4. Artificial Intelligence's Role in Fraud and Counterfeit

Author(s)	Context	AI Utility
Aarvik (2019)	Anti-corruption	Working large data sets reveals or predicts fraud or corruption. AI systems replace corruption-prone processes
Patricio & Rieder (2018)	Precision agriculture	Advanced AI techniques such as Deep Belief Networks (DBN) enable the construction of robust computer vision for precision Agriculture
Musra et al. (2020)	Agriculture and food stability	AI alongside IoT and big data enhances greenhouse monitoring, drone-based crop imaging, food quality assessment, and food safety
Jim et al. (2020)	Vegetable farming	The use of AI increases the accuracy of vegetable monitoring of fertilizing and sowing. Which allows for the detection of



		counterfeit seeds
Sharma, Kumar & Sharma (2022)	General Agriculture	AI addresses disease management, counterfeit inputs, crop growth management, and soil properties.

Note: The table summarizes the authors, context, and utility of artificial intelligence in various agricultural domains, emphasizing its role in fraud and counterfeit detection.

3. RESULTS AND DISCUSSION

From the two sets of reviewed studies, it is apparent that the Kenyan agri-food supply chain can benefit from leveraging artificial intelligence technology to monitor and control food production. Indeed, evidence in the Kenyan context documents the potential inherent in AI in monitoring and controlling food production. For instance, project FARM (Financial and Agricultural Recommendation Models) is a project being undertaken in the Kakamega region under the collaboration of Capgemini, a French consultancy firm, and Agric, an East African social enterprise to advise farmers on appropriate planting times (Wight, 2019). In this project, Capgemini uses AI to crunch farming data and send insights to farmers' cell phones. Through their testimonies, farmers participating in the project are upbeat about the benefits. They receive an SMS on how to tend their farm work and farm projects.

Another example of the potential of AI is FAO's adoption of the technology to fight the Fall Armyworm (FAW) spread that has recently plagued East Africa (Bramhall, 2021). FAO developed the Fall Armyworm Monitoring and Early Warning System (FAMEWS) mobile app, which tracks the insect's changes over space and time to gain knowledge of its behavior in a new context and inform the best response. This way, farmers and agricultural extension workers directly manage their crops to prevent further infestations and reduce damage.

With such evidence on the potential of AI to provide necessary information for farmland evaluation and control, we argue that sustainable agricultural development in Kenya requires research to focus on Agri-tech systems such as AI, which can revolutionize the agri-food supply chain. Lack of farmland monitoring and control has resulted in poor soil fertility associated with low yield and land degradation (Birch, 2018). The absence or underuse of inorganic and organic fertilizers, continuous cropping, and soil erosion are associated with less than two tons per hectare of maize yield among smallholders in Kisii compared to the required nine tons (Mulinge et al., 2016). Therefore, AI is poised to control soil fertility by using modern soil testing methods that calculate parameters such as temperature, pH level, moisture content, organic matter, NPK,



humidity, carbon level, and organic matter that help evaluate soil fertility. Such information helps identify the lack of nutrients and fertilizer required to boost soil fertility for smallholder farmers.

Effects of climate change in Kenya are unmistakable as manifested in rising, erratic and unpredictable temperatures that threaten agricultural productivity. Therefore, leveraging AI is a sure way of forecasting and predicting weather patterns. Research shows that the nowcasting AI system can expect more accurate short-term rain predictions, including storms and floods (Bochenek & Ustrnul, 2022). The predictive analytics advanced by AI enables farmers to acquire information on the timing of sowing the seed to maximize yield. Pricing of harvested maize remains a contentious issue in Kenya. Such instability in pricing has not allowed farmers to plan their production. Yet AI can guide farmers on the demand level, future price patterns, and crop type to sow for maximum rewards.

From the above research evidence, we posit that sustainable agricultural production systems in Kenya require that the logistical challenges farmers experience, especially in the first and last-mile logistics, be eliminated. While this may prove difficult, we argue that technology, especially AI and the Internet of Things (IoT), can be leveraged in the logistics of the agriculture supply chain.

For instance, AI can handle mass data, making it highly effective in inventory management. It is further argued that intelligent systems can expedite the analysis and interpretation of huge data sets, enabling timely demand and supply forecasts (Preil & Krapp, 2022). Through their intelligent algorithms, AI systems facilitate the prediction and discovery of new consumer habits and enhance visibility and transparency into all aspects of the supply chain. Suffice it to say that AI could be the panacea to dirty deals that threaten Kenya's food security.

Indeed, as reported in The East African Newspaper dated October 17, 2018, various forms of corruption undermine Kenya's food security (Mukami, 2018). For instance, in 2018, the National Cereals and Produce Board (NCPB) had some of its officials colluding with traders disguised as farmers to embezzle Ksh1.9 billion. In another incident, a South African company was awarded a multi-million shilling deal by senior state officials to supply Kenya with maize. However, the award process was fraught with irregularities (Mukami, 2018). Such dirty deals could be eliminated by leveraging AI to enhance supply chain visibility. With it, stakeholders can track produce as it travels from supplier to manufacturer or NCPB in this case, and then to the consumer.

Farmers in Kenya have often spent endless days and nights in queues trying to deliver their produce to the NCPB and they spend colossal amounts of money. However, such inefficiency in

warehousing at the NCPB can be solved by AI systems that guarantee the speed and accuracy that a human cannot. Employing AI systems would also save valuable time and costs for such farmers. Moreover, migration to AI systems could be critical to farmers who usually spend so much on last-mile logistics. Some farmers, in desperation, sell their produce to intermediaries at throw-away prices. Automation of the NCPB could, for instance, bring in robots that provide greater speed and accuracy. Besides, AI systems are bound to reduce reliance on manual efforts, speed up the entire process, and facilitate timely farmers' produce delivery.

From these reviewed studies, it is apparent that leveraging artificial intelligence can help reimagine the agri-food supply chain in Kenya by identifying and eliminating counterfeit agricultural goods. Through AI systems, farmers gain the tools to detect and avoid low-quality and counterfeit seeds. Indeed, the seed market in Kenya has become so fraudulent that sometime in the year 2021, farmers in the Rift Valley had a standoff with local seed manufacturers following a poor harvest believed to have been due to substandard or fraudulent seeds (Njagi, 2021). According to Njagi, the lack of field extension services and a traceability system in rural Kenya has allowed suspicious agro-dealers to thrive in selling fake fertilizers and seeds. Improving traceability, therefore, justifies the need to leverage AI systems.

Perhaps, the Kenya government's endeavor for AI systems is explained by the push by the Kenya Seed Company to help farmers verify the authenticity of seeds using mobile phone technology (Lang'at, 2018). In this Kenya Seed Company initiative, stickers containing a scratch-off code are attached to seed bags. Farmers scratch and send the code via SMS message and get an instant response confirming the validity of the seed. In this way, farmers are helped to avoid fake seeds. Besides, the Ministry of Agriculture has also come up with a phone number where a farmer can send an SMS to confirm the genuineness of Agriculture inputs stockist.

Therefore, it is clear that despite being expensive, artificial intelligence has the promise to eliminate counterfeiting in the agri-food supply chain in Kenya. Although the anti-counterfeit authority calls farmers to join the war against counterfeit Agro-inputs (ACA, 2021), perhaps the main potential for eradicating counterfeit inputs lies in machine intelligence, which is demonstrated by the Kenya Seed Company and Ministry of Agriculture's SMS initiatives.

4. CONCLUSION

Ending zero hunger and promoting sustainable agriculture as stipulated by sustainable Goal no. 2. will require changes in Kenya's agri-food supply chain. Changing the chain by leaning more towards practices that enhance visibility and efficiency could help the country address food

needs for all. Future practices might need to align with emerging digital technologies such as AI. For instance, AI has the potential to end hunger and poverty, ensure better health, and fight corruption (Vinuesa et al., 2020). The AI benefits of monitoring and controlling of outputs of farmlands should give further incentives for leveraging AI systems. The ability of AI to forecast food shortages places this technology at the forefront of ending hunger, improving nutrition, achieving food security, and promoting a sustainable, agro-food supply chain. Moreover, AI systems provide data that can be used to analyze scenarios efficiently, anticipate potential risks and take remedial action to improve the agri-food supply chain.

Another major contribution of using AI systems in the agri-food supply chains is efficiency in supply chain logistics. Ending hunger means having food reach everyone. Therefore, AI systems can guarantee that foods reach everyone by navigating the challenges farmers experience in the first and last-mile logistics. Produce, food transportation and tracking appear to improve when AI-controlled drones or other transportation modes automate service delivery. Moreover, such an efficient transportation network alleviates inventory predictions by enabling ease of goods tracking. It is argued that suppliers and consumers can track food or produce sources to identify organic and non-organic products (Gui-e & Jian-Guo, 2020). Still, on the agri-food supply chain, AI can maximize delivery routes, minimize fuel expenses and ensure quick delivery times. Therefore, artificial intelligence systems are likely to lower costs experienced with intermediaries in the first and last-mile logistics. Meanwhile, AI optimizes warehousing and storage. Through the genetic algorithm (GA) and radial basis function (RBF), AI can develop time series forecasting models for perishable produce (Niu & Feng, 2021).

The other elements AI systems are bound to impact in Kenya are fraud and counterfeiting in agricultural inputs. Numerous cases of food fraud and counterfeit inputs can be stopped through AI. It is refreshing to realize that efforts are on in Kenya to address fake inputs through mobile technology, albeit minimally. These efforts demonstrate the desire to improve the agri-food supply chain through AI systems. Although we acknowledge that it may ultimately be difficult to comprehensively integrate machine intelligence in the agri-food supply chain, we posit that sustainable agriculture is achievable by engaging machine intelligence to cut down costs in the first and last-mile logistics and maximize farming yield.

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