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# A REVIEW OF APPLICATION OF MACHINE LEARNING IN AGRICULTURE SUPPLY CHAIN TO IMPROVE FOOD AND AGRICULTURE INDUSTRY

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## Abstract
AI has been widely used in the field of agriculture. AI is a creative tool that enables machines to mimic the human capabilities and intelligence. It works by imitating the various activities and processes of humans. The world's population is expected to reach 9 billion by 2050, which means that the need for more food and agricultural production is a serious challenge for the industry. Due to various factors such as climate change, COVID-19 pandemic, resource scarcity, and socioeconomic conjecture, it is difficult to predict how much food and agricultural production will be needed by 2050. AI and machine learning have the potential to improve the efficiency and profitability of the food and agriculture sectors. The prospect to the challenges among others include training of humans to operate AI and Machine learning system. This is needed inorder to curb the major problem of unemployment which AI and Machine learning system will introduce due to the capability of the system to do the majority of the repetitive works and tasks.

**Keywords:** Artificial Intelligence, Machine Learning, Agriculture, Food, Farming, Industry

## Introduction
Agriculture is a critical part of any economy. It is seen as the bedrock of sustainability of any economy (Kekane, 2013) and it plays a key role in sustaining long-term growth. In the past, it was limited to food and crop production (Fan, Shen, Yuan, Jiang, Chen, Davies, and Zhang, 2012),

though, may vary by countries (Dekle and Vandenbroucke, 2012). In the last two decades, agriculture has evolved into a wide range of activities that are focused on processing, marketing, and distributing crops and livestock products. This supports the development of the local economy and generates national trade. Currently, agricultural activities serve as the basic source of livelihood, improving GDP (Oyakhilomen and Zibah, 2014), being a source of national trade, reducing unemployment, providing raw materials for production in other industries, and overall develop the economy (Awokuse, 2009).

As the population increases, the pressure on the agricultural system is expected to rise. This is why it is necessary that various agricultural activities are modernized. The global food production target has been estimated to increase by 6 to 10% by 2050 (Krishna, 2016) to feed the growing population. This increase in demand is expected to trigger food shortages. In addition, due to the emergence of various food safety scandals and incidents in the food sector such as bovine spongiform encephalopathy and dioxin in poultry (Ben-Ayed, Kamoun-Grati, and Rebai, 2013), a comprehensive traceability system is required in the food chain. Climate change and water scarcity are some of the factors that will affect the productivity of croplands in the next decades. This is why the establishment of a sustainable agricultural paradigm is needed.

Agri-tech and precision farming are new scientific fields that use data-intensive approaches to improve the productivity of croplands while minimizing their environmental impacts. The data collected by these tools can be used to make faster and accurate decisions. With the help of digital technologies, such as AI, these fields can help improve the decision-making process of farmers and enhance the profitability of their businesses. AI's introduction in agriculture is expected to be supported by other technological advancements, such as the internet of things. Through the use of data collected by AI, systems can predict the optimal time to sow and harvest a crop based on their

previous performance. They can also inform the users about the ideal conditions for optimal production. The use of AI technology in agriculture will help minimize the impact on the environment and provide a steady supply of food.

Machine learning (ML) is a field of artificial intelligence that enables machines to learn and improve on their own without being programmed. This discipline was established to enable developers to create systems that can learn and interpret large amounts of data. Among other definitions, ML is defined as the scientific field that gives machines the ability to learn without being strictly programmed (Richardson, Signor, Lidbury, and Badrick, 2016). Year by year, the number of papers related to the topic of AI and ML in agriculture (Zhou, Lin, Xu, Chen, Guo, Sun, and Yang, 2018) and food security (Maione and Barbosa, 2018) has increased. In this paper, we present a comprehensive review of the application of ML in agriculture and food industry.

## Artificial Intelligence and Machine Learning Approach

The artificial intelligence (AI) is a creative tool that simulates the human intelligence and ability processes by machines, principally computer systems, robotics, and digital equipment (Patel, Rai, Das, and Singh, 2021). An AI can perform various tasks such as natural language processing (NLP), which is a process that interprets and interprets verbal communication. The AI encoding process begins with acquiring data and creating algorithms to turn it into actionable information. It then learns how to make the most accurate results using predefined algorithms. The use of AI in various sectors has been on the rise. Some of these include finance, healthcare, and retail.

Machine learning (ML) is a major theme of AI. It involves learning from experience to perform a task. Data in this process is typically described in terms of attributes, which are usually defined as features or variables. A feature can be a sum of multiple digits, such as 0 or 1, or it can be a binary

or a number. The performance of the ML model in a specific task is measured by a performance metric that is improve with experience over time. To calculate the performance of ML models and algorithms, various statistical and mathematical models are used. After the training stage, the model can be used to perform various tasks, such as identifying new examples or predicting future results using the experience obtained during the training process.

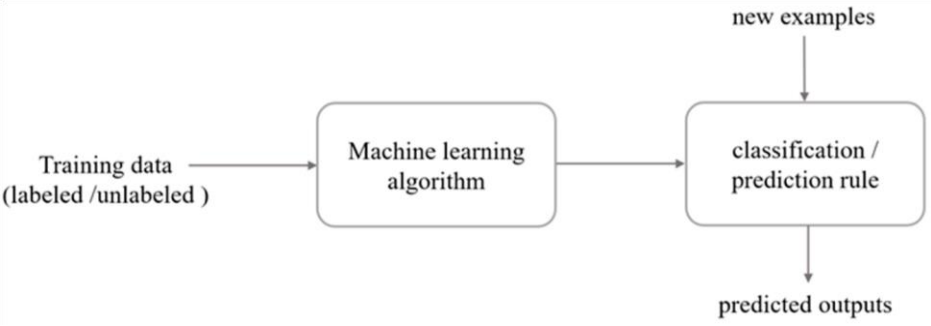


**Figure 1.** A typical machine learning approach.

Machine Learning tasks can be divided into various broad categories depending on the type of learning (supervised/unsupervised), the model(classification, regression, clustering, and dimensionality reduction) used to implement the selected task, and the learning signal that the system produces.

In supervised learning, outputs and inputs are presented with a general rule that maps them to the outputs. This rule can be used to constrain the outputs or provide feedback on the actions taken by the system. In the supervised setting, the trained model predicts the missing outputs. In unsupervised learning, it learns by uncovering hidden patterns.

AI has become more prevalent in the agri-food industry. Its ability to provide assistance and knowledge in the areas of decision-making and service creation is often utilized in the different phases of the supply chain. AI in agriculture is focused on providing precision and forecasting decision-making to improve the productivity of the farm (Patel, Rai, Das, and Singh, 2021). It can

also identify patterns and predict unexpected problems in the field in order to solve comprehension problems in the agricultural field and for the identification of pests and its suitable method of treatment, as well as the management of the irrigation process and water consumption by setting up smart irrigation systems.

Due to the increasing popularity of AI in the farming industry, various factors such as biotic and abiotic factors are being assessed using remote sensing and sensors (Patel, Rai, Das, and Singh, 2021). AI is also being used in various applications to improve the efficiency of the farming industry. Aside from monitoring defective crops, it can also identify pests and diseases and provide timely forecasts. In a study conducted by Sujatha, Chatterjee and Brohi (2021), the authors compared the performance of deep learning and machine learning methods in detecting and identifying the citrus plant leaf disease. The authors showed that the VGG-16 deep learning method gave the best result in terms of disease classification accuracy.

The advancement of AI has allowed tech businesses to improve the productivity of crop-based businesses by identifying and managing pests and diseases. Crane-Droesch, (2018) developed a new approach was introduced that combines deep neural networks with classical statistical models. They were able to predict the future harvests of corn using data collected in the US Midwest.

Through the use of AI, farmers can benefit from the data gathered by the system by monitoring their crops and predicting their weather conditions. This benefit can help them increase their profits and minimize risk. In 2018, a weather forecasting system was developed by combining a weather model with a recurrent neural network. The system was able to collect data such as temperature, wind speed, humidity, and precipitation (Fente and Singh, 2018).The researchers noted that the system was able to provide high-accuracy forecasts. It can also identify soil defects and provide a better understanding of the nutrients in the soil by analyzing the patterns of flora within a farm.

Suchithra and Pai, (2020) classified and predicted the soil fertility indices and pH levels of Kerala north central laterite Indian region soil by using the Extreme Learning Machine (ELM) technique with different activation functions such as hard limit, sinesquared, triangular basis, hyperbolic tangent, and Gaussian radial basis. The researchers discovered that the algorithm performed better than 80% on most of the problems when it came to predicting the pH level. It was also able to provide better predictions than the gaussian radial basis.

One of the main advantages of AI technology is its ability to reduce the use of chemicals. For instance, by using robotic equipment to manage weeds, AI techniques could help farmers avoid using chemicals on the whole field. Due to the accuracy of AI technology, it can also help farmers protect their crops from weeds. Another advantage of using AI is that it can reduce the number of human errors and provide an accurate and robust decision-making process on the right time with low cost (Kamilaris and Prenafeta-Boldu, 2018).

## Machine learning Application in Agriculture Supply Chain to Improve Agriculture and Food Industries

Machine learning (ML) is becoming more prevalent in the agriculture supply chain. It is used for the prediction of various farm inputs' requirements, and it can also identify potential issues in the field. The use of ML algorithms in the main four clusters (preproduction, production, processing, and distribution) of the agriculture supply chain is becoming more and more important (Ahumada and Villalobos, 2009). It is used in the preproduction step, the ML technologies are used, especially for the prediction of crop yield, soil properties, and irrigation requirements.

In the next phase of the production process, the use of ML can be used for predicting the weather and disease detection. The third cluster of the processing phase, utilization of ML approaches is applied, especially to estimate of the production planning to reach a high and safe quality of the product.

Preproduction: The preproduction cluster is a part of the agriculture supply chain that involves the prediction of various factors such as crop yield and soil properties. Through the use of data collected by farm equipment and nutrients, machine learning algorithms can predict the optimal production levels for different crops. Various algorithms such as the Bayesian network, regression, decision tree, clustering, deep learning, and ANN (Elavarasan, Vincent, Sharma, Zomaya, and Srinivasan, 2018) are used for crop yield prediction. According to the prediction of soil management properties, several ML algorithms are used in learning soil properties. Nahvi, Habibi, Mohammadi, Shamshirband, and Al Razgan, (2016) used the SaE (self-adpative evolutionary) ML algorithm to boost the performance of the extreme learning machine (ELM) architecture to estimate daily soil temperature. Additionally, Kumar, Singh, Kumar, and Singh, (2015) proposed a novel method named the CSM (Crop Selection Method) to resolve crop selection problems and help improve net yield rate of crops over the season.

In addition, Ayed, Ennouri, Amar, Moreau, Triki, and Rebai, (2017) analyzed 18 worldwide table olive cultivars by using morphological, biological, and physicochemical parameters and the Bayesian network to study the influence of these parameters in tolerance, productivity, and oil content. They revealed that oil content was highly influenced by the tolerance of the crop. The importance of irrigation management is also acknowledged in the preproduction phase. In fact, to achieve an effective irrigation system (better decision in when, where, and how much to irrigate), researchers used soil moisture data, precipitation data, evaporation data, and weather forecasts as

input data for simulation and optimization of predicted models based on ML adequate algorithms (Goap, Sharma, Shukla, and Krishna, 2018).

Production: During the production phase, various factors play a crucial role. Some of these include the weather forecasts, crop protection against pathogens, and water and nutrient deficiencies. Many different ML algorithms are used to simulate effective models for weather prediction as stated by Ayed and Hanana (2021) (ANN, deep learning, decision tree, ensemble learning, and instance-based learning), for crop protection (clustering and regression), ANN, deep learning, weed detection (ANN, decision tree, deep learning, and instance-based learning), crop quality management (clustering and regression), and harvesting (deep neural networks, data mining techniques such as k mean clustering, k nearest neighbor, ANN, and SVM). During the harvest stage, which is the last phase of the production process, machine learning algorithms are used to predict the fruit or crop color.

Processing: The processing cluster is a part of the agriculture supply chain that involves handling different stages of the production process. These include equipment selection, cooking, and drying. Modern food processing technology is being used by implementing software algorithms based on machine learning. Some of these include the ANN, the clustering, and the Bayesian network (Ayed and Hanana, 2021). Arora and Mangipudi (2021) proposed support vector machine (SVM) classifier and artificial neural network (ANN) models to detect the presence of nitrosamine in the red meat food samples, and the obtained predictive modeling results revealed that the highest testing accuracy was obtained using the deep learning model. Farah et al. (2021) analyzed milk samples using differential scanning calorimetry and machine learning tools. The researchers were able to detect fraud and identify adulterated samples.

Distribution: The distribution cluster is the last step in the supply chain that involves the processing and consumption of food. Machine learning algorithms can be used in this area to improve the efficiency of the distribution process. The goal of these predictive techniques is to improve the quality and safety of the food products by identifying potential issues before they occur (Ayed, Ennouri, Amar, Moreau, Triki, and Rebai, 2017). They can also predict the buying behavior and provide helpful recommendations for the consumers. The use of genetic algorithms for inventory management helps in reducing the risk of running out of inventory. The use of ML genetic algorithms helps in predicting daily demand and to ensure that there are no inventory-related problems (Dolgui, Tiwari, Sinjana, Kumar, and Son, 2018). Modern agriculture has become more efficient through the introduction of new technologies such as robots and mechanization a revolutionary era has come for agriculture and food industry, from rudimentary to high efficiency of agriculture with the introduction of mechanization, innovative technologies, computerized analysis, and decision, improving farming activities and crop productivity (Krishna, 2016).

Revolutionizing machines known as “agribots” are now being used in agriculture to perform various tasks, such as soil preparation, seed sowing, pest treatment, and fruit harvesting. These machines can reduce energy consumption and time spent in manual work. As a whole crop management, agricultural drones can be used starting from soil treatment (herbicide), going to sowing step, plant treatment (pesticide), and physiological control and observation, and ending with harvest time determination (Krishna, 2016). Drones are now being used by farmers to provide various services such as water, fertilizer, and pesticides, allowing them to take control of their crops and farm operations. Through satellite-guided technology, these systems can also map farm areas and provide data on a farm's production (Krishna, 2016). In the late 1900s, one farmer was

able to produce enough food grains to feed a family of four. With the advent of smart agriculture, this ratio is expected to increase significantly.

**Challenges of AI and ML**

Despite the advantages of AI, its disadvantages are still present. One of these is the potential unemployment threat posed by the rise of artificial intelligence. In fact, smart machines and robots could replace the majority of the repetitive works and tasks; thus, human interference is becoming less, which will cause a major problem in the employment standards. Machines can do only those tasks which they are programmed or developed to do. Other technological challenges aside from having to learn and improve themselves. AI machines could also crash and produce irrelevant outputs. Aside from the hardware and software, the maintenance costs associated with developing and maintaining AI-capable machines are also significant. This is because they update constantly. Due to the complexity of these systems, maintaining them regularly consumes huge amounts of resources. It also increases their cost. Beyond the advantages of AI, its systems can also cause issues related to resource consumption, e-waste problem, market concentration, job displacement and even the ethical framework. AI practice can also expose the farm to pests and diseases. It can also make the harvesting season less productive.

AI systems also require a huge amount of data to perform their tasks. For instance, a farm with a large area of land might require multiple data points to perform their tasks.

**Prospects AI and ML**

1. Training of humans to operate AI and Machine learning system. This needed inorder to curb the major problem of unemployment which AI and Machine learning system will

introduce due to the capability of the system to do the majority of the repetitive works and tasks.

2. AI and Machine Learning machines should be developed to perform a very detailed and specific task so as to prevent crashing or giving irrelevant outputs. The machines should be used only for the specific task it was programmed to do.
3. Low cost AI and Machine learning systems should be developed inorder not to affect the cost of food in the market.
4. AI and Machine learning systems should be developed to consume less energy.

## Conclusions

The agriculture and food industry is one of the most vital sectors of society. Its primary products are used in various multi-tier supply chains including four clusters or stages of the agriculture supply chain (preproduction, production, processing, and distribution) to reach the end consumer. Due to the increasing population and the need for more food production, the use of digital technologies such as artificial intelligence and machine learning is becoming more prevalent in the agriculture industry. In this study, the main applications of AI and machine learning algorithms in the agriculture supply chain was examined. Machine learning-based systems are gradually evolving into real-time intelligence platforms that can provide better decisions and actions based on their findings. In the future, it is expected that the usage of ML models will be even more widespread, allowing for the possibility of integrated and applicable tools.

Currently, various approaches and solutions are not connected to the decision-making process in the agriculture supply chain. Through the use of machine learning technology, this process can be automated and provide real-time data analysis and decision support for the agriculture industry. Despite the various technological solutions that can make farming more efficient, the need for high

energy inputs and quality food remains. Robotics and autonomous systems (RAS) are set to transform global industries. The use of AI and machine learning technology in the agriculture industry will have a significant impact on sectors that rely on low productivity such as agro-food (food production from the farm to the retail shelf).

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