



Article Info

Received: 10th January 2025Revised: 9th May 2025Accepted: 10th May 2025^{1,2,3,4,5,6}Kwara State University, Malete, Nigeria.⁷Corporate Farmers International Limited, Lagos Nigeria

*Corresponding author's email:

ronke.babatunde@kwasu.edu.ngCite this: *CaJoST*, 2025, 2, 207-220

AI-Driven Precision Agriculture: A Narrative of the Potential for Sustainable Crop Management

Ronke S. Babatunde¹, Abdulwaheed Musa², Ololade L. Abdulrahman³, Busola Alao⁴, Jumoke Ajao⁵, Latifat Olatinwo⁶, and Akinwale Alabi⁷

In precision agriculture, artificial intelligence (AI) has become a game-changing technology that allows farmers to maximize crop management and boost output. Recently, developments in machine learning and AI have opened up new opportunities for precision agriculture, particularly in the field of crop management. Early disease identification is made possible by computer vision and machine learning techniques, which also enable tailored interventions to reduce yield losses. Farmers can receive personalized advice on the best practices for planting, irrigation, and fertilizer management via chatbots and advisory services powered by AI. Artificial intelligence algorithms combined with sensor networks allow for just-in-time decision making by providing real-time weather, plant health, and soil monitoring. Despite the well-established advantages of AI in precision agriculture, there are still difficulties which calls for continual research. This work presents a narrative of the most recent developments in the use of AI in agricultural farming across a range of domains in Nigeria. This was done by reviewing and identifying the AI methodological approach used in allied research carried out for crop management. Appraisal of the researches, AI technique employed, contributions and milestones in this domain, amassed in the literature reveals plethora of obstacles encompassing restricted data accessibility, interpretability of models, and implementation in resource-constrained settings amongst others. It is therefore recommended that critical attention be given to address these restrictions so as to expand the potential of AI-driven solutions and attaining precision agriculture's full promise for global food security.

Keywords: Artificial Intelligence, Agriculture, Smart Farming, Crop Management, Sustainability.

1. Introduction

Exploring the potential of AI technology for boosting production efficiency while mitigating negative environmental consequences cannot be overemphasized. The idea is reducing the hazards in agriculture and promoting intelligent farming. Implementing AI technology and strategic management approach has a resultant effect on farming practices which include increased productivity and reduced waste, thereby contributing to sustainable agricultural development. (Senthil et. al., 2025). Furthermore, Precision agriculture is an approach that leverages advanced technologies, such as artificial intelligence (AI), to optimize various aspects of crop production. The integration of AI into precision farming holds immense promise in revolutionizing traditional farming methods and enhancing global food security. AI-driven precision farming techniques enable farmers to make more informed, data-driven decisions across the crop management lifecycle. AI plays a pivotal role in precision irrigation, ensuring optimal water usage by

analyzing soil conditions, weather patterns, and plant water requirements. (Mesi'as-Ruiz et. al., 2023). AI algorithms utilize real-time data from soil moisture sensors, weather forecasts, and plant water requirements to enhance irrigation plans. This guarantees that crops receive the correct amount of water at the optimal time, reducing waste and enhancing water usage efficiency. Additionally, computer vision and machine learning models can detect nutritional deficits, pests, and illnesses in crops. By precisely mapping these difficulties, AI allows for the targeted application of fertilizers and pesticides where they are needed. This lowers overall chemical usage while preserving crop health and productivity (Yadav and Sidana, 2023). Precision agriculture techniques have been increasingly adopted worldwide to optimize cultivation practices, achieve sustainable crop production and help farmers meet consumer demand for sustainable and high-quality products. (Akkem et. al., 2024). The implications of research in

this domain is towards a sustainable agriculture in the world and beyond. This means that machine learning and AI solutions can help farmers reduce inputs and minimize environmental impact while meeting consumer demand for sustainable and high-quality crop products. However, adequate highlights of outcomes of studies about the economic, environmental, and social implications of precision farming has the potential to shape the future of agriculture (Bharadiya and Tzenios, 2023). Additionally, there is a substantial knowledge gap because there is no unified framework that incorporates yield-affecting factors into a comprehensive model, allowing for more accurate predictions. On the other hand, research into agricultural forecasting is limited in Nigeria, and researchers rely on traditional statistical models that do not adequately meet the region's specific challenges. This calls for continual research in this domain.

2. Materials and Methods

This narrative review examined the existing literature in AI applications for crop management, which is intended to provide an overview of the algorithms vis-à-vis technique used, key contribution and findings as well as breaches in the current study. The literature search was conducted using databases including PubMed, Scopus, Web of Science, and Google Scholar. The search strategy employed a combination of keywords and subject headings, including "crop production," "disease resistance," "environmental condition," "climate change," "AI in Agriculture," "Precision Farming in Nigeria,"

The search was limited to articles published in English, with specific date restrictions of 2020 to 2024, to capture the most recent research on the topic. However, emphasis was placed on more recent publications (within the last 2 years) to highlight current trends and developments.

The selection of articles for inclusion was guided by the relevance to the review's scope. These are studies focusing on the impact of climate change on crop yield, research addressing major diseases affecting crops in Sub-Saharan Africa and articles discussing modern farming practices for crop cultivation.

Both empirical research articles (quantitative and qualitative) and review articles were included. Theoretical papers and book chapters that provided significant conceptual insights were also considered. Studies with a primary focus outside the geographical region of interest were generally excluded, unless they offered findings with broader applicability.

Considering the narrative nature of this review, a formal data extraction form was not used. Instead, key information was extracted and synthesized

thematically. This involved reading and summarizing the selected articles, identifying recurring themes and patterns, synthesizing information related to the research questions and organizing the information into a coherent narrative structure.

3. Appraisal of Related Research

(Vinu & Mane, 2023) discusses the use of IoT devices and machine learning to monitor soil conditions and predict optimal crops. The research aims to increase agricultural productivity and water management efficiency by proposing an IoT-based smart agriculture system to monitor soil moisture, temperature, pH and provide crop predictions to farmers. It utilizes a Raspberry Pi controller and sensors which include DHT-11 for collection of real-time data. Machine learning techniques was used to analyze the sensor data to determine suitable crops and irrigation requirements. The technique adopted was semi supervised learning based on Q learning algorithms. Numerical values of the result of the experiment carried out was not reported. The method was validated using various real life data, hence a viable prototype solution was developed.

Sebastian *et. al.*, (2023) explores the sustainable development of AI applications in the context of agriculture. The applications cover various aspects of farming, including irrigation, nutrient management and fertilization, weed control, pest/disease control, yield prediction, crop recommendation and automation. The work conducted two systematic reviews. The first aimed to gather information on sustainable agriculture and the environmental costs of conventional practices. The second focused on identifying explicit AI applications and their impact. Several outcomes from the reviews reveal that sustainable AI development drives agriculture towards a more sustainable future. This implies that various applications of AI which have been implemented in sustainable agriculture development pointing out the biggest challenge remains to precisely determine the positive impacts on the environment from AI technology. The study recommends further research on the impact of AI applications in agriculture on sustainability characteristics such as climate change and biodiversity.

Konduru *et.al*, (2023) developed a system for plant disease detection and classification using deep learning models. 50,000 images of Apple, Corn and Tomatoes plants were collected from plant village and online sources. The outcome was a dataset created comprising images from various sources and augmented images to ensure that all the classes are balanced, resulting in over 50,000 images that belong to 25 different classes comprising only three crops; including apples, corn, and tomatoes. The Convolutional Neural Network (CNN), Alexnet and MobileNet were used to analyze and evaluate the performance of the models on the

new dataset. The models were trained on the new dataset for 100 epochs. MobileNet outperformed the other two models, attaining 99.69% training accuracy, 94.37% validation accuracy, 96% average precision and 96% recall.

Murugamani, et.al, 2022 developed a system to detect the most appropriate plant development parameters using machine learning. The study identified that monitoring systems based on artificial intelligence (AI) and wireless sensors are in high demand and give exact data extraction and analysis. Image processing-based machine learning techniques were used to improve the prediction state and the soil quality was been monitored. The regression technique of artificial intelligence was used to identify and classify cotton leaf diseases. The information was delivered to farmers via an Android app after infection identification. The Android app also allows soil parameter values like moisture, humidity, and temperature to be displayed along with the chemical level in a container. The app was able to detect defects, so that pesticides can be sprayed automatically on the afflicted plants. The support vector machine (SVM) algorithm delivers an accuracy of 98.34% for the identification of bacterial blight diseases.

Rachid et.al, 2023 used apple production as a case study and developed a machine learning approach to identify optimal cultivation practices for sustainable apple production in precision agriculture in the Msemrir town Morocco. Precision agriculture techniques, including irrigation and fertilization management in improving apple yield and size was explored. The work demonstrated the potential of ML techniques in developing predictive models for apple production in specific regions and identified optimal cultivation practices. The work was benchmarked on dataset collected from farms of cultivation practices and apple yield and size data from 10 farms in the town and used correlation-based feature selection and three Machine Learning algorithms (Linear Regression, Decision Tree, and Random Forest) to develop predictive models. The results showed that irrigation, fertilization, and pruning are the most important cultivation practices for apple production in the region, and the Random Forest model performed the best in predicting apple yield and size based on the selected practices. The work identified small size of the dataset as a major limitation, which limited the generalizability of the results to other regions. The work concluded that the use of ML techniques can help farmers optimize cultivation practices and achieve sustainable apple production by reducing inputs such as water and fertilizer and minimizing environmental impact.

Emmanuel et. al., 2023 proposes a framework that integrate weather, temperature and soil humidity to improve farm management and sustainability. The framework establishes a value chain optimized to

facilitate enhanced monitoring and decreased labor expenses. Four key technologies that have significantly transformed agriculture in driving smart farming were employed in the study, which include the Internet of Things (IOT), Big Data Analytics, Artificial Intelligence (AI) and Machine Learning (ML), Robotics and Automation, Drones and Unmanned Aerial Vehicle. The study introduces a concept Agriculture 4.0 with the sole aim of raising industry production and efficiently apparently increasing and improving food output by 70% or more. The study observed that modern farming relies heavily on technological devices, increasing the risk of system failures, cybersecurity breaches, and technological obsolescence, which can disrupt agricultural operations, particularly for farmers lacking resources or expertise. The study was able to provide evidence of the effective utilization of these technologies, illustrating how to effectively harness the capabilities of Agricultural 4.0.

Girish et. al., 2023 developed an efficient decision making system for sustainable fertilization. The work used machine learning to resolve the issue of inadequate use of fertilizers which can significantly damage crop yields taking factors like rainfall and the specific nutrient needed into consideration. The proposed machine learning technology will provide a potential solution by leveraging data related to crop fertility and rainfall. The design was carried out using random forest (RF) algorithm, with the implementation of K fold cross-validation. The RF, which consist of decision trees where trained using different data subsets and it hyper-parameters whose inputs were the crop types and location was tuned. There were three random forests with 50 decision trees each for N, P, K, producing the class average of prediction for all trees. The result of the study was an application able to provide weather alerts and notifications, the quality of nutrients and fertilizer required for effective growth and yield while considering the climate conditions.

(Bijlwan & Ranjan, 2023) explores the latest developments in the application of AI, ML, and DL for crop disease and pest identification and classification, shedding light on how these technologies revolutionizes the way the challenges of agriculture can me mitigated. The work used Wheat and Rice as case studies, benchmarking on images of crop disease and pest. A system that identifies the crop disease and their pest was developed using the CNN methods which are VGG16, ResNet-50, Inception, MobileNet-V3 and EfficientNet-B0 and Vision Transformer (ViT). The DL models were able to accurately distinguish between different types of diseases, such as powdery mildew, rust, and blight. Also, the system effectively classified pests such as like aphids, spider mites, and white flies The work concluded that DL technologies can analyze images of plants and detect subtle signs of damage or infestation that

might be missed by the human eye, hence the model serve as a tools that helps wheat farmers make informed decisions regarding irrigation, fertilization, and disease control.. The authors further used DL models to analyze rice genetics to identify genes associated with resistance to specific diseases and pests, leading to the creation of more resilient rice varieties for Rice farming.

Szira, et. al, 2023 discussed how to address the challenges posed by a rapidly growing global population, changing climate patterns, and the imperative to ensure food security while minimizing environmental impact. The study is centered on an innovative approach that harnesses the power of advanced technologies and data-driven methodologies to optimize every facet of Precision Agriculture, emphasizing its benefits, challenges and legal regulation. The work identified that the adoption of precision farming practices holds promise for enhancing resource efficiency, increasing crop yields, and promoting environmental sustainability. Precision farming underscore the need for a holistic approach that addresses technical, economic, social, and legal considerations. The work concluded that collaboration between technology developers, policy makers, farmers, and researchers are the only means by which these challenges can be mitigated and the full potential of precision farming can be unlocked by addressing issues related to investment, data privacy, technology access, and knowledge transfer.

(Cemal & Derya 2023) used a deep learning based model to classify disease in grape plants using the images of leaves. The work aim to develop an improved and effective model to provide reliable and robust prediction. Computer vision-based solutions were implemented by using machine learning techniques for accurate identification of plant disease at early stages. The study employs SVM, DT, KNN, RF, logistic regression (LR), naive Bayes (NB) and CNN. The dataset used contains grape disease images, obtained from PlantVillage dataset which includes 3251 images of grape leaves, divided into four categories: the healthy, Isariopsis leaf spot, Esca and black rot. The data was preprocessed and passed to the machine learning models for training and testing. The performance of the trained models were evaluated based on accuracy, precision, recall, and f-score. The result of the experiment indicated that the deep learning model identified the diseases on the images than the machine learning models.

Zhaoan et. al, 2023: introduced a framework that combines DRL with RNNs, utilizing Gym-DSSAT to determine optimal nitrogen fertilization strategies. This study underscores the critical importance of tailoring fertilization management practices to the specific weather conditions of each year, especially in the face of extreme weather events. An

assessment of the impacts of climate variability on agricultural outcomes and management was carried out, with a particular focus on scenarios involving higher temperatures and inadequate precipitation. It utilizes an RL approach, in which during a learning process, the agent interacts with the agricultural environment by taking actions in agricultural management and receiving rewards as feedback. The work identified that adaptability is essential for optimizing crop yield while simultaneously minimizing nitrogen input. Also, maintaining flexibility in response to variables, extreme influences of weather and other factors affects crop performance.

As stated in (Patil, 2023) certainly, the AI-Driven Farmer Support System is a transformative tool for Indian agriculture and rural development. It leverages historical data and advanced data analytics to predict crop yield and market prices, aiming to empower farmers to make informed decisions. The system's holistic analysis considers diverse factors influencing agricultural production, including rainfall, temperature, market dynamics, and prior crop yields. By providing data-driven recommendations, the system aims to empower farmers to align their crop choices with market demand and optimize yields. The system's commitment to eco-friendly practices contributes to sustainability and environmental responsibility. Strong user adoption and engagement underline the system's practicality and acceptance. The feedback mechanism plays a pivotal role in its continuous improvement. The AI Farmer Support System holds promise for empowering farmers, promoting sustainability, and expanding its impact through scalability and collaboration, representing a significant step towards improving Indian agriculture and promoting a sustainable future.

Nipuna et. al., 2023 develop an AICropCAM system for plant-level and canopy-level feature analysis in precision agriculture. The work considered dataset consisting images captured in corn and soybean fields for training and testing deep convolutional neural network (DCNN) models. The research methodology involved several key activities such as: Gathering and preparing images for analysis, designing the hardware components for the AICropCAM system. Developing software for data exchange between the edge device and the Cloud, Creating DCNN models for crop classification, canopy segmentation, plant counting, weed counting, and insect identification, training and fine-tuning the DCNN models for optimal performance, implementing the AICropCAM system in a corn and soybean field for real-world testing. Raspberry Pi 4B was used for testing DCNN models with varying power consumption levels. LoRa technology was utilized for data transmission in the IoT system. The result shows that integration of technologies for early and informed crop prediction decisions will foster

sustainable environments and increased production rates and enhance the overall economy.

(Siropayan et al., 2022) The most significant farming applications are irrigation management, pest and disease control, greenhouse condition monitoring, soil and water quality monitoring, precision agriculture and dairy management. Vertical farming environments are in industrial buildings, container farms, in-store farms where the consumption or the purchase is high like supermarkets or restaurants, and appliance farm which targeted for in-house environments. Due to operating and investment costs, traditional farming is currently more financially competitive than vertical farming at the cost of environmental change. In the literature, these various machine learning models are applied in farming domain for crop and yield management, disease, weed, pest detection. One of the image datasets is used to detect for already stored diseases imaging and the other for query image implementation. Regarding these studies, a closed vertical agricultural system is proposed that will be monitored by an image capture system to detect diseases on plants. While the output layer was frozen, the ResNet50 model could not continue training, the added layer trained itself with the train dataset for 25 epochs. With, 125 training epochs on ResNet50 and 25 additional training epochs on the new layer, the model gave an accuracy of about 86%. An important improvement that can be made to this project would be to fulfill its deployment goals, a self-feeding image recognition system would be a very important study point and help to provide new sets of images for studies later.

(Venkata & Chowdary, 2023) implemented a machine learning-based crop recommendation system, incorporating Naive Bayes and Decision Tree models. The classifier accuracy of various models, including Linear Regression, Decision Tree, Naïve Bayes, Support Vector Machine (SVM), XGBoost, and Random Forest was experimented on, demonstrating the efficacy of the machine learning models in crop recommendation. The methodology section emphasizes the importance of data collection for building a crop recommendation system, stressing the need to collect data from a variety of sources to ensure its representativeness of the real world and account for regional variations in climate and soil conditions. The work concludes by advocating for the adoption of a machine learning-based crop recommendation system as a promising approach to assist farmers in making informed decisions, thereby enhancing agricultural productivity and potentially increasing income. The proposed system is positioned as a valuable tool for farmers, offering user-friendly insights based on data analysis and bridging the gap between traditional farming practices and technological advancements. Ultimately, the adoption of the machine learning-based approach holds the potential to transform the

way farmers engage with their land, promoting prosperity and responsible agricultural practices

Sakshi et al., 2023)research on forecasting crop yields in contemporary agriculture, addressing challenges from population growth and climate change. It emphasizes technology and data-driven approaches to create dependable predictive models. The target of the work was to develop a comprehensive system merging advanced analytics, machine learning, and remote sensing for accurate crop yield forecasts. The procedure includes data collection, preprocessing, model selection, validation, model training, evaluation, stakeholder engagement, construction of a user-friendly interface and deployment, with a focus on ongoing monitoring and ethical considerations. The work highlight algorithm choice and data quality as the most important criteria to build a machine learning crop management system. The conclusion underscores the significance of precise crop yield forecasts for economic stability, food security, and sustainable agriculture. It emphasizes machine learning's potential in aiding farmer decisions and the need for continual model enhancement and accessible implementation for diverse farming communities.

(Bulut & Hacıbeyoğlu, 2023) carried out an experimental study, which utilized five machine learning and deep learning methods to carry out hydroponic farming with IoT and machine learning for efficient, sustainable agriculture. The experimental hydroponic system utilized Arduino sensors for data collection, focusing on nutrient solution parameters and environmental factors. Arduino Uno controlled irrigation, light, and data transmission to Firebase via NodeMCU ESP8266. In the dataset, pH and EC values are categorized based on their deviation from the equilibrium point, aiding in system understanding. pH is classified as natural, basic, or acidic, while EC is categorized as balanced, requiring additional nutrients, or needing water. The dataset also evaluates the system status, considering irrigation and light conditions, with corresponding numerical classifications. The classification system enables insights into nutrient utilization by the plant and facilitates monitoring plant development in the hydroponic system. The machine learning algorithms used for system state and nutrient solution classification were SVM, kNN, logistic regression, decision tree, naive bayes, DNN, CNN, RNN, and LSTM,. Architecture, activation functions, and optimization algorithms varied among the models, with dataset learning occurring over 10 epochs.

The LSTM model exhibited superior performance compared to the other models, with an accuracy rate of 51.2%. The results exhibited superior precision and recall in comparison, indicating enhanced accuracy in predicting positive class instances and detecting genuine positives.

The deep neural network model demonstrated outst

anding performance, with a precision, recall, F1-Score, and accuracy of 99.7%. The aforementioned model demonstrated a high level of accuracy in correctly classifying positive cases and effectively identifying real positives, hence establishing itself as the most successful model among those that were assessed.

The results of the research, based on data obtained from a prototype system, indicate that machines can predict the system with higher accuracy, especially in forecasting EC and pH values.

Su et al., 2022 presents a study on the application of machine learning algorithms to assess the productive performance of conservation agriculture (CA) on a global scale. The authors address the limitations of traditional meta-analysis in summarizing large amounts of information by a single mean effect value, especially when considering agricultural practices, which often have non-linear impacts on crop yields and vary widely depending on factors such as soil properties and local climate conditions. To overcome these limitations, the study introduces a new approach based on standard machine learning algorithms to analyze large experimental agricultural datasets. The proposed machine learning pipeline standardizes the process of comparing the performance of different cropping systems and mapping them at the global scale. The framework includes several steps covering algorithms selection, model training, model tuning by cross-validation, model testing, and global projection of results. The study evaluates and compares several machine-learning models for their ability to estimate the productivity of CA systems and analyze uncertainty in the model outputs. The research aims to provide data-driven global maps describing the spatial distribution of the productivity of CA versus conventional tillage (CT). This innovative approach has the potential to provide valuable insights into the performance of conservation agriculture practices and their implications for global food security and sustainability.

To optimize crop production, reduce waste, and increase crop yields while minimizing costs, Elbasi et. al., 2023 integrated machine learning algorithms in agriculture by analyzing data from farms and incorporating IoT sensor data in real-time. This enable farmers to make more informed decisions about factors affecting crop growth. This was achieved by deploying multiple classifiers that were fine-tuned and evaluated to identify the most suitable ones for the input data. The data contain 2200 records encompassing 22 distinct crop labels. Feature reduction and augmentation techniques were incorporated to enhance crop detection and assist farmers in selecting appropriate features for accurate predictions. The work achieved a classification accuracy of 99.59% with the Bayes Net algorithm and 99.46% with Naïve Bayes Classifier

and Hoeffding Tree algorithms. The research highlighted the potential benefits of machine learning in agriculture, which include early disease detection, increased crop production efficiency, and reduced prices during food shortages.

Li et. al., 2023 focused on improving crop benefits in rice-rape, rice-wheat, and rice-garlic rotations in Southwest China using intelligent decision-making with machine learning. A data-intensive approach was used to analyze key factors and provide strategies for enhancing benefits. The dataset included 237, 493, and 210 datasets for rice-rape, rice-wheat, and rice-garlic systems, respectively.

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method was used to determine the comprehensive scores of different crop rotation systems. This is a multi-criteria decision analysis method used to evaluate and rank alternatives based on multiple conflicting criteria. The study utilized a random forest model for predictive analysis of optimizing agricultural inputs based on machine learning analysis. Gray relational analysis (GRA) was performed using SPSS for further analysis. The results showed that optimizing agricultural inputs based on machine learning analysis could improve the effectiveness of crop rotation systems

Stefan et. al., 2023 developed a novel approach to crop rotation planning using reinforcement learning. The work utilized reinforcement learning to train an agent for generating realistic crop rotation sequences based on successor crop suitability matrices, soil nitrogen level, contribution margin, and cultivation breaks. The method involved using literature and normalized difference vegetation index (NDVI)-measurement-based data along with crop-specific attributes to train a Deep-Q Network (DQN)-based reinforcement learning agent for crop rotation planning. The dataset included successor crop suitability matrices, crop-specific attributes like contribution margin and nitrogen demand, and NDVI measurements obtained from satellite images. The generated crop rotation sequences were validated by practitioners and experts, confirming their realism, compliance with existing rules, and practical applicability. The contribution of the research was providing a data-driven method for generating crop rotation sequences that align with agricultural best practices and can enhance decision-making in agriculture.

(Cavalcante de Oliveira & Diogne de Souza e Silva, 2023) conducted a systematic review of literature on artificial intelligence (AI) technologies applied in agriculture to optimize resources and increase productivity. The study utilized the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology. The work analyze 906 relevant studies, selecting 176 for bibliometric analysis and 17 for benefits, challenges, and trends

analysis of AI technologies in agriculture, which ensures a comprehensive and structured approach to data collection and analysis. The analysis revealed an increase in publications over the last five years, with over 20 different AI techniques applied in the 176 studies, including machine learning, convolutional neural networks, IoT, big data, robotics, and computer vision. Countries such as India, China, and the USA were highlighted for their contributions to AI technologies in agriculture, focusing on crop management, prediction, disease, and pest management. The work concluded by providing insights into the benefits, challenges, and trends of AI technologies in agriculture, offering a roadmap for future directions in AI for agricultural applications.

Olutomilola et. al., 2023 develop a plantain peeling machine using locally sourced materials to address the challenge of peeling plantains due to their curvature. The machine consisted of spike-rollers, slitting and scraping blades, peeling chamber, drive assembly, and an electric motor, with key components simulated for fabrication. The work leveraged on earlier conceptual design of an electrically powered plantain peeling machine using SolidWorks CAD software and spring-loaded peeling cutters. Experimental determination of average forces required to peel unblanched and blanched plantain fingers guided the machine's design. SolidWorks computer-aided design software was utilized for model development and design analysis of the machine components. Experimental data on the average peeling forces for unblanched and blanched plantain fingers were collected to inform the machine's design. The average peeling force for unblanched plantain fingers was 56 N, while blanched fingers required forces ranging from 1.6 N to 12 N based on blanching duration. The major contribution of the work was the development of a plantain peeling machine using locally available materials and experimental data on peeling forces contributes to enhancing plantain processing efficiency and productivity in Nigeria.

Salihu et. al., 2023 focused on automating the detection and classification of corn diseases using Convolutional Neural Networks (CNNs). The CNN model was employed for disease identification and data augmentation techniques were carried out in order to enhance model robustness. A diverse and well-annotated dataset of corn plant images was collected and preprocessed for model training and evaluation to minimize the loss function. Compared with other methods such as AlexNet and GoogleNet, the CNN model achieved an impressive accuracy of 95.53% in disease detection and classification. The research aimed to enhance crop resilience, minimize losses, and promote sustainable agricultural practices by providing actionable insights to stakeholders like farmers and agronomists. By leveraging CNNs and data augmentation, the study

improved disease management strategies, facilitated early intervention, and ultimately aimed to enhance crop yield and food security.

(Su, 2020) focuses on crop plant signaling for real-time plant identification in smart farms. The work aim at automating weed control systems in an efficient and non-invasive manner. To achieve this, the work utilizes crop plant signaling, which is a novel robot-plant interaction technique that visualizes fluorescent signals on crop plants for weed identification. Fluorescent Proteins (FPs) was used as biological markers for imaging living plant tissues, with specific proteins like mEmerald, mTagBFP2, mScarlet-I, and TurboRFP being detected on plant leaves. The study demonstrated the successful detection of lettuce plants and sprayable weeds using FP markers, reducing manual weeding time significantly. The research contributes to the development of automated systems for accurate and real-time plant recognition in agricultural systems, potentially reducing labor costs and optimizing herbicide use while preserving resources like soil and water.

The study by Conradt (2022), on choosing multiple linear regressions for weather-based crop yield prediction, tackles the challenge of predicting crop yield based on weather conditions using the ABSOLUT v1.2 model, focusing on the districts of Germany. The technique employed is multiple linear regression, which is utilized to establish the relationship between weather variables and crop yield outcomes. Whereby, indicating that the traditional methods for selecting these variables are often based on expert choices or simplistic methods such as stepwise regression. The study introduces a more systematic approach to optimize this process, aiming to enhance predictive performance while maintaining the principal approach of multivariate linear regressions. The machine learning aspect of the study involves the application of the ABSOLUT v1.2 model, which is designed to handle the complexities of weather-based crop yield prediction. The dataset comprises weather-related data specific to the districts of Germany, which is used to train and test the predictive model. The results of the study demonstrate the effectiveness of multiple linear regression in conjunction with the ABSOLUT v1.2 model for accurate crop yield prediction, highlighting its potential for practical application in agricultural planning and management. The results of the study also demonstrated that the ABSOLUT method could achieve competitive predictive performance compared to traditional regression and other machine learning approaches which highlighted the method's ability to identify spatial patterns of yield changes, demonstrating its utility in diverse and heterogeneous landscapes like Germany.

The article by Saini and Nagpal (2023), on PSO-CNN-Bi-LSTM: A Hybrid Optimization-Enabled Deep Learning Model for Smart Farming, presents a hybrid deep-learning model designed for smart farming applications. The study addresses the challenge of accurately predicting and classifying crop diseases to enhance decision-making in smart farming. The proposed model, PSO-CNN-Bi-LSTM, combines Convolutional Neural Networks (CNN) and Bidirectional Long Short-Term Memory (Bi-LSTM) networks with Particle Swarm Optimization (PSO) for improved performance. The model was trained and tested on a comprehensive dataset of crop images, which included various disease manifestations. The result shows that PSO-CNN-Bi-LSTM model demonstrated high accuracy in disease prediction and classification, outperforming traditional methods and showing promise for real-world agricultural applications. This hybrid approach leverages the strengths of CNN for feature extraction and Bi-LSTM for sequence prediction, while PSO optimizes the model parameters, resulting in a robust tool for smart farming.

The study on artificial intelligence-based solutions for climate change, by Chen *et. al.*, 2023, explores climate change and how it poses a significant threat, causing damage to urban and natural systems, resulting in global economic losses exceeding \$500 billion. This study related that AI enables efficient resource use in agriculture, enhancing crop yields and reducing waste. AI optimizes pre-construction and mid-stage industrial processes, reducing energy consumption and improving efficiency. The study explores how Artificial intelligence (AI) can play a crucial role by integrating internet resources to provide accurate climate change predictions. The study reviews recent research and applications of AI in mitigating climate change effects across various domains. The focus areas are on Energy Efficiency, Carbon Sequestration and Storage, Weather and Renewable, Energy Forecasting, Grid Management, Building Design and Transportation, which can address climate change issues. This researchers opines that AI enables efficient resource use in agriculture, enhancing crop yields and reducing waste. The article does not specifically mention a dataset, but it reviews AI applications across these domains. The result of the study shows that smart manufacturing can reduce energy consumption, waste, and carbon emissions by 30–50%. Furthermore, combining smart grids with AI optimizes power systems, reducing electricity bills by 10–20%, intelligent transportation systems significantly cut carbon dioxide emissions and AI contributes to natural resource management and resilient city design.

Ngugi *et. al.*, 2023, addresses the need for accurate and early detection of crop diseases. The researchers indicated that traditional methods have limitations, however deep learning (DL) algorithms

was explored as a solution. The paper focuses on DL techniques, which have outperformed conventional methods. DL algorithms, such as Convolutional Neural Networks (CNN), K-nearest neighbor (KNN), support vector machines (SVM), and artificial neural networks (ANN), are employed. Specifically, the authors propose a drone imaging-enabled DL approach for real-time detection and classification of 11 impactful crop disease categories. The study utilizes leaf images of healthy and diseased crops captured via agricultural drones. However, the review highlights the need for a comprehensive and expansive image dataset covering a wider array of crop varieties. The review analyzes the performance of various ML and DL techniques which emphasizes on the lack of focus on emerging DL algorithms like capsule neural networks and vision transformers. Researchers often concentrate on individual plant diseases or specific ML/DL algorithms. The review of this study advocates for a unified framework that combines multiple ML and DL algorithms to effectively address the complexities of various plant diseases.

In the article by El-Shafeiy, Abohany, Elmessery, and El-Mageed (2023), on estimation of coconut maturity based on fuzzy neural network and sperm whale optimization, addressed how to estimate the appropriate stage of maturity of coconut water. Basically, as coconuts age, the flavour of coconut water varies, making it crucial for the beverage industry to determine the maturity level accurately. The authors propose an adaptive model called FNN-SWO (Fuzzy Neural Network and Sperm Whale Optimization). FNN-SWO combines fuzzy neural networks and the Sperm Whale Optimization (SWO) algorithm. SWO is a meta-heuristic optimization algorithm embedded in the model while Fuzzy techniques and neural networks are used as essential building blocks. In the study, three subsets of data were divided based on three levels of coconut water maturity: tender, mature, and very mature. These subsets were used to validate the combined FNN-SWO model. The results of the study showed that the proposed FNN-SWO model outperformed several conventional techniques, including Support Vector Machine, Naïve Bayes, FNN, and Artificial Neural Network. The model also provided a better prediction outcome in terms of recall, F1-score, specificity, and accuracy. It also indicated that it effectively estimated coconut water maturity, saving time compared to existing techniques.

Ngo *et. al.*, 2023 presents an innovative approach to addressing the challenges of nutrient management in agriculture through a big data framework. The researchers developed an electronic agricultural record (EAR) system to integrate diverse datasets into a unified data warehouse using Hive and Elastic search. This system analyzes large volumes of

agricultural data to recommend optimal fertilizer quantities for crops, thereby enhancing crop yield, improving quality, and reducing environmental impact. By leveraging statistical methods, the study provided specific fertilizer recommendations for the top ten crops in the EU, such as Spring Barley and Winter Wheat, tailored to varying environmental and management conditions. Also, the contribution to knowledge lies in the successful integration and management of large-scale agricultural data, which has been a significant challenge in the field. The EAR system exemplifies how big data can be harnessed to generate precise agronomic recommendations, thereby advancing the efficiency and sustainability of modern farming practices. This research sets a precedent for future studies aiming to optimize agricultural inputs and underscores the potential of big data in transforming agricultural systems globally.

Wang et. al., 2024 aimed at enhancing the detection and classification accuracy of rice crop diseases using deep learning and IoT technologies. The objective is to tackle challenges related to variations in leaf characteristics that complicate disease detection. The model's significant contributions include introducing an innovative deep learning architecture for better feature computation, utilizing IoT systems for real-time monitoring, and demonstrating superior performance over existing methods. Future work will address image quality issues, standardize dataset collection, and explore pre-trained models to improve training, with a focus on expanding the system to various crop types.

Rout et. al., 2022 provides an overview of various remote monitoring techniques used in biodiversity conservation. It highlights the key contributions of Geographic Information Systems (GIS) for spatial-temporal analysis, habitat mapping, and species distribution modeling. The article also discusses the applications of active remote sensing technologies like RADAR and LiDAR for wildlife monitoring and habitat assessment. Additionally, it emphasizes the role of molecular techniques such as RFLP, AFLP, RAPD, microsatellites, and SNPs in enhancing the genetic data for biodiversity conservation. The article concludes by stressing the need for a multidisciplinary approach, integrating advanced technologies like artificial intelligence and machine learning, to effectively monitor and conserve biodiversity at a global scale.

Sri et. al., 2024 discusses the importance of enhancing agricultural productivity to meet the demands of a growing population amidst limited natural resources. The study focuses on utilizing machine learning techniques, such as the AdaBoost Decision Tree, Artificial Neural Network (ANN), and K-Nearest Neighbour (KNN) algorithms, to predict agricultural yields accurately. The Grey Level Co-occurrence Matrix method is employed for feature

selection, and data from various sources including yield, pesticide use, rainfall, and temperature are analyzed. The collaboration between the Food and Agriculture Organization (FAO) and the World Data Bank facilitated the compilation of a comprehensive dataset for the study. The results show that the AdaBoost decision tree achieved a high accuracy rate of 99% in predicting agricultural yields. Additionally, the research highlights the significance of precision agriculture in ensuring sustainable food production for the future.

Escandón-Panchana et al. (2024) examines the use of geomatic tools in agricultural management, focusing on their application in agricultural mapping, land use and cover analysis, agricultural cadastre, and precision agriculture. The study, conducted through a systematic review of scientific literature, reveals that geomatic tools like GIS, GPS, UAVs, and remote sensing are increasingly employed in agriculture, leading to improved practices, sustainable resource management, and enhanced decision-making for stakeholders. The findings highlight the benefits of geomatics in promoting sustainable practices like crop rotation, water conservation, and efficient resource management, while also contributing to food security, environmental conservation, and economic development in rural and urban areas.

Barrena-González et. al., 2024 addresses the critical need for accurate soil property mapping in Extremadura, Spain, where 70% of the surface is at risk of degradation. The study evaluates six machine learning (ML) techniques to map nine soil properties across three depths (0–5, 5–10, and >10 cm), utilizing 22 environmental covariates. The Random Forest (RF) model emerged as the most accurate, followed by Cubist, while the Support Vector Machine was effective with limited data. The study underscores the significance of sample size and environmental covariates, such as vegetation and topographic indices for physical properties, and climatic variables for chemical properties and nutrients. These findings highlight the potential of ML techniques in enhancing soil mapping accuracy, which is crucial for environmental management, agriculture, and sustainable land use planning. The contribution to knowledge lies in demonstrating the superior performance of the RF model for regional soil property mapping and identifying the most influential environmental covariates. The study provides a methodological framework for employing ML techniques in soil mapping, which can be applied to other regions facing similar environmental challenges. This research advances the understanding of how different ML algorithms perform in predicting soil properties and emphasizes the need for detailed, up-to-date soil databases to monitor and mitigate soil degradation processes effectively.

Papadakos et al., 2023 created a system named “The Message-in-a-Bottle (MiB) ecosystem”, which is a digital platform developed to enhance the wine industry by integrating multi-dimensional data to create engaging interactive stories around wine labels, focusing on sustainability and safety issues to increase competitiveness and customer loyalty. Key features include storytelling incorporating sustainability data, a crowd-sourced approach for validating wine authenticity, food and wine pairing recommendations, augmented reality experiences, and a user-friendly data management interface for producers. MiB leverages digital technologies like precision viticulture, AI, and blockchain to improve transparency and sustainability, and is designed to be generic and support multiple wine enterprises.

Liao, Li and Wang, 2023 examined the impact of natural and socio-economic factors on rice yield and nutrient balance in southwest China, particularly in the Sichuan Basin. It highlights that while socio-economic factors have a minimal overall effect on rice yield, proximity to urban areas, roads, and rivers positively influences yields. The study employs a new model that integrates fertilizer response field experiments with multi-source environmental data and machine learning algorithms to accurately simulate rice yield responses under varying nutrient conditions. The findings reveal that fertilizer input has significantly contributed to rice yield stability, increasing yields by approximately 2.3–2.4 that over the past decade, although nutrient use efficiency has declined. This research contributes to knowledge by providing a comprehensive analysis of the spatial and temporal dynamics of nutrient sustainability in rice production, addressing gaps in existing models that often overlook the intricate relationships between soil nutrients and crop yield at a regional scale. The integration of advanced modeling techniques offers a more precise framework for managing farmland nutrients, which is crucial for sustainable agricultural practices in the face of increasing environmental challenges.

Kartal, Iban and Sekertekin. (2024) proposes a novel approach to forecasting Vegetation Health Index (VHI) values using Convolutional Long Short-Term Memory (ConvLSTM) networks and remotely sensed data from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite. The study introduces a “global scale” method incorporating global minimum and maximum values to enhance the robustness of the forecasting model. The results show that the 1-layer ConvLSTM structure generally provided better forecasts than 2-layer and 3-layer structures, with average Root Mean Square Error (RMSE) values of 0.025, 0.026, and 0.026 for 1-step, 2-step, and 3-step ahead VHI forecasts, respectively. The proposed global scale model using ConvLSTM outperformed the traditional VHI calculation method. This research represents a

pioneering effort to implement ConvLSTM networks for VHI forecasting, contributing significantly to vegetation health monitoring, resource management, agriculture, and environmental monitoring.

Tanaka et al. (2023) discusses the potential of using satellite data for timely forecasting of crop harvests to enhance global food security. The study highlights how climate change and regional conflicts can lead to abnormal fluctuations in crop production, affecting food prices and consumption worldwide. By utilizing satellite data, the researchers were able to predict crop yields in major exporting countries like Russia, Ukraine, and Brazil ahead of the harvest season. This early prediction allows farmers in the opposite hemisphere to adjust their production plans, thereby stabilizing global food supply and prices. For instance, accurate early predictions of wheat and soybean harvests significantly reduced-price fluctuations and improved household consumption stability in importing countries. The contribution to knowledge from this study lies in demonstrating the practical benefits of cross-hemispheric agricultural response mechanisms facilitated by satellite-based crop forecasting. The research bridges a critical gap by providing empirical evidence on how timely and reliable forecasting can mitigate the adverse impacts of production shocks, thus offering a robust tool for enhancing the resilience of the global food system against climate and geopolitical disruptions. This advancement underscores the transformative role of satellite technology in global agricultural management and food security.

4. Summary of the AI/ML Methodological Approaches Used in Crop Management Research

The literature amasses plethora of AI and ML techniques been applied to improve agricultural practices and outcomes. The appraisal in section 2.1 reports some of the key approaches, which are further discussed in this section. These include **Supervised Learning**: encompassing Classification (used for tasks such as crop disease detection, weed identification, and soil type classification), Regression (applied in yield prediction, soil property analysis, crop growth modeling, and estimating optimal resource inputs such as water and fertilizer). Algorithms such as Linear Regression, Logistics Regression and ABSOLUT v1.2 are used. **Unsupervised Learning**, in which the major task is Clustering, utilized for grouping similar crop varieties, identifying patterns in soil characteristics, or segmenting agricultural land based on various features. **Deep Learning**: encompassing Convolutional Neural Networks (CNNs), ResNet50, widely used in image-based tasks like crop disease detection, pest identification, and crop quality assessment, Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks,

applied in time-series analysis for crop yield forecasting and climate impact prediction.

Reinforcement Learning such as Deep-Q Network: used in developing optimal crop management strategies, such as irrigation scheduling and pest control. **Ensemble Methods:** Random Forests and Gradient Boosting, used in various prediction tasks, combining multiple models for improved accuracy. **Support Vector Machines (SVMs), Naïve Bayes, Hoeffding Tree Algorithms:** applied in crop classification, yield prediction, and soil property analysis. **Bayesian Networks:** used for modeling complex relationships in agricultural systems, such as crop-soil-climate interactions. **Optimization:** Genetic Algorithms, Particle Swarm Optimization (PSO), and Sperm Whale Optimization (SWO): applied in optimizing crop breeding programs and developing crop rotation strategies. **Transfer Learning:** used to adapt models trained on a crop or region to new crops or geographical areas with limited data. These approaches were often combined with other technologies and data sources such as Remote Sensing and Satellite Imagery, Internet of Things (IoT) Sensors, Hyperspectral Imaging, and Drone Technology which enable high-resolution, on-demand aerial imagery for precision agriculture. The overall goal is to enhance agricultural productivity, sustainability, and resilience in the face of climate change and growing global food demand.

However, research in this field is faced with numerous challenges, extending from unavailability of quality data, model interpretability issues, problem with domain knowledge integration, real-time on-site model implementation issues due to unavailability of edge computing devices, bias of model and sustainability.

5. Conclusion and Future Research Direction

In this rapidly evolving field, progressive research promises the delivery of more sophisticated, integrated approaches that combine multiple AI/ML techniques with domain-specific knowledge to address the complex challenges in crop management.

These include enhancement of precision agriculture via advanced sensor integration, micro-level crop management, predictive modeling to determine how different crop varieties will perform under various climate conditions, AI-Powered Robotics and Drone technology, smart irrigation, precision fertilization, integrated pest management, AI-driven NLP systems to mitigate language barriers and allow farmers worldwide to share knowledge and experiences.

These future directions highlight the potential for AI and ML to significantly transform sustainable agriculture. The major challenges will be to guarantee that new technologies are developed

responsibly, made available to all farmers, and actually contribute to the sustainability and resilience of food system production. The goal is not only to raise productivity, but to do it in a way that protects our natural resources, improves biodiversity, and secures food security for future generations.

Conflict of Interest

The authors declare no conflict of interest.

Authors Contribution

RSB: Conceptualization, Methodology, Relevant article collations, Original draft preparation. AM: Conceptualization, Supervision, Reviewing and Editing. OLA: Investigation, Review of articles, Validation. BA: Investigation, Review of articles, Validation. LO: Investigation, Review of articles. AA: Validation, Investigation.

Funding

This research is funded by the Federal Ministry of Communication Innovation and Digital Economy (FMCIDE) Nigeria, in collaboration with National Information Technology Development Agency (NITDA), in the 2023 intervention of NAIRS research grant.

References

1. Vinu V., Mane Kalpita. (2023): Soil Quality Monitoring and Crop Prediction Using IOT and Machine Learning. International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; Vol. 11 No. 12. pp. 1001-1005- Available at www.ijraset.com
2. Sebastian Zurner, Lukas Peter, Deutschlander Martin Schieck, and Bogdan Franczyk. (2023). "Sustainable Development of AI Application in Agriculture". University of Economics and Business, Center for Intelligent Mana, 27th International Conference on Knowledge Based and Intelligent Information and Engineering system (KES 2023), Vol 225, PP. 3546- 3556, 2023
3. S. Konduru , M. Amiruzzaman , V. Avin, and M. R. Islam. (2023). "Plant Disease Detection and Classification; Using Deep Learning Models", Department of Computer Science West Chester University West Chester, PA 19383, USA , pp 66-75.
4. C. Murugamani, S. Shitharth, S. Hemalatha, Pravin R. Kshirsagar , K. Riyazuddin, Quadri Noorulhasan Naveed, Saiful Islam, Syed Parween Mazher Ali, and Areda Batu. (2022). "Machine Learning Technique for Precision

- Agriculture Applications in 5G-Based Internet of Things”, *Hindawi Wireless Communications and Mobile Computing*. Article-ID 6534238, 11 pages, 2022. <https://doi.org/10.1155/2022/6534238>
5. E. Rachid, A. Altaf, E.Badia , and Z.Jamal, (2023). “A Machine Learning Approach to Identify Optimal Cultivation Practices for Sustainable apple Production in Precision Agriculture in Morocco ”, *Laboratory of Engineering Sciences and Modeling, Faculty of Sciences- Ibn Tofail University, Kenitra, Morocco, E3S Web of Conferences* 469, 00052, pp 1-9.
 6. Emmanuel K., Zag .E., Jess .K., Mustapha .A., and Nelly .E., (2024).“Agricultural 4.0 Leveraging on Technological Solutions: Study for Smart Farming Sector”, *School of information Technology University of Cincinnati Ohio, United States*, vol 14, pp 24-84.
 7. Girish Saunshi, Dr. Rajesh Yakkundimath, Shridhar Chini, Dr. M. C. E lemme & Dr. Yerriswamy T, (2023). An Efficient Decision Making System for Sustainable Fertilization. *Global Journal of Computer Science and Technology*, Vol 23, PP. 1-25
 8. Amit Bijlwan, Rajeev Ranjan, GBPUAT, and Pantnagar, (2023). Agriculture with Artificial Intelligence, Machine Learning and Deep Learning for Crop Disease and Pest Identification and Classification, 2023, PP. 31-35.
 9. Z. Szira, E. Varga ,T. László and G. Milics. (2023). The Benefits, Challenges and legal Regulation Of Precision Farming”, In *The European Union, Eu-Agrarian Law Vol-69*, 10.2478/eual-0001.
 10. Cemal Sofuoglu and Derya Birant. (2023). “The Using of Convolutional Network For Grape Plant Disease Classification”; *Uludağ University Journal of The Faculty of Engineering*, Vol. 28, No. 3, pp 802-820.
 11. Zhaoan Wanga, Shaoping Xiaoa , Junchao Lia , Jun Wangb, (2023).“Learning-based agricultural management in partially observable environments subject to climate variability”, *Department of Mechanical Engineering, Iowa Technology Institute, University of Iowa, 3131 Seamans Center, Iowa City, 52242, Iowa, USA , Vol-14*, pp 1-14.
 12. Patil, P. (2023). AI-Driven Farmer Support System-Literature Review (Vol. 10). *JETIR*. www.jetir.orgc28
 13. Siropayan, M., Celikel, O., & Pinarer, O. (2022). Artificial Intelligence Driven Vertical Farming Manage-ment System. <https://hal.science/hal-04355624v2>
 14. Venkata, I., & Chowdary, N. (2023). Crop Recommendation using Machine Learning. *International Journal of Research Publication and Reviews Journal homepage: www.ijrpr.com (Vol. 4)*. www.ijrpr.com
 15. Sakshi Mundhe, Jitu Sanap, Pooja Jadhav, Vaishnavi Kalsadkar, & Prof. Chiranjit Das. (2023). Forecasting Crop Yield For Sustainable Agriculture. *International Journal of Advanced Research in Science, Communication and Technology*, 29–34. <https://doi.org/10.48175/ijarsct-14205>
 16. Bulut, N., & Hacıbeyoğlu, M. (2023). GAZI JOURNAL OF ENGINEERING SCIENCES Hydroponic Agriculture with Machine Learning and Deep Learning Methods. *Gazi Journal of Engineering Sciences*, 9(3), 508–519. <https://doi.org/10.30855/gmbd.0705083>
 17. Su, Y., Zhang, H., Gabrielle, B., & Makowski, D. (2022). Performances of machine learning algorithms in predicting the productivity of conservation agriculture at a global scale. *Frontiers in Environmental Science*, 10. <https://doi.org/10.3389/fenvs.2022.812648>
 18. Nipuna Chamara A, Geng Bai A, Yufeng Ge (2023): AICropCAM: Deploying classification, segmentation, detection, and counting deep-learning models for crop monitoring on the edge. *Computers and Electronics in Agriculture* 215. Pp.1-13. <https://doi.org/10.1016/j.compag.2023.108420>
 19. Elbasi, E.; Zaki, C.; Topcu, A.E.; Abdelbaki,W.; Zreikat, A.I.; Cina, E.; Shdefat, A.; Saker, L. (2023). Crop Prediction Model Using Machine Learning Algorithms. *Appl. Sci.* 2023, 13, 9288. <https://doi.org/10.3390/app13169288>
 20. Li Xin-rui, Li Xia-fei, Liu Tao, Yin Hui-lai, Fu Hao, Luo Yong-heng, Bai Yan-fu, Yang Hong-kun, Yang Zhi-yuan, Sun Yong-jian, Ma Jun, Chen Zong-kui. (2023). Strategies for improving crop comprehensive benefits via a decision-making system based on machine learning of rice-rape, rice-wheat and rice-garlic rotation systems in Southwest China.. *Journal of Integrative Agriculture*. pp.1-23
 21. Stefan Fenz, Thomas Neubauer, Jürgen Kurt Friedel, Marie-Luise Wohlmuth. (2023). AI- and data-driven crop rotation planning. *Computers and Electronics in Agriculture* 212 (2023)

108160. pp.1-11. <https://doi.org/10.1016/j.compag.2023.108160>
22. Cavalcante de Oliveira, R., & Diogne de Souza e Silva, R. (2023). Artificial Intelligence in Agriculture: Benefits, Challenges, and Trends. 13(13). <https://doi.org/10.3390/app13137405>
 23. Olutomilola, E. O., Akinola, O. J., & Maradesa, O. J. (2023). Development of a Plantain Peeling Machine. Development of a Plantain Peeling Machine. 6(2). pp.250-260. Published by Adeleke University Journal of Engineering and Technology. Nigeria. <http://aujet.adelekeuniversity.edu.ng/index.php/aujet/article/view/353>
 24. Salihu S. A., Ajeigbe M. A., Balogun A. O., Usman-Hamza F. E., Akintola A. G., & Mojeed H.A. (2023). Detection and Classification of Corn Diseases Using Convolutional Neural Networks. Published by Adeleke University Journal of Engineering and Technology, 6(2), pp. 46 – 25. <http://aujet.adelekeuniversity.edu.ng/index.php/aujet/article/view/353>
 25. Conradt, T. (2022). Choosing multiple linear regressions for weather-based crop yield prediction with ABSOLUT v1.2 applied to the districts of Germany. International Journal of Biometeorology, 66, 2287-2300. <https://doi.org/10.1007/s00484-022-02356-5>
 26. El-Shafeiy, E., Abohany, A. A., Elmessery, W. M., & Abd El-Mageed, A. A. (2023). Estimation of coconut maturity based on fuzzy neural network and sperm whale optimization. Neural Computing and Applications, 35, 19541-19564. <https://doi.org/10.1007/s00521-023-08761-0>
 27. Chen, L., Chen, Z., Zhang, Y., Liu, Y., Osman, A. I., Farghali, M., Hua, J., Al-Fatesh, A., Ihara, I., Rooney, D. W., & Yap, P. (2023). Artificial intelligence-based solutions for climate change: a review. Environmental Chemistry Letters, 21, 2525-2557. <https://doi.org/10.1007/s10311-023-01617-y>
 28. Ngugi, H. N., Ezugwu, A. E., Akinyelu, A. A., & Abualigah, L. (2024). Revolutionizing crop disease detection with computational deep learning: a comprehensive review. Environmental Monitoring and Assessment, 196(1-3), 302.
 29. Saini, P., & Nagpal, B. (2023). PSO CNN Bi LSTM: A Hybrid Optimization Enabled Deep Learning Model for Smart Farming. Environmental Modeling & Assessment, 29, 517–534. <https://doi.org/10.1007/s10666-023-09920-2>
 30. Mesías-Ruiz GA, Pe´ rez-Ortiz M, Dorado J, de Castro AI and Peña JM (2023) Boosting precision crop protection towards agriculture 5.0 via machine learning and emerging technologies: A contextual review. Front. Plant Sci. 14:1143326. doi: 10.3389/fpls.2023.1143326
 31. Tanaka, T., Sun, L., Becker-Reshef, I., Song, X.-P., & Puricelli, E. (2023). Satellite forecasting of crop harvest can trigger a cross-hemispheric production response and improve global food security. Communications Earth & Environment, 4, 334. <https://doi.org/10.1038/s43247-023-00992-2>
 32. Kartal, S., Iban, M. C., & Sekertekin, A. (2024). Next-level vegetation health index forecasting: A ConvLSTM study using MODIS Time Series. Environmental Science and Pollution Research, 31, 18932-18948. <https://doi.org/10.1007/s11356-024-32430-x>
 33. Liao, G. T., Li, T. X., & Wang, Y. D. (2023). Nutrient sustainability and rice yield in the Sichuan Basin, SW China. *Communications Earth & Environment*, 4, 388. <https://doi.org/10.1038/s43247-023-01036-5>
 34. Papadakos, P., Chrysakis, I., Patkos, T., Flouris, G., Samaritakis, G., Angelakis, D., Basina, N., Tsampanaki, N., Pratikaki, A., Baritakis, P., Loulakakis, I., Gouma, M., Kioupakis, A., Apostolidi, C., Lyrarakis, B. (2023). Message-in-a-Bottle: Engaging stories around sustainable and safe wine products. Discover Sustainability, 4(43), 1-3. <https://doi.org/10.1007/s43621-023-00160-8>
 35. Barrena-González, J., Lavado Contador, F., Repe, B., & Pulido Fernández, M. (2024). Looking for Optimal Maps of Soil Properties at the Regional Scale. *International Journal of Environmental Research, 18*(60). <https://doi.org/10.1007/s41742-024-00611-8>
 36. Escandón-Panchana, P., Herrera-Franco, G., Jaya-Montalvo, M., & Martínez-Cuevas, S. (2024). Geomatic tools used in the management of agricultural activities: a systematic review. Environment, Development and Sustainability. <https://doi.org/10.1007/s10668-024-04576-8>
 37. Sri Nagesh, O., Budaraju, R. R., Kulkarni, S. S., Vinay, M., Ajibade, S.-S. M., Chopra, M., Jawarneh, M., & Kaliyaperumal, K. (2024). Boosting Enabled Efficient Machine Learning Techniques for Accurate Prediction of Crop

- Yield. *Discover Sustainability*, 5, 78. <https://doi.org/10.1007/s43621-024-00254-x> [T1]
38. Rout, G. K., Montalbo, F. J. P., Das, R., Patra, S., Mahapatra, G. P., Maurya, G. K., ... & Rout, J. R. (2022). An overview of remote monitoring methods in biodiversity conservation. *Environmental Science and Pollution Research*, 29, 80179-80221. <https://doi.org/10.1007/s11356-022-23242-y>
39. Ngo, V. M., Duong, T.-V. T., Nguyen, T.-B.-T., Dang, C. N., & Conlan, O. (2023). A big data smart agricultural system: recommending optimum fertilisers for crops. *International Journal of Information Technology*, 15*(1), 249–265. <https://doi.org/10.1007/s41870-022-01150-1>
40. Wang, Y., Dhamodharan, U. S. R., Sarwar, N., Almalki, F. A., Naith, Q. H., R, S., & Mohan, D. (2024). A hybrid approach for rice crop disease detection in agricultural IoT system. *Discover Sustainability*, 5, 99. <https://doi.org/10.1007/s43621-024-00285-4>.