Global Journal of Engineering Innovations & Interdisciplinary Research

Original Article

Machine Learning Techniques for Crop, Fertilizer Prediction and Disease Detection

T Sai Lalith Prasad[1], P Yuvaraj[2], B Bala Shiva[2], T Gnaneshwar[2]

[1]Assitant Professor, Department of Artificial Intelligence and Data Science, Vignan Institute of Technology and Science, Hyderabad, India

[2]UG Student, Department of AI&DS, Vignan Institute of Technology and Science, Hyderabad, India

Correspondence

T. Sai Lalith Prasad

Assistant Professor, Department of Artificial Intelligence and Data Science, Vignan Institute of Technology and Science, Hyderabad, India

- Received Date: 25 May 2025
- Accepted Date: 15 June 2025
- Publication Date: 27 June 2025

Keywords

Machine learning(ML);Crop decisions ;Fertilizer; Disease detection; Harvesting techniques; Sensors; Drones; Data-driven decisions

Abstract

Agriculture is an important part of a country's economy, but with the population growing, weather patterns changing, and resources dwindling, the food demands of today's world are becoming more challenging to meet. Smart farming, or precision agriculture, is a modern solution to these challenges. It utilizes technology, especially machine learning (ML), to help farmers make better decisions about their crops. ML allows machines to learn and get better with time without having to be directly programmed. This paper examines how ML is being used in farming for such important questions as: Which crops should one grow in that particular area? What fertilizer does the soil prefer? How does one detect diseases and treat them? In this regard, new farming techniques also make it easy to harvest crops, thus not requiring much human labor.ML is not technology; it's changing the way farmers work. For instance, consider a farmer who used to decide how to manage his crops with the help of years of experience. Now, they can make much more accurate data-driven decisions through ML. Farmers can use the sensors and drones to check how healthy their crops are in real-time, then problems can easily be identified, and solutions would be implemented rapidly. This means that not only time is saved but also assists the farmer in being more productive, with guesswork reduced. The use of ML in agriculture makes agriculture become more sustainable. By using resources like water, fertilizer, and pesticides more efficiently, farmers can minimize waste and lower their environmental footprint. This is important because the climate is changing and it is not easy to predict weather patterns anymore. Smart farming practices help in creating a more resilient agricultural system, one that can adapt to changing conditions and continue to produce food for future generations. In the end, ML is not just about increasing productivity but making farming more efficient, environmentally friendly, and secure for everyone.

Introduction

TAgriculture is the backbone of a country's economy that supports the economy and social and cultural aspects of life. For many centuries, farming has been the primary job for most people in the world. As the global population grows and is expected to reach 9.1 billion by 2050, food demand will increase 70 percent. However, with less land available for farming due to urbanization, it is becoming harder to meet these growing food needs using traditional farming methods.

Farmers face many challenges today, especially because of climate change. Unpredictable weather, including floods, droughts, and heatwaves, makes it harder to predict crop yields and farming cycles. The biggest drawback of modern agriculture is overusing chemical fertilizers and pesticides, which have resulted in poisoning the soil and pollution of the water sources that have further adverse effects on productivity. To mitigate these issues, innovative, resource-effective farming technologies are required. Smart farming or precision agriculture utilizes cutting-edge technology to make agriculture a more effective and sustainable enterprise. One key element of this is machine learning (ML), artificial intelligence that allows machines to learn from data and improve upon themselves without requiring explicit programming.

Machine learning in agriculture can look at vast quantities of data so farmers can better make decisions regarding the use of soil conditions, weather patterns, and crop health. For example, ML algorithms can recommend the best crops to plant according to soil type, nutrient levels, and pH. Using weather data, farmers can also determine the best times to plant and harvest to avoid losses due to weather. Precision farming includes tools such as drones and satellite imagery to monitor crop health. ML analyzes these images to spot early signs of disease, pests, or nutrient deficiencies, allowing farmers to take action before the problem worsens.

Citation: Prasad TSL, Yuvaraj P, Bala Shiva B, Gnaneshwar T. Machine Learning Techniques for Crop, Fertilizer Prediction and Disease Detection. GJEIIR. 2025;5(4):086.

Additionally, ML can help farmers optimize irrigation systems by determining the right amount of water for crops, ensuring that resources are used efficiently and sustainably.

Impact of ML on farming is not just about technology; it is also about enhancing the lives of farmers. Traditionally, farmers have relied on their experience and intuition to make decisions. However, these decisions are often based on guesswork and can be inaccurate. With ML, farmers can now use data to make decisions with greater precision and confidence. For example, instead of manually inspecting crops, farmers can use sensors and drones to monitor their fields in real time. This saves time and allows them to quickly address any issues, boosting productivity and reducing losses. Better crop management and higher yields are also achieved through better decision-making in matters such as when to plant, what fertilizers to use, and how to control pests.

ML also supports environmental sustainability. The reduction of waste and minimization of the environmental impact of farming can be achieved by using resources such as water, fertilizers, and pesticides more efficiently in smart farming. For instance, ML reduces the amount of nutrient runoff from fertilizers, thus reducing water pollution and creating healthier ecosystems. Through the improvement of irrigation practices, ML conserves water, which has become scarce in many regions. Water use efficiency benefits the environment and enables farms to withstand droughts better. Overall, precision agriculture helps in building a more resilient agricultural system that can be able to adjust to changing conditions and contribute to a sustainable and secure food supply.

In the future, ML will continue improving farming practices. The more data available and as technology advances, farming will be more efficient and will help farmers grow more food while using fewer resources. The recognition of the value of these technologies by governments and agricultural institutions will also mean more investments, which will soon help tackle the global challenge of food security. Agriculture will become ever-efficient, sustainable, and capable of meeting the needs of a population which does not stop growing with the wide adoption of ML and other digital technologies. In conclusion, ML is changing the face of farming by providing farmers with more informed decisions and resource use as well as enhanced crop yields and sustainability and resilience in agriculture. As the world continues to battle climate change and a growing population, ML offers one of the bright paths to a sustainable future for farming.

Methodology

The proposed system will improve farming through the application of machine learning, analyzing large volumes of data. It involves information regarding crops, diseases, and

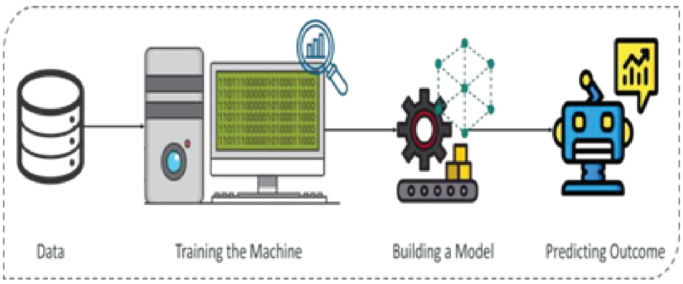

Figure 1. Machine learning process

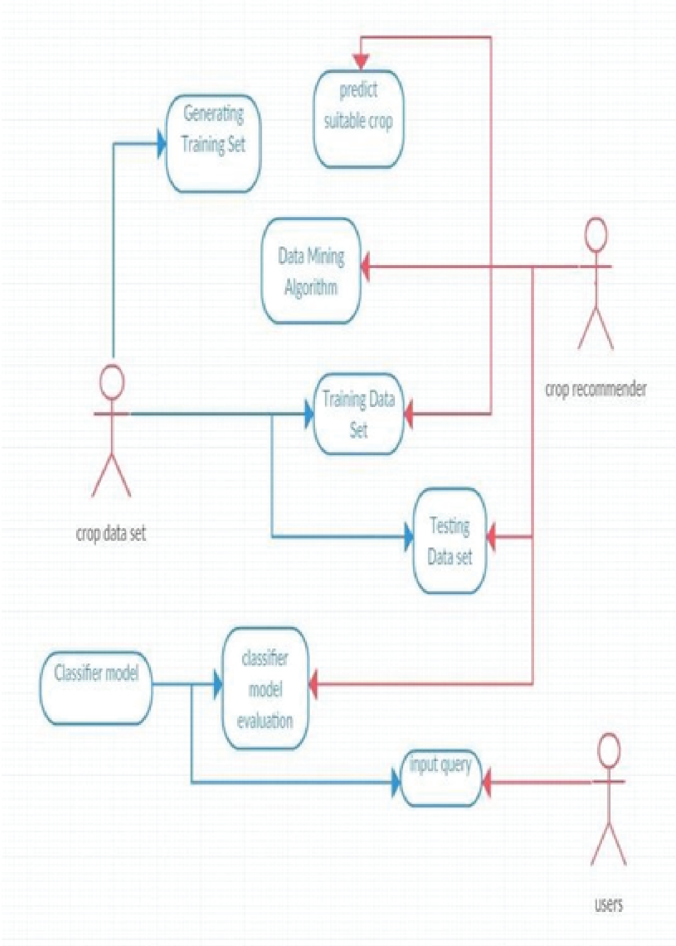

Figure 2. Technical Architecture

fertilizers to improve decision-making on farms. This is how it works step by step: The system will collect data from various sources such as weather stations, soil sensors, and satellite images. It has information on soil conditions, weather patterns, and the health of the plants. Collected data are cleaned to eliminate errors and missing information, thereby ensuring that data used for prediction is accurate and useful.

The Random Forest algorithm is used as it can deal with large volumes of data and take into account many factors such as soil type and weather to give the best crop to be cultivated. The system uses historical data about crop yields, soil conditions, and climate to train the Random Forest algorithm. Based on this, it can predict the best crops to grow in specific areas, helping farmers make smarter choices for higher yields.

Linear Regression is utilized to determine the optimal quantity and type of fertilizers for use on crops with respect to nutrient levels in soils and other factors. The system, based on available data regarding soil, including the nutrient levels of the soil, uses the Linear Regression model for the recommendation of the appropriate fertilizers. Thus, waste is reduced and unnecessary costs are reduced while crop health is improved.

Convolutional Neural Networks use images of crops to detect diseases such as blight and mold. From there, images can be checked against the symptoms for early plant disease detection and alerted to treatment to prevent potential crop loss by the farmer in time.

The system comprises an easy interface where the farmer can select what he or she needs help with-from crop recommendations to fertilizer suggestions or disease detection. Based on the farmer's choice, the system processes all data as it compiles and provides specific recommendations, which may include which crops to plant, how much fertilizer to apply, or how to treat diseases affecting the plants.

The effectiveness of the system is measured by how accurately it predicts crops, recommends fertilizers, and detects diseases. It continues to improve by learning from new data. The more farmers use it and give feedback, the smarter and better it becomes at providing accurate recommendations.

This system uses machine learning to help farmers by providing useful recommendations for growing crops, using fertilizers, and detecting diseases. By analyzing large amounts of data, it helps farmers make better decisions, save time, and increase crop yields. The system's ability to learn from real-time data and improve over time makes it a valuable tool for sustainable farming.

Random Forest Algorithm for Crop Prediction

RF algorithm is a machine learning technique which is used in classification tasks and is very powerful. It consists of multiple decision trees, wherein each tree will make a decision based on the given set of data, and finally, the decision is taken on the basis of the majority vote of all the trees. This approach, first introduced by Tin Kam Ho in 1995, uses a method called bagging, which helps improve the stability and accuracy of the predictions. In addition, it involves random selection of features at each split of the tree, adding another layer of randomness to the process. There are a few key factors that control how a random forest model is built, including the number of trees to use, the minimum number of data points required at a node, and the number of features to consider at each split.

The algorithm has many advantages. For one, it's very accurate and works well with large datasets. It can work well with hundreds of variables and thereby is really a versatile performer at many different jobs. Also, the algorithm could help identify what of the variables matter most when a prediction should be made. Furthermore, Random Forest doesn't break with missing data at all; even imbalanced data works nicely.

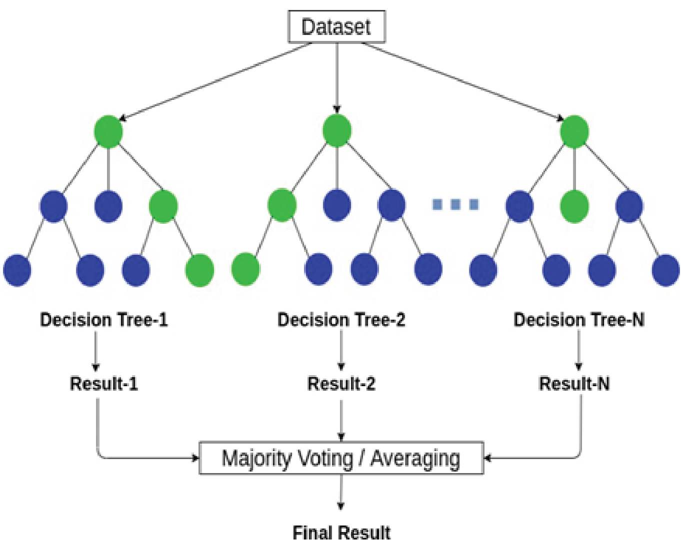

Figure 3. Random Forest Illustration

Another advantage is that it reduces the risk of overfitting, meaning it doesn't make overly complex models that perform poorly on new data. The process of building a random forest involves several steps. First, a random sample is selected from the training data.

This sample is then used to construct a decision tree, and at each split of the tree, a random subset of features is used to decide how best to partition the data. The process is repeated many times to construct many trees. Then, when all the trees are constructed, the final prediction is based on the majority vote of all the trees. Because of its strength and adaptability, Random Forest is the most popular machine learning method.

Linear Regression Algorithm For Fertilizer Prediction

Linear Regression is a machine learning algorithm that predicts a value based on the relationship between variables.

It is a type of supervised learning, meaning it learns from labeled data. The main goal of Linear Regression is to find the connection between a dependent variable-the one we want to predict-and one or more independent variables-the factors that influence the dependent variable.

In simple words, Linear Regression tries to forecast an output-say a man's salary on the basis of a known input-his number of years at work. The way it goes about this is by drawing the best possible straight line through data points on a graph called a regression line, which depicts a relationship between an input and its corresponding output. The closer the data points are to this line, the better the model is at making predictions. Linear regression is applied in the event where a linear relationship is anticipated to exist between variables such that they can be modeled with a straight line.

Convolution Neural Network for Disease Detection

A central technology of machine learning is known as an artificial neural network (ANN), with applications that are wide and include the tasks such as classifying images, audio processing, or understanding text. Various neural networks serve specific tasks: to predict word sequences, RNNs such as the long short-term memory (LSTM) networks come into the application; on the other hand, for the tasks that have to do with image classification, CNNs have been mostly utilized. In this discussion, we will focus on the basics of CNNs, but first, let's revisit some fundamental concepts of how neural networks work.

A basic neural network has three main layers. The Input Layer is where we feed the data into the model. The number of neurons in this layer matches the number of features in the data, such as the number of pixels in an image. Next, the data moves into the Hidden Layers, where the real processing happens. There can be several hidden layers in a network, and each layer can have a different number of neurons. These neurons help the model learn patterns in the data. The output of one layer is computed by multiplying it with weights (learnable parameters) and adding biases, and then passing through an activation function to introduce nonlinearity.

Finally, the data reaches the Output Layer, where the model makes a prediction. In classification tasks, the output is passed through a logistic function, like sigmoid or softmax, which transforms it into a probability for each class. Once the model makes a prediction, we compare it to the actual result and calculate an error. This error is then used in a process called Backpropagation, whereby the model adjusts the weights to reduce the error.

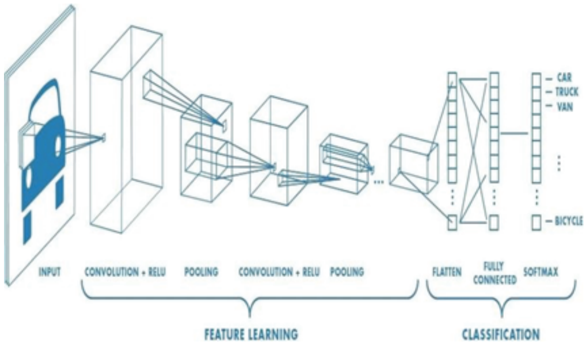

Figure 4. Convolution Nueral Network

Result and discussion

The ML-based applications have yielded encouraging outcomes for increasing the productivity of agriculture, improving resource usage, and decision-making with the help of data. Key models like Random Forest, linear regression, Convolutional Neural Networks, are applied in smart farming for challenges like crop prediction, pest detection, and irrigation management.

In crop prediction, Random Forest-based machine learning algorithms have shown impressive accuracy in selecting the best crop to plant by taking into consideration soil conditions, weather patterns, and historical data. These models can process massive datasets containing different environmental factors, and provide targeted recommendations to the farmers to get the maximum yields and optimize the use of their land. In several studies, the model has achieved more than 90% accuracy in crop performance prediction. Hence, it is a very reliable tool to help improve crop selection and rotation.

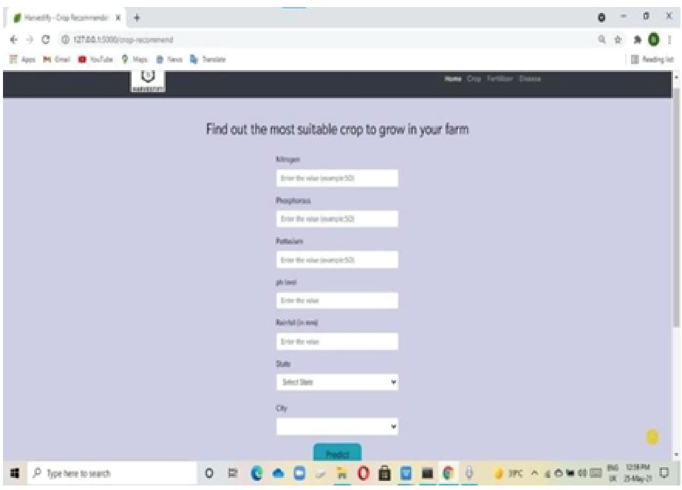

Figure 5. Crop Prediction

The image depicts a user-friendly web interface designed for predicting the most suitable crop to grow based on specific agricultural parameters. Users can input essential soil and environmental data, including Nitrogen, Phosphorus, Potassium levels, soil pH, rainfall (in mm), and their location (state and city). By clicking the "Predict" button, the system processes the data using machine learning algorithms to recommend the optimal crop for the given conditions. This tool aims to assist farmers in making informed decisions to enhance productivity and sustainability in farming practices.

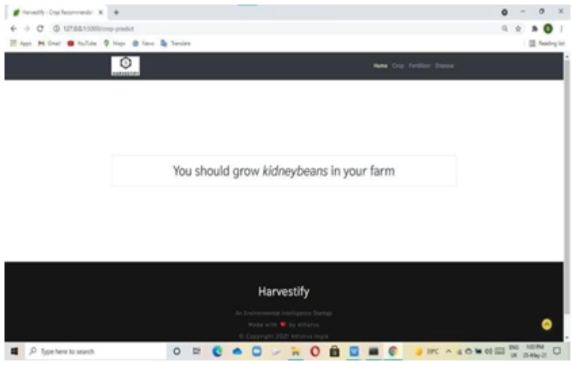

Figure 6. Result of Crop Prediction

This image displays the output of a crop recommendation system, which suggests the best crop to cultivate based on the provided data. The screen shows a clear result, indicating that "kidney beans" are the most suitable crop for the given conditions. The platform, named "Harvestify," is an environmental intelligence startup dedicated to assisting farmers in optimizing agricultural practices. The design emphasizes simplicity and usability, providing farmers with actionable insights to enhance productivity and sustainability.

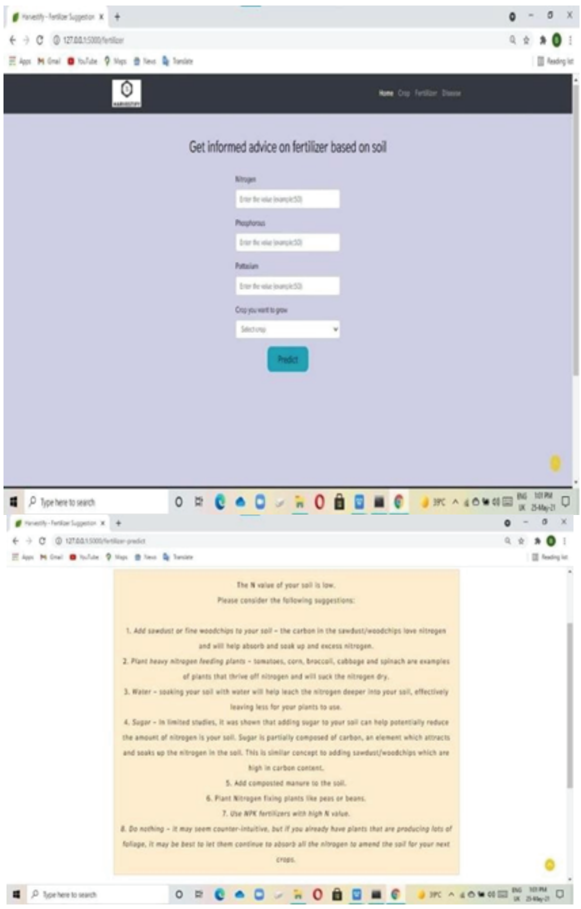

Figure 7. Result of Fertilizer Prediction

The images showcase a Fertilizer Suggestion System, an intuitive web platform designed to help farmers improve soil fertility. Users can input key soil parameters like Nitrogen, Phosphorus, and Potassium levels. If low nitrogen levels are detected, the system suggests practical solutions such as adding composted manure, planting nitrogen-fixing crops like beans or peas, applying high-nitrogen fertilizers, or incorporating organic materials like sawdust to retain nitrogen.

This tool simplifies decision-making by offering both organic and chemical options, making it adaptable to different farming styles. With its user-friendly interface, it empowers both large-scale farmers and small gardeners to adopt sustainable practices and optimize soil health, bridging the gap between soil science and real-world farming.

By combining ease of use with science-backed recommendations, the Fertilizer Suggestion System paves the way for smarter farming. Its dual approach ensures farmers can tailor solutions to their needs, balancing productivity with sustainability. This innovative platform not only enhances crop yields but also promotes responsible resource management, contributing to the long-term health of agricultural ecosystems.

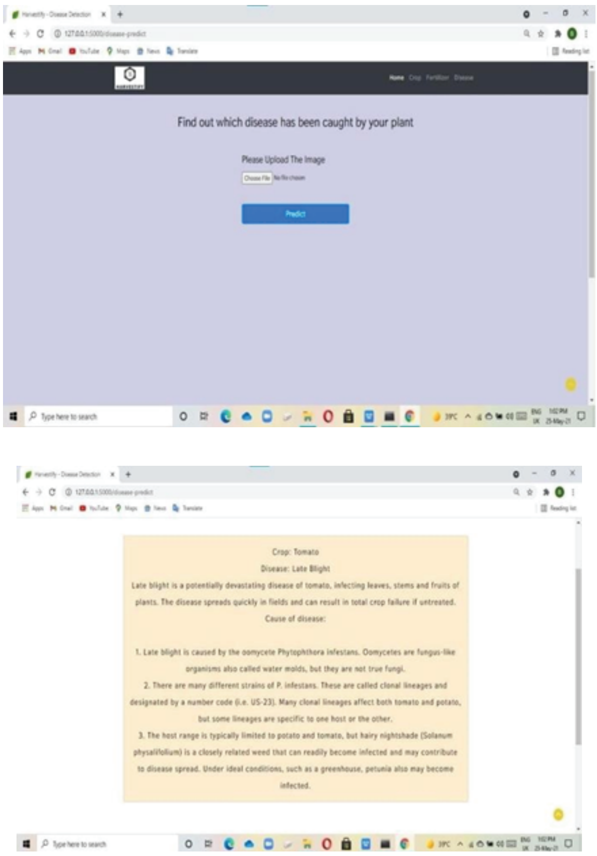

Figure 8. Result of Disease Prediction

The image illustrates a web-based Plant Disease Detection platform designed to assist farmers in identifying plant diseases early. The platform features a user-friendly interface where users can upload images of diseased plants for analysis. Leveraging machine learning and image processing, the system diagnoses specific diseases, such as Late Blight in tomatoes, which is caused by the pathogen Phytophthora infestans. The platform provides detailed information about the disease, including its clonal lineages (e.g., US-23) and its host range, which includes crops like potatoes and certain weeds such as hairy nightshade.

This image highlights the integration of AI in agriculture, showcasing how technology simplifies disease detection and enhances crop protection. By offering timely and accurate diagnostics, the platform empowers both large-scale farmers and small growers to manage plant health effectively and sustainably.

Ultimately, the image underscores the transformative potential of artificial intelligence in modern farming practices. By making advanced plant pathology accessible through an intuitive digital tool, the platform not only helps prevent crop losses but also promotes sustainable agricultural methods. This innovation paves the way for smarter, more resilient farming systems that can adapt to changing environmental conditions and ensure food security for future generations.

Conclusion

Smart farming, or precision agriculture, leverages advanced technologies like Machine Learning (ML) and Deep Learning (DL) to enhance productivity, sustainability, and resource efficiency in farming. ML algorithms, especially regression models, allow farmers to predict critical agricultural factors such as soil properties, weather, and crop yields. These predictions guide decisions on irrigation, fertilization, and planting, optimizing resource use and minimizing waste.

DL techniques, such as Convolutional Neural Networks (CNNs), revolutionize crop health monitoring by analyzing images to detect diseases, pests, and nutrient deficiencies. Classification algorithms like Decision Trees and Random Forests assist in identifying plant diseases and weeds, enabling timely interventions. Smart farming also includes automated systems like smart irrigation and robotic harvesting, which improve resource management, reduce labor costs, and ensure quality produce.

Beyond productivity, ML and DL contribute to environmental sustainability by helping farmers adapt to changing weather patterns, improve crop resilience, and reduce climate-related risks. These technologies also optimize supply chains, predict market demand, and enable targeted soil and nutrient management, promoting long-term sustainability in agriculture. Overall, the integration of ML, DL, and IoT is transforming agriculture into a more efficient and environmentally responsible industry.

References

1. Adamchuk, V. I., Hummel, J. W., Morgan, M. T., Upadhyaya, S. K. (2004). On-the-go soil sensors for precision agriculture. Computers and electronics in agriculture, 44(1), 71-91.
2. C. F. Gaita´n, "Machine learning applications for agricultural impacts under extreme events," in Climate Extremes and Their Implications for Impact and Risk Assessment, Elsevier, 2020, pp. 119-138. 15
3. S. J. Parikh and B. R. James, "Soil: The Foundation of Agriculture," Nature Education Knowledge, vol. 3, no. 10, 2012. 16. F. R. Troeh and L.M. Thompson, Soils and Soil Fertility, Oxford University Press, 1993.
4. Gebbers, R., Adamchuk, V. I. (2010). Precision agriculture and food security. Science, 327(5967), 828- 831.
5. Gubbi, J., Buyya, R., Marusic, S., Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. Future generation computer sys-tems, 29(7), 1645-1660.
6. Jawad, H. M., Nordin, R., Gharghan, S. K., Jawad, A. M., Ismail, M. (2017). Energy- efficient wireless sensor

networks for precision agriculture: A review. Sensors, 17(8), 1781.

7. Liakos, K. G., Busato, P., Moshou, D., Pearson, S., Bochtis,
8. (2018). Machine learning in agriculture: A review. Sensors, 18(8), 2674.
9. Nex, F., Remondino, F. (2014). UAV for 3D mapping applications: a review. Applied geomatics, 6(1), 1-15.
10. Pierce, F. J., Nowak, P. (1999). Aspects of precision agriculture. In Advances in agron- omy (Vol. 67, pp. 1-85). Academic Press.
11. Samuel, A. L. (1959). Some studies in machine learning using the game of checkers. IBM Journal of research and development, 3(3), 210-229.
12. Sharma, R., Kamble, S. S., Gunasekaran, A., Kumar, V., Kumar, A. (2020). A system- atic literature review on machine learning applications for sustainable agriculture supply chain performance. Computers Operations Research, 104926.
13. Stafford, J. V. (2000). Implementing precision agriculture in the 21st century. Journal of Agricultural Engineering Research, 76(3), 267-275.
14. Turing, A. M. (2009). Computing machinery and intelligence. In Parsing the Turing Test (pp. 23-65). Springer, Dordrecht.
15. V. Hakkim, E. Joseph, A. Gokul and K. Mufeedha, ”Precision farming: the future of Indian agriculture,” Journal of Applied Biology and Biotechnology, pp. 68-072, 2016.
16. Zhang, Naiqian, Maohua Wang, and Ning Wang. ”Precision agriculture—a worldwide overview.” Computers and electronics in agriculture 36.2-3 (2002): 113-132.
17. R. Bhallamudi et al., "Deep Learning Model for Resolution Enhancement of Biomedical Images for Biometrics," in Generative Artificial Intelligence for Biomedical and Smart Health Informatics, Wiley Online Library, pp. 321–341, 2025.
18. R. Bhallamudi et al., "Artificial Intelligence Probabilities Scheme for Disease Prevention Data Set Construction in Intelligent Smart Healthcare Scenario," SLAS Technology, vol. 29, pp. 2472–6303, 2024, Elsevier.
19. R. Bhallamudi, "Improved Selection Method for Evolutionary Artificial Neural Network Design," Pakistan Heart Journal, vol. 56, pp. 985–992, 2023.
20. R. Bhallamudi et al., "Time and Statistical Complexity of Proposed Evolutionary Algorithm in Artificial Neural Networks," Pakistan Heart Journal, vol. 56, pp. 1014–1019, 2023.
21. R. Krishna et al., "Smart Governance in Public Agencies Using Big Data," The International Journal of Analytical and Experimental Modal Analysis (IJAEMA), vol. 7, pp. 1082–1095, 2020.
22. N. M. Krishna, "Object Detection and Tracking Using YOLO," in 3rd International Conference on Inventive Research in Computing Applications (ICIRCA-2021), IEEE, Sept. 2021, ISBN: 978-0-7381-4627-0.
23. N. M. Krishna, "Deep Learning Convolutional Neural Network (CNN) with Gaussian Mixture Model for Predicting Pancreatic Cancer," Springer US, vol. 1380-7501, pp. 1–15, Feb. 2019.
24. N. M. Krishna, "Emotion Recognition Using Skew Gaussian Mixture Model for Brain–Computer Interaction," in SCDA-2018, Textbook Chapter, ISBN: 978-981-13-0514, pp. 297–305, Springer, 2018.
25. N. M. Krishna, "A Novel Approach for Effective Emotion Recognition Using Double Truncated Gaussian Mixture Model and EEG," I.J. Intelligent Systems and Applications, vol. 6, pp. 33–42, 2017.
26. N. M. Krishna, "Object Detection and Tracking Using YOLO," in 3rd International Conference on Inventive Research in Computing Applications (ICIRCA-2021), IEEE, Sept. 2021, ISBN: 978-0-7381-4627-0.
27. T. S. L. Prasad, K. B. Manikandan, and J. Vinoj, "Shielding NLP Systems: An In-depth Survey on Advanced AI Techniques for Adversarial Attack Detection in Cyber Security," in 2024 3rd International Conference on Automation, Computing and Renewable Systems (ICACRS), IEEE, 2024.
28. S. Sowjanya et al., "Bioacoustics Signal Authentication for E-Medical Records Using Blockchain," in 2024 International Conference on Knowledge Engineering and Communication Systems (ICKECS), vol. 1, IEEE, 2024.
29. N. V. N. Sowjanya, G. Swetha, and T. S. L. Prasad, "AI Based Improved Vehicle Detection and Classification in Patterns Using Deep Learning," in Disruptive Technologies in Computing and Communication Systems: Proceedings of the 1st International Conference on Disruptive Technologies in Computing and Communication Systems, CRC Press, 2024.
30. V. P. Krishna and T. S. L. Prasad, "Weapon Detection Using Deep Learning," Journal of Optoelectronics Laser, vol. 41, no. 7, pp. 557–567, 2022.
31. T. S. L. Prasad et al., "Deep Learning Based Crowd Counting Using Image and Video," 2024.