A Comprehensive Study on the Emerging Effect of Artificial Intelligence in Agriculture Automation

Md. Ridoy Sarkar
Dept. of Computer Science
American International University-Bangladesh (AIUB)
Dhaka, Bangladesh
sarkarridoy3@gmail.com

Syed Rayhan Masud
Dept. of Computer Science
American International University-Bangladesh (AIUB)
Dhaka, Bangladesh
21-45276-2@student.aiub.edu

Md Ismail Hossen*
Dept. of Computer Science
American International University-Bangladesh (AIUB)
Dhaka, Bangladesh
ismail.hossen@aiub.edu*

Michael Goh
Faculty of Information Science And Technology (FIST)
Multimedia University
Melaka, Malaysia
michael.goh@mmu.edu.my

Abstract- Agriculture is one of the oldest and most important professions in the world. It plays a vital role in the economic sector. The impact and application of artificial intelligence (AI) have been prominent and evident in the agriculture sector. The world population is increasing which will require more food and agricultural products. AI can help us to produce the additional requirement of agricultural products. Agriculture faces many challenges like crop disease, lack of irrigation, water management, the effect on the environment, low output, and improper soil treatment. It can be solved by the applications of AI. The use of AI in soil management, weeding, crop monitoring and disease management can solve the problems of farmers. The application of AI in agriculture is producing more with less manpower, land, and time. AI in agriculture can foster smart farming practices to limit the loss of farmers and give them high returns. This research is conducted to review several key aspects of AI in the field of agriculture. Besides, it has highlighted the anticipation and future scopes and challenges of AI in the agricultural sectors.

Keywords- Agriculture, Artificial intelligence, Farmer, Soil management, Crop, Weeding.

I. INTRODUCTION

Today's world is the world of technology. The progression of technology has created such technology called artificial intelligence. Artificial intelligence is the imitation of human intelligence processes by machines especially computer systems that can think, behave, and able to make decisions like a human. The food and Agriculture Organization (FAO) of the United Nations projected that the world's population will increase from 7.3 billion to 9.8 billion by 2050. According to the same survey, a 50% increase in food production will be needed to feed the additional 2 billion people[1]. It means the agriculture section will have to take extra pressure and farmers will have to do more with less. Traditional methods of farming cannot fulfil the requirement. AI-powered solution is needed for the challenge of global food production to increase by 50% by 2050 to feed extra 2.5 billion people. AI will not only enable to improve the efficiencies but will also improve the quality, and quantity and ensure fast go-to-market for crops.

The term artificial intelligence was first coined in 1956 by John McCarthy[2]. Over time, as in many other sectors, AI technology has been used in agriculture to achieve automation. The application of AI in agriculture will be enabled by technological advances like the Internet of Things (IoT), Machine Learning (ML) and Deep Learning (DL). AI in agriculture enables us to capture the intricate details of each situation and provide a solution that is the best fit for that particular problem. Major AI techniques that solved many complex problems are ML, Machine Vision, Robotics and Automation and Natural Language processing.

The key to AI is to simplify problem-solving which may include the use of an artificial neural network (ANN). ANN is more widely used and applied for research purposes than the others. ANN is a processing algorithm that mimics the way nerve cells work in the human brain to learn things and make decisions in a manner[3]. AI methods are logical and based on algorithms and programs. So, artificial intelligence, machine learning and deep learning are mostly theories and hypotheses.

Agriculture and AI complement each other. The main purpose of agriculture is to produce food and other human needs to sustain and enhance life. Al plays the main role to achieve the purpose of agriculture. AI provides farmers with real-time inside of fields. The agriculture sector uses artificial robots and drones which are playing an impactful and vital role in this sector. AI application in agriculture has a good impact on the natural ecosystem. It can increase the work safety of farmers. All these factors should keep the food price low. By implementing AI technology in agriculture, the additional needs for food production could be accelerated. The research discusses the use, impacts, capability towards agriculture, tools that are using used and many more aspects relevant to this domain.

II. IMPACT OF AI ON AGRICULTURE

AI innovation has been applied in various segments of agriculture to raise efficiencies and profitability. AI managing the challenges of agriculture from soil preparation to crop marketing. This section describes the several impacts of AI on agriculture.

A. Soil Health Monitoring

Soil is an important natural resource. Over the few decades, soil health monitoring and management have become increasingly important. Good knowledge of different types of soil and conditions can have a great impact on crop yield. AI-powered methods have been introduced in agriculture to monitor soil health and management. In 2018 for soil testing IBM developed a mini soil testing system that can successfully test five indicators based on a colourimetric test. The micro-fluidic chip inside the card performs chemical analysis and an AI-driven machine vision algorithm estimate the value of the colourimetric test[4]. ANN can predict the moisture content of soil [5]. A support vector machine (SVM) can predict the mean weight diameter of soil[6]. AI can identify carbon sources and carbon sinks in different places. In ARIES (2018), different models were used as input up ANN suggesting the carbon sequestration source model, carbon flow model, potentially stored carbon release sink model, and greenhouse gas emissions model[4]. Management oriented modelling (MOM) is an AI-driven soil management practice. It is an effective tool for checking nitrogen leaching[7].

B. Crop Health Monitoring

Artificial intelligence has provided many new ways to increase yield and reduce crop damages. On many occasions crop health depends on choosing the perfect crop for harvesting. Remote sensing (RS) techniques, including hyperspectral imaging and 3D laser scanning, are effective in creating crop matrices on thousands of acres of arable land[8]. Measuring the growth of plants is very important in crops health monitoring. A total of 17 essential elements are needed for the growth of crops[9]. Various computer vision algorithms are being used to measure and predict crop growth. Different techniques have been introduced to monitor the different types of crops. COMAX and COTFLEX for cotton management[10], [11]. Many AI-powered sensors are used for agricultural monitoring which is ultimately related to crop health monitoring. Sensors like MQ4 & MQ7 are used for natural gas sensing and carbon monoxide sensing, respectively [12]. A summary of the application of AI in crop health monitoring is shown in Table 1.

TABLE 1. SUMMARY OF CROP HEALTH MONITORING AI APPLICATIONS

Paper	Application	Algorithm	Result
[13]	Measurement of plant growth indicators	Machine learning, CIE, Threshold segmentation	Achieved a very good result
[14]	Grape growth monitoring	Computer vision	Identification of individual barriers and grape bunches was accurate
[15]	Diagnosis of nitrogen content in rice leaves	MATLAB	Blade change process quantified
[16]	Observing the heading date of wheat	Computer vision	The absolute error of the method is 10.14% days compared to other methods
[17]	Monitoring the growth of paddy	Remote sensing	Achieved a good result

C. Irrigation

AI has turned the traditional irrigation system into an automated irrigation system. This kind of system does not require human intervention. In addition, it not only reduces excess water wastage but also reduces labour. An example of an automatic irrigation system is the use of Arduino[18]. In this system, Arduino read the conditions using soil moisture sensors. If the soil is dry, then check the availability of water using water level sensors. If the water is available, the pump is turned on and is turned off automatically when a sufficient amount of water is supplied. Another example is Raspberry Pi3. In this system, Nod MCUs and soil moisture sensors spread evenly throughout the area of irrigation. Wireless LAN connects the nods with Raspberry Pi3[19]. The developed system of Raspberry Pi3 uses Random Forest regressor to predict the weather. It can gradually adapt to region-specific climate conditions. The system gets updated every 30 minutes at a regular interval. It is an autonomous system with little to no human intervention. Farmers are using various sensors like soil moisture sensors, rain and frost sensor, air sensor, and pH meter sensor to create different irrigation systems. These sensors are used for real-time or historical data to report watering routines and change watering schedules to prove efficiency. One of the main key tools of an irrigation system is a soil moisture sensor. The soil moisture sensor measures the water content in the soil and estimates the amount of water stored in the soil horizon. It helps the irrigators to understand what is happening at the root of a crop. This system combines an advanced technology of sprinklers with nozzles. It collects information from sensors and sends predefined user orders to actuators that turn sprinklers on and off[20], [21]. AI technology is used in Evapotranspiration(ET) to create different types of irrigation systems [22], [23]. It depends on temperature, wind, solar radiation, and relative humidity. If farmers can determine how much water has entered and left plants through ET, they can calculate how much water needs in any condition.

D. Weather Forecasting

Crops are sensitive to climate change. Different parameters like temperature, wind flow, sunlight, rainfall, and humidity can affect crop productivity. Hurricanes, tornadoes, hurricanes, and hailstorms are the result of climate change that could cost millions of dollars. Al-driven weather forecasts help farmers update themselves about environmental conditions. Weather forecasting using AI is primarily based on machine learning algorithms. Numerical Weather Prediction (NWP), a popular machine learning model can provide short-term weather forecasts or long-term climate change predictions by studying and manipulating vast data sets transmitted from weather satellites, relay stations and radiosondes[24]. ANN, Ensemble Neural Network, Backpropagation Network, Radial Basis Function Network, General Regression Neural Network, Genetic Algorithm, Multilayer Perceptron, Fuzzy Clustering are some AI-driven techniques for weather forecasting. Google's AI forecast tool that can predict rainfall six hours ahead of precipitation uses the UNET convolutional neural network (CNN).

E. Weeding

The presence of weeds increases the cost of agriculture and reduces crop yield. A study by the Indian Council for agricultural research said India loses $11 billion worth of agricultural products due to weeds[25]. Therefore, the control or eradication of weeds is very important for crop yield. To eradicate the weeds farmers usually use herbicides. In traditional methods, farmers spray herbicides all over the farmland which is known as broadcast spraying. But this kind of broadcast spraying is a waste of herbicides and harmful to the environment. With the help of AI, farmers can detect and differentiate weeds from crops. Weeds identification is done by Image preprocessing and neural network. In this method, Images of crop fields are captured. Then the images go through some filtering processes. After that, the image segmentation algorithm of the Deep Convolutional neural network (DCNN) is used to separate crops from weeds[26]. With smart spraying technology, farmers can use minimal herbicide to eradicate weeds. It eventually lowers the cost of weed management. Then robotic nozzles with high precision target those weeds and spray a dose of herbicide according to the previously calculated weed's size and age[27]. Smart spraying technology sprays herbicides with precise dosages only to target plants and avoid crops & open soil areas. Blue River is an AI-powered famous and smart spraying technology. It uses a "see & spray" system. With this technology, farmers can eliminate 90% of herbicide volume[28]. A summary of the application of AI in weeding operations is shown in Table 2.

Table 2. Summary Of Application Of Ai In Weeding Operation

Paper	Application	Algorithm/Method	Result
[29]	Weed detection	Fuzzy time classification, Color, and texture-based algorithm	The accuracy rate is 92.9%
[30]	Precision weed management	Machine vision	Low cost and very effective
[31]	Weed estimation	HOG (Histogram of Oriented Gradients), Multispectral images	Analyze large areas of crops in less time
[32]	Weed detection in agricultural fields	Convolution Neural Network	The accuracy rate is 70.5%
[33]	Weed detection in crops	SVM, Image processing	A distinction between crops and weeds
[34]	Identification of potato plants and three different weeds	Computer vision expert system based on a neural network	The recognition rate is 98.38% and the average PC execution time of less than 0.08s

F. Disease and Pest Management

Plant disease reduces the production and quality of the crop. Farmers spend billions of dollars on disease management. AI-based disease management can help farmers to detect and get rid of diseases. CNN has identified leaf disease with higher accuracy. Vegetable leaf diseases can be detected by the CNN model based on image segmentation[35]. Computer vision (CV) technology also detects crop disease. SVM uses the color, texture, and shape of leaves to classify and identify diseases[36]. Image recognition technology, an AI-based technology is used to identify and treat pests. The YOLOv3, an AI-driven model uses CNN to classify and label the pest. CNN with the usage of image processing techniques counts the number of pests on any plant automatically[37]. Farmers use pesticides to protect crops from pests. Overuse of pesticides is harmful to the environment. Integrated pest management (IPM) is an environmentally friendly method for pest management. The effects of IPM can be better than chemical control in the long term [38].

III ROBOTS AND DRONES

Robots are introduced to agriculture for their automation, precision & efficiency. Farmers use robots to find new ways to increase crop production and ease their work. Robots use technologies like AI and CV to perform their tasks. CV system includes a camera(s) to collect information, and then send it to the robot. The robot then takes the necessary steps according to the given information. With this technology, robots can perform tasks like harvesting, growth monitoring, picking, sorting & packing. Intelligent Agrobots-based on machine vision and ML are being used for sowing seeds[39]. Smart and autonomous agricultural robot prototypes are being implemented in this process[40], [41]. Many wedding robots do weed operations based on AI. Robots use image processing, CNN, SVM and various algorithms to detect weeds, and then spray herbicide doses[42], [43]. Dogtooth Technologies designed a robotic arm that is capable of harvesting fruits like strawberries that need sensitive picking with machine vision and motion planning algorithms, robot identifies and locates the ripe fruits[44]. Apple harvesting robots use 'computer vision and deep learning to pick apples from trees with mechanical hand(s)[45]. Cambridge University made a robot called Vegebot. It uses machine vision to harvest lettuce. Using a camera, it scans the lettuce and gives a thumbs up or down for harvesting.

Drones are used to facilitate agriculture. Drones, known as unmanned aerial vehicles (UAVs), are managing and streamlining agricultural operations. It does all its work through flying. State estimation and controlling are two main components of drone flight. AI and ML are making state estimation and controlling capabilities of a drone to adapt to the environment[46]. Another important feature of the drone is mapping. AI-powered CV algorithms improve the mapping capabilities of the drone. With the help of AI, drones are being implemented in agricultural operations such as spraying, monitoring, identification, disaster management, image capturing, processing and analysis. Drones can use different kinds of spraying methods for crop spraying. Hydraulic energy sprayers, Gaseous energy sprayers, Centrifugal energy sprayers, and kinetic energy sprayers are some of them[47]. Drone can notify the farmers of how much sunlight the crop is getting from the sun. ML helps drones to analyze which part of farmland needs to be irrigated, and which part is affected by weeds and diseases. Different companies and organizations made specialized drones to perform agricultural tasks specifically. As T16 from DJI, eBEE SQ from senseFly, Quantix Mapper from Dragonfly, and Drone4Agro V3 are a few of them. These drones use AI, ML, IoT, GPS, RTK and many more different technologies to do the specified agricultural works.

IV CHALLENGES OF ADOPTING AI IN AGRICULTURE

Although AI has redefined and improved agriculture in many amazing ways, it has some challenges as well. The first and most important issue is the lack of knowledge and skills in AI. AI technologies in agriculture require a different level of skill set. AI technology is made of software, hardware, sensors, and other various tools. Farmers need to train themselves to apply and operate these technologies properly. However, most of the farmers neither have the time nor good instructors to train them. Another thing that leads to a challenge is the gap between farmers and AI engineers. Most farmers usually do not study AI, ML or IoT. On the other hand, engineers do not often study agriculture and work in the fields, or methods used in agriculture. Sometimes unusual situations occurred in agriculture. AL and ML need time to analyze, process, study and then propose a solution. By then the situation may get out of hand. Another major issue is the cost of technology. There are 2 kinds of cost, first one is the cost of equipment and the other one is the cost of maintenance. Drones and agricultural robots are not cheap. Farmers need to pay a large amount of money to buy them. Hence, many companies offer these machines and technologies on a rental basis as a percentage of the crop. Farmers have to spend money to keep the machines running. Eventually, it raises the cost of the crop. The durability of AI technology is very important. Besides, technology keeps changing rapidly in this modern era. If farmers need to buy devices now and then it will not be economical for them. These machines and devices require regular updates. The updating process can be complicated and costly, but if the farmers do not update the device timely and proper, it may not work.

V FUTURE SCOPE

The applications of artificial intelligence in agriculture show successful results. The scope of AI in agriculture could be further expanded in the future. Agriculture technologies and system, including AI and ML, is projected to triple in revenue by 2025, reaching 15.3 billion dollars, according to BI Intelligence Research. AI application in agriculture is required to solve agricultural problems and ensure better harvests. Framers depend on nature and weather for their cultivation. AI and machine learning work as a predictive analyst by analyzing previously collected data and recommending the right time to sow seed, defining the crop choices, and Hybrid seed choices to generate more yield. ML models can also suggest tweaks in cropping patterns to boost yields. Microsoft in collaboration with International Crop Research Institute for the Semi-Arid Tropics (ICRISAR), has developed an AI-sowing. The app sends sowing advisories to farmers on optimal data to sow. It is speculated that AI-based advisories would be useful to increase production by 30%. The biggest challenge of farming is crop damage due to any kind of disaster including pest attacks. Microsoft is yet another initiative that has collaborated with United Phosphorus Limited to build a Pest Risk Prediction API that leverages AI and ML to indicate in advance, the risk of pest attack. AI-empowered sensors and algorithms can be installed in robots to harvest fruits and crops for quick harvesting. Machines can take decisions at a level equivalent to the human brain using ML and

DL. These decisions are based on thousands of data and more accurate than the human brain. One of the biggest concerns of farmers is the fluctuations in crop prices. With the help of technologies like big data, AI and ML, it can detect pest and disaster infestations, estimate crop output, and forecast prices which can guide the farmers and government on the future price patterns, demand level and type of crop to sow for maximum benefits. A tech-based company named NatureFresh, based out of the USA is developing technology to predict the amount of time a crop will take to produce a crop. This technology would be able to determine the amount of yield that will be available to sell in the future. AI can optimize every inch of a farm, take the right decisions, perform difficult and long-term tasks in a short time. It is a key tool in the transition from conventional agriculture to sustainable automated agriculture.

IV CONCLUSION

AI has revolutionized agriculture. Adopting AI in agriculture is one of the best ways to meet the ongoing demand for food. The agriculture industry faces various challenges. AI-driven technologies can help to face these challenges. ML has been applied to various machines for agricultural work. The application of AI in agriculture helps to automate it and shift traditional farming to precise cultivation for higher crop harvesting and better quality. AI in agriculture is essential to meet our needs. In future, agriculture is going to be governed by AI to meet the increasing demand for agricultural products. By minimizing the gap between farmers and AI engineers, training farmers about using AI-powered solutions and lessening the cost of adopting AI would produce more with less.

ACKNOWLEDGMENTS

The authors would like to thank all researchers in this domain from where authors have got sufficient relevant and updated the information about the research.

REFERENCES

[1] FAO, 2017 The State of Food and Agrivulture Leveraging Food Systems for Inclusive Rural Transformation. 2017.
[2] P. E. Ekmekci and B. Arda, "History of Artificial Intelligence," SpringerBriefs in Ethics, no. December, pp. 1–15, 2020, doi: 10.1007/978-3-030-52448-7_1.
[3] D. Shah, R. Dixit, A. Shah, P. Shah, and M. Shah, "A Comprehensive Analysis Regarding Several Breakthroughs Based on Computer Intelligence Targeting Various Syndromes," Augment. Hum. Res. 2020 51, vol. 5, no. 1, pp. 1–12, Mar. 2020, doi: 10.1007/S41133-020-00033-Z.
[4] A. Sarkar, P. P. Maity, and A. Mukherjee, "Application of AI in Soil Science," no. February, pp. 1–3, 2021.
[5] O. A. Sanuade, P. Adetokunbo, M. A. Oladunjoye, and A. A. Olaojo, "Predicting moisture content of soil from thermal properties using artificial neural network," Arab. J. Geosci., vol. 11, no. 18, 2018, doi: 10.1007/s12517-018-3917-4.
[6] P. Bhattacharya, P. P. Maity, M. Ray, and N. Mridha, "Prediction of mean weight diameter of soil using machine learning approaches," Agron. J., vol. 113, no. 2, pp. 1303–1316, 2021, doi: 10.1002/agj2.20469.
[7] M. Li and R. S. Yost, "Management-oriented modeling: Optimizing nitrogen management with artificial intelligence," Agric. Syst., vol. 65, no. 1, pp. 1–27, Jul. 2000, doi: 10.1016/S0308-521X(00)00023-8.
[8] J. Thomas, "Application of Artificial Intelligence in Thyroidology," Artif. Intell., no. May, pp. 273–283, 2020, doi: 10.4324/9780429317415-15.
[9] M. A. Culman et al., "A Novel Application for Identification of Nutrient Deficiencies in Oil Palm Using the Internet of Things," Proc. - 5th IEEE Int. Conf. Mob. Cloud Comput. Serv. Eng. MobileCloud 2017, pp. 169–172, Jun. 2017, doi: 10.1109/MOBILECLOUD.2017.32.
[10] H. Lemmon, "Comax: An Expert System for Cotton Crop Management," Science (80-.)., vol. 233, no. 4759, pp. 29–33, Jul. 1986, doi: 10.1126/SCIENCE.233.4759.29.
[11] N. D. Stone and T. W. Toman, "A dynamically linked expert-database system for decision support in Texas cotton production," Comput. Electron. Agric., vol. 4, no. 2, pp. 139–148, Aug. 1989, doi: 10.1016/0168-1699(89)90031-8.
[12] K. S. Babu and D. C. Nagaraja, "Calibration of MQ-7 and Detection of Hazardous Carbon Mono-oxide Concentration in Test Canister," Int. J. Adv. Res. Ideas Innov. Technol., vol. 4, no. 1, pp. 18–24, 2018, doi: xx.xxx/ijariit-v4i1-1145.
[13] M. P. Rico-Fernández, R. Rios-Cabrera, M. Castelán, H. I. Guerrero-Reyes, and A. Juarez-Maldonado, "A contextualized approach for segmentation of foliage in different crop species," Comput. Electron. Agric., vol. 156, pp. 378–386, Jan. 2019, doi: 10.1016/J.COMPAG.2018.11.033.
[14] R. Pérez-Zavala, M. Torres-Torriti, F. A. Cheein, and G. Troni, "A pattern recognition strategy for visual grape bunch detection in vineyards," Comput. Electron. Agric., vol. 151, pp. 136–149, Aug. 2018, doi: 10.1016/J.COMPAG.2018.05.019.
[15] Y. Sun, H. Duan, and N. Xian, "Fractional-order controllers optimized via heterogeneous comprehensive learning pigeon-inspired optimization for autonomous aerial refueling hose–drogue system," Aerosp. Sci. Technol., vol. 81, pp. 1–13, Oct. 2018, doi: 10.1016/J.AST.2018.07.034.
[16] Y. Zhu, Z. Cao, H. Lu, Y. Li, and Y. Xiao, "In-field automatic observation of wheat heading stage using computer vision," Biosyst. Eng., vol. 143, pp. 28–41, Mar. 2016, doi: 10.1016/J.BIOSYSTEMSENG.2015.12.015.
[17] A. M. Ali et al., "Integrated method for rice cultivation monitoring using Sentinel-2 data and Leaf Area Index," Egypt. J. Remote Sens. Sp. Sci., vol. 24, no. 3, pp. 431–441, Dec. 2021, doi: 10.1016/J.EJRS.2020.06.007.
[18] F. A. Okoye, E. Z. Orji, and G. O. Ozor, "Using Arduino Based Automatic Irrigation System to Determine Irrigation Time for Different Soil Types in Nigeria," Int. J. Adv. Res. Comput. Commun. Eng. ISO, vol. 7, no. July 2018, pp. 42–47, 2018.
[19] R. Ilakkiya and A. Murugesan, "Smart Agriculture Irrigation System Using Raspberry Pi," South Asian J. Eng. Technol., vol. 8, no. S 1, pp. 19–24, 2019.
[20] A. Mitra, Pooja, and G. Saini, "Automated Smart Irrigation System (Asis)," Proc. - 2019 Int. Conf. Comput. Commun. Intell. Syst. ICCCIS 2019, vol. 2019-Janua, no. October, pp. 327–330, 2019, doi: 10.1109/ICCCIS48478.2019.8974466.
[21] K. Jha, A. Doshi, and P. Patel, "INTELLIGENT IRRIGATION SYSTEM USING ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING: A COMPREHENSIVE REVIEW," Int. J. Adv. Res., vol. 6, no. 10, pp. 1493–1502, Sep. 2018, doi: 10.21474/IJAR01/7959.
[22] C. Arif, M. Mizoguchi, M. Mizoguchi, and R. Doi, "Estimation of soil moisture in paddy field using Artificial Neural Networks," Int. J. Adv. Res. Artif. Intell., vol. 1, no. 1, pp. 17–21, 2012, doi: 10.14569/ijarai.2012.010104.
[23] H. M. Al-Ghobari and F. S. Mohammad, "Intelligent irrigation performance: evaluation and quantifying its ability for conserving water in arid region," Appl. Water Sci., vol. 1, no. 3–4, pp. 73–83, Dec. 2011, doi: 10.1007/S13201-011-0017-Y/TABLES/8.

[24] S. Al-Yahyai, Y. Charabi, and A. Gastli, "Review of the use of numerical weather prediction (NWP) models for wind energy assessment," Renew. Sustain. Energy Rev., vol. 14, no. 9, pp. 3192–3198, 2010, doi: 10.1016/j.rser.2010.07.001.

[25] Y. Gharde, P. K. Singh, R. P. Dubey, and P. K. Gupta, "Assessment of yield and economic losses in agriculture due to weeds in India," Crop Prot., vol. 107, pp. 12–18, May 2018, doi: 10.1016/J.CROPRO.2018.01.007.

[26] J. Yu, A. W. Schumann, Z. Cao, S. M. Sharpe, and N. S. Boyd, "Weed Detection in Perennial Ryegrass With Deep Learning Convolutional Neural Network," Front. Plant Sci., vol. 10, p. 1422, Oct. 2019, doi: 10.3389/FPLS.2019.01422/BIBTEX.

[27] K. Sabanci and C. Aydin, "Smart robotic weed control system for sugar beet," J. Agric. Sci. Technol., vol. 19, no. 1, pp. 73–83, 2017.

[28] T. Engineering and M. Herron, "from the President Looking both ways :," 2017.

[29] M. Reinecke and T. Prinsloo, "The influence of drone monitoring on crop health and harvest size," undefined, pp. 5–10, Aug. 2017, doi: 10.1109/NEXTCOMP.2017.8016168.

[30] N. C. Eli-Chukwu, "Applications of Artificial Intelligence in Agriculture: A Review," Eng. Technol. Appl. Sci. Res., vol. 9, no. 4, pp. 4377–4383, Aug. 2019, doi: 10.48084/ETASR.2756.

[31] A. E. Puerto Lara, C. Pedraza, and D. A. Jamaica-Tenjo, "Weed Estimation on Lettuce Crops Using Histograms of Oriented Gradients and Multispectral Images," pp. 204–228, Jan. 2020, doi: 10.4018/978-1-7998-1839-7.CH009.

[32] H. C. Ngo, U. R. Hashim, Y. W. Sek, Y. J. Kumar, and W. S. Ke, "Weeds detection in agricultural fields using convolutional neural network," Int. J. Innov. Technol. Explor. Eng., vol. 8, no. 11, pp. 292–296, 2019, doi: 10.35940/ijitee.K1327.0981119.

[33] C. Pulido, L. Solaque, and N. Velasco, "Weed recognition by SVM texture feature classification in outdoor vegetable crop images," Ing. e Investig., vol. 37, no. 1, pp. 68–74, 2017, doi: 10.15446/ing.investig.v37n1.54703.

[34] S. Sabzi, Y. Abbaspour-Gilandeh, and G. García-Mateos, "A fast and accurate expert system for weed identification in potato crops using metaheuristic algorithms," Comput. Ind., vol. 98, pp. 80–89, Jun. 2018, doi: 10.1016/J.COMPIND.2018.03.001.

[35] S. P. Mohanty, D. P. Hughes, and M. Salathé, "Using deep learning for image-based plant disease detection," Front. Plant Sci., vol. 7, no. September, p. 1419, Sep. 2016, doi: 10.3389/FPLS.2016.01419/BIBTEX.

[36] B. S. Ghyar and G. K. Birajdar, "Computer vision based approach to detect rice leaf diseases using texture and color descriptors," Proc. Int. Conf. Inven. Comput. Informatics, ICICI 2017, no. Icici, pp. 1074–1078, 2018, doi: 10.1109/ICICI.2017.8365305.

[37] C. J. Chen, Y. Y. Huang, Y. S. Li, C. Y. Chang, and Y. M. Huang, "An AIoT Based Smart Agricultural System for Pests Detection," IEEE Access, vol. 8, pp. 180750–180761, 2020, doi: 10.1109/ACCESS.2020.3024891.

[38] R. Peshin, K. S. U. Jayaratne, and R. Sharma, "IPM Extension: A Global Overview," Integr. Pest Manag. Curr. Concepts Ecol. Perspect., pp. 493–529, Jan. 2014, doi: 10.1016/B978-0-12-398529-3.00026-9.

[39] D. Bini, D. Pamela, and S. Prince, "Machine Vision and Machine Learning for Intelligent Agrobots: A review," ICDCS 2020 - 2020 5th Int. Conf. Devices, Circuits Syst., pp. 12–16, 2020, doi: 10.1109/ICDCS48716.2020.243538.

[40] P. Kanade and P. Ashwini, "Smart Agriculture Robot for Sowing Seed," Ijesc, vol. 11, no. 01, pp. 27563–27565, 2021, doi: 10.5281/zenodo.4533314.

[41] S. N. G, B. D, B. K, M. Ausim, and V. K, "An Automated Sowing Seed using AG-ROBOT," Int. J. Eng. Res. Technol., vol. 8, no. 11, Aug. 2020.

[42] X. Wu, S. Aravecchia, P. Lottes, C. Stachniss, and C. Pradalier, "Robotic weed control using automated weed and crop classification," J. F. Robot., vol. 37, no. 2, pp. 322–340, 2020, doi: 10.1002/rob.21938.

[43] F. Johnson, "ARTIFICIAL INTELLIGENCE FOR WEED DETECTION -A TECHNO-EFFICIENT ARTIFICIAL INTELLIGENCE FOR WEED DETECTION - A TECHNO-EFFICIENT APPROACH Femi Temitope Johnson and Joel Akerele," vol. 9102, no. December, pp. 2299–2305, 2020, doi: 10.21917/ijivp.2020.0326.

[44] R. Bogue, "Fruit picking robots: has their time come?," Ind. Rob., vol. 47, no. 2, pp. 141–145, 2020, doi: 10.1108/IR-11-2019-0243.

[45] W. Jia, Y. Zhang, J. Lian, Y. Zheng, D. Zhao, and C. Li, "Apple harvesting robot under information technology: A review," Int. J. Adv. Robot. Syst., vol. 17, no. 3, pp. 1–16, 2020, doi: 10.1177/1729881420925310.

[46] J. R. Davidson, A. Silwal, C. J. Hohimer, M. Karkee, C. Mo, and Q. Zhang, "Proof-of-concept of a robotic apple harvester," IEEE Int. Conf. Intell. Robot. Syst., vol. 2016-Novem, pp. 634–639, Nov. 2016, doi: 10.1109/IROS.2016.7759119.

[47] T. Talaviya, D. Shah, N. Patel, H. Yagnik, and M. Shah, "Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides," Artif. Intell. Agric., vol. 4, pp. 58–73, Jan. 2020, doi: 10.1016/J.AIIA.2020.04.002.