ARTIFICIAL INTELLIGENCE EQUIPPED WITH IOT FOR AUTOMATION AND ENHANCED CROP YIELD

Abstract

Human civilization is facing great risk of food scarcity due to rapidly increasing population. Increased crop production is need of time. Several researchers are making attempt to develop pest resistant varieties with improved yield but it is not able to address the food security issues in entire world. Humans cannot afford losses in crop products due to fluctuations in environmental factors or pests especially when millions of people are starving and not able to secure one time meal. The technological advancement and its widespread usage in agriculture can provide a sustainable solution to the problem. Several artificial intelligence tools including IoT, machine learning and suitable algorithms can help humans to not only have better control over crop production and optimized yield, but also provide real time analysis and prediction of weather, soil like conditions and help avoiding pathogen's attack. It can reduce requirement of manpower and eliminate errors in agricultural practices. Current article provides an insight of basic concept of smart agriculture and includes valuable information about different AI-Tools and IoT.

Keywords: Artificial Intelligence, Cloud computing, Internet of Things (IoT), Robotics, Sensors,

Authors

Santosh Kumar Singh
Department of Life Science
Sri Sathya Sai University for Human Excellence
Kalburgi, Karnataka, India
santosh.s@sssuhe.ac.in

Devendra D N
Department of Life Science
Sri Sathya Sai University for Human Excellence
Kalburgi, Karnataka, India

Imran Husain
Department of Bioengineering
Faculty of Engineering and Information Technology
Integral University
Lucknow, India
imranhussain@iul.ac.in

I. INTRODUCTION

Rising population is demanding the higher crop yields to feed millions of people of the world. Geopolitical scenarios are contributing to severe and uneven distribution of food to the people. Changes in the weather pattern in various parts of the world is affecting the agricultural production more than ever. Several microbial diseases have become prominent in current years and causing a lot of harm to the crops, putting the interest of millions at sake. Despite of the development of advanced technologies, its wide applications for improved agricultural practices is far away from the targets in policies of most of the government and private sectors. So, development of technology- based approach for agriculture, livestock breeding, improved traits in crops and many more areas are the need of time.

The population of the world is increasing at high pace and at the same time climate changes are wreaking havoc. Due to this, the agriculture sector is facing a huge challenge to increase food-grain output and productivity. However, the conventional approach of expanding cropland is no longer a viable option in many countries. As a result, agriculture automation emerges as the crucial and necessary solution of the hour. The implementation of automated systems reduces the time and labour required for various farm operations, enabling farmers to save costs and increase their profits. With the burden of manual tasks lightened, farmers can focus on strategic decision-making and optimizing their overall agricultural practices.

The revolution in digital technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) plays a pivotal role in transforming traditional farms into smart systems. These intelligent technologies facilitate real-time monitoring, control, and visualization of diverse farm operations. By providing data-driven insights comparable to human expertise, AI and IoT empower farmers to make informed decisions that lead to improved outcomes and more effective farming practices.

Another benefit of automation in agriculture is that it reduces the environmental impact of agriculture. By using automated systems to precisely control irrigation, fertilizer, and pesticide application, farmers can make better use of resources. By carefully managing the use of water, fertilizer, and pesticides, farmers not only become more efficient, but they also reduce the negative impacts of overconsumption of resources on the environment. This improves the sustainability of agriculture and makes it more compatible with environmental conservation objectives[1].

The technological advancements in machine learning, artificial intelligence, Internet of Things (IoT) and different expert systems can help us not only to increase the total crop production but it can also enhance the capacity of sustainable management of different factors for crop growth and increase the nutritional quality of the agricultural products[2]. Though the technology is rarely available to the farmers of far away and remote areas due to its management constraints and higher cost. There are several merits and problems in current system of development and must be tackled to make it reachable to all parts of the world without any reservation. The concept of technology use in agriculture has been transformed into new - Next Gen Agriculture concept and strategies. Current article will help in understanding various tools and systems available at present and provide its utilization methods. It also states details of AI models and robotic systems available in India and world

giving insight of some model systems. The readers will be able to understand the gaps, challenges and applications in Agriculture 4.0.

1. **Agricultural Revolution Terminologies:** The role of information and communication technology (ICT) in various sectors including agricultural applications can help the farmers in smart agriculture strategies. Now new approaches are being welcomed citing more tools and internet utilization for better optimization of agriculture practices. Agriculture 1.0 term is used for the decades of development in which small and less sophisticated tools were developed and used in crop production. Onset of heavy tools and machinery, few decades later brought a revolution in farming system. Production was enhanced many folds and was able to cope up with the food requirements of rising population. Further industrial revolution and use of robotics in different sectors started a new era called as Agriculture 3.0 in 20^{th} Century. It helped to overcome the problems of manpower in agricultural sectors. In 21^{st} century, internet has created so many opportunities with just on click. 4-G and 5-G platforms have provided higher working capacity with unimaginable speed and accuracy. Big Data, Cloud computing, IoT, artificial intelligence, expert systems to control environmental factors and operating procedures has brought a revolution now days referred as Agriculture 4.0. Thus, old days agriculture is transformed into smart agriculture and farmers as smart farmers. Now days, if a farmer is sitting in New York, doing regular job is able to control and operate his/her own farmland in India, thousands of kilometres away from home, then it's possible because of remote sensing technology, internet and other advancements. Today we are at the emergence of a new age popularly called as 'Agriculture 5.0. The concept of Agriculture 5.0 indicates the trend of involvement of emerging technologies as Deep learning, neural networks, IoT, Artificial intelligence, advanced machine learning tools and cloud computing for a huge mass of data collected from even remote locations. It is also called as Age of new Energy Agriculture[2].

2. **The Benefits of Artificial Intelligence and IoT in Smart Farming**

- **Soil Health Monitoring:** IoT-based soil health monitoring systems can help farmers to monitor the soil moisture, temperature, pH level, and nutrient content in real-time. This information can be used to optimize the use of fertilizers and water, thereby reducing wastage and increasing crop yield[3].
- **Crop Health Monitoring:** IoT-based crop health monitoring systems can help farmers to monitor the growth, health, and quality of crops in real-time. This information can be used to detect diseases, pests, and nutrient deficiencies early, and take corrective actions to prevent crop loss.
- **IoT-Based Smart Irrigation:** IoT-based smart irrigation systems can help farmers to optimize the use of water by monitoring the soil moisture level, weather conditions, and crop water requirements in real-time. This information can be used to automate the irrigation process and reduce water wastage.
- **Real-Time Weather Forecasting:** IoT-based weather forecasting systems can help farmers to predict weather conditions accurately and plan their farming activities accordingly. This information can be used to optimize the use of fertilizers, pesticides, and water, and reduce crop loss due to extreme weather conditions.

- The information from IoT subsystems in agriculture can be integrated using AI algorithms to help farmers make informed decisions about crop management. Alerts can be sent to the farmer's mobile device with recommendations on optimal crop management practices. This can increase crop yield and contribute to easier and informed management of the crops[3].

II. AUTOMATION IN DECISION MAKING & MONITORING AGRICULTURAL FARMS FROM REMOTE LOCATIONS

Different AI methodologies & application tools are in advance phase of development in several sectors as commerce industries, robotic systems in medical health care as well as mechanical applications, social media, face recognition and voice identification in mobiles and attendance machines in educational as well as defence sectors, agriculture, games etc. Even Indian Government is using AI technology to filter thousands of suggestions received on uniform civil code. Development of smart sensors for climatic as well as edaphic (soil related) factors along with machine learning, image processing and expert systems can be used to revolutionize agriculture. Artificial intelligence-based systems can improve the quality of grains/fruits/other agricultural products and maintain sustainable, reliable and stable farming system[4].

All artificial intelligence-based strategies use machine learning as important tool. Machine learning can help in monitoring activities in agriculture and provide automation. It reduces labour charges and uniform control systems can be applied in large area. Different algorithms are written for machine learning that help in precision agriculture[4]. These machine learning algorithms enable machines to learn and memorize about type of soil/land, soil texture, fertilizer levels, geographical structure of farming areas, type of crops to be grown in particular season and time etc. After this stage, AI tools can perform actions such as automated monitoring and decision making with accurate prediction of temperature, humidity, yield, pathogen level etc[5]. Different algorithms are also available for selection of suitable crops as well as harvesting time and methods to reduce the loss of products that is common in Indian habitats. Choosing the right kind of machine learning algorithms is most important and it is dependent on the data availability, size of farming area, budget particulars and other factors. The best example of an optimized algorithm is the support vector machine (SVM) which has very high accuracy rates of 90%-97% as reported by several authors[6].

1. **Addressing the Challenges is First Step in Automation:** Collection of data from remote locations is a big problem. If data is collected in improper amount, it will not serve the purpose. If the data is not processed and responses are late towards the problems in fields like pathogen attack or wide temperature variations, it would lead to loss of crops. The automation of farming system can provide data for analysis and processing in real time. Cloud computing can help in collection and processing of huge amount of data in real time, even from remote locations. Several villages are devoid of internet connections or poor internet speed. This is one of the biggest reasons of crop loss in remote locations. Digitalization of villages can serve the purpose and solve this problem. Even sometime government offices and legal issues in ownership of lands also create obstacles in developing smart farming systems. Other humanly factors like privacy issues, fear of income loss etc also play important role in de-popularizing the smart farming systems in

countries like India. So, government policies and promotion schemes can remove such problems and involve sufficient number of stakeholders in adopting such practices.

2. **Processing of Images & Videos Using AI:** Most of the data collected by AI tools are in the form of images of stem, twigs, leaves, soil samples soil texture etc. The processing of images for better data interpretation is very significant. Any damage to plant parts or infection to plant parts should be processed and analysed for better response. Usually, images are pre- processed into matrix of numbers and different operations are applied to the matrix. These operations are important and done for each pixel of the received image/s. After that image enhancement might be needed to avoid distortions, contrast deviation, or blurring, if any[7]. An expert system helps in noise reduction, image sharpening, brightness adjustment and contrast increase to produce clear images suitable for processing and analysis. Corrupted images are removed from data analysis and images are restored and compressed. Compression reduces the size and enable handling the heavier data in short period of time. The dots, blurs, speckles or stains are removed by image smoothing and increasing pixel value of image/s. Some novel artificial intelligence techniques such as convolutional neural networks (CNNs) are being used in computer applications to enhance images[8].

III. ROLE OF CLOUD COMPUTING

Cloud computing can help in collection of large amounts of data from distant locations and storage prior its usage. The transmission of collected data from remote locations can be stored and prevent its loss. It can be used for the processing of collected data. The generated results could be interpreted immediately for real time response. It's very usable especially during pathogen attacks in crops where immediate response is required even from remote locations. There are three connected layers in Cloud computing services; Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS)[9].

IV. IOT & SENSORS

Sensors are one of the most important tools in precision agriculture and automation based on AI. It can convert the physically sensed data converting it to digital format/s. These digital formats become the input for an algorithm which process and send it to the transceiver. A smart sensor must have below components[10,11]:

1. A sensing device to measure factors like heat, temperature, humidity, mineral load, soil texture, etc.).
2. Tools to translate and condition the sensed signal into data.
3. A processing unit is connected which is loaded with appropriate algorithm. It has memory and user interface to process the digital data.
4. A transceiver unit for information exchange and interpretation.

Different sensors have diverse applications and farmers can monitor real-time data like need of watering to plants, increasing or decreasing the temperature of poly house, type and time of fertilization etc. Some examples of sensors are provided here to help readers to access them in practical applications. Water content sensors measure the ratio of the amount

of water in the tested soil to the total amount of the tested soil[12]. This measurement is based on type of soils and appropriate sensor must be chosen as per requirement in diverse locations. Volumetric water content sensors provide information about water stored in soil layers to ensure the correct type and amount of water needed for specific crop. Electrical conductivity sensors measure the saline content in soil by estimating the solute concentration. Salinity is a major issue in certain parts of country and is hazardous for crop yield[13]. pH sensor can measure the acidity and alkalinity of the field. It can help to choose the right kind of acidic or alkaline fertilizer for the specific crop and soil[14]. An outline of the working mechanism of smart farming system is given in figure 1.

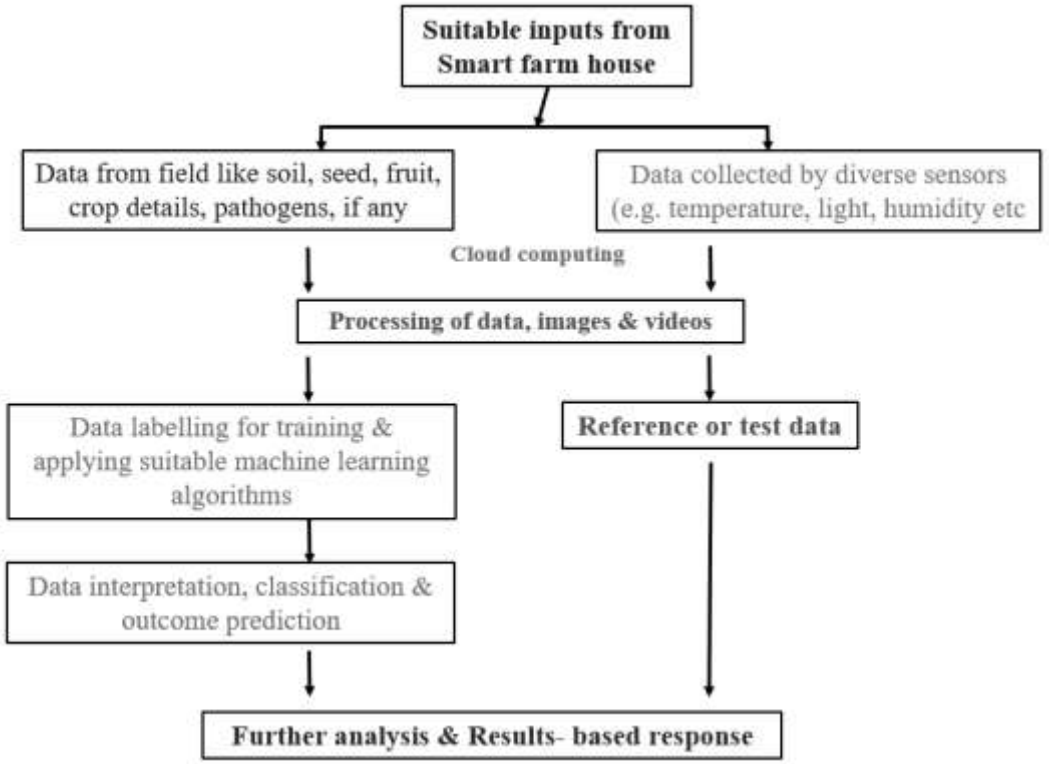

Figure 1: An Outline of Working Mechanism of a Smart Farming System

Weed seeker sensors identify and remove dangerous weeds[15]. Similarly, temperature sensor alert about the deviation/s in temperature that can reduce total photosynthetic yield by denaturing the enzymatic activities that are vital for optimum metabolism in plant cells[16]. Zigbee is a wireless protocol for sensors for soil temperature, moisture, light intensity, humidity, camera, wind direction, CO_2 saturation, misting etc and utilize web service, data analysis, user application interface, web and cloud computing[17,18]. Similarly, nRF wireless protocol is used in sensors for soil temperature, humidity, moisture, wind speed etc. RFID tags are used in sensors for air temperature, air humidity, soil moisture and light and uses SMS, e-mails, google spreadsheets as its application[19].

V. ROBOTICS IN SMART FARMING

Evolution in robotics, enable robots to assist in farming activities and automation in precision agriculture. [20]Khadatkar et al. 2022 emphasized the available robotic systems for various farm operations and suggested different approaches and technologies in various agricultural operations. For example, robotic transplanters use computer graphics or machine vision systems for transplanting operations[21]. Intercultural operations such as removal of weeds are done by mechanical weeders or chemical spraying. Robotic weeders use vision-based systems and can detect diverse weeds, guide weeders and uproot them mechanically[22]. Gonzalez-de-Soto et al. 2016 developed[23] a robotic patch spraying system for the automated precise application of herbicides. Some robotic systems can identify and differentiate ripened and raw fruits before collecting them mechanically. They are equipped with sensors and grippers and detach fruits based on shape, color etc. Incorporating GPS technology, vision-based sensor navigation to direct robots, harvesting and soil analysis systems are important developments in autonomous robotics[24].

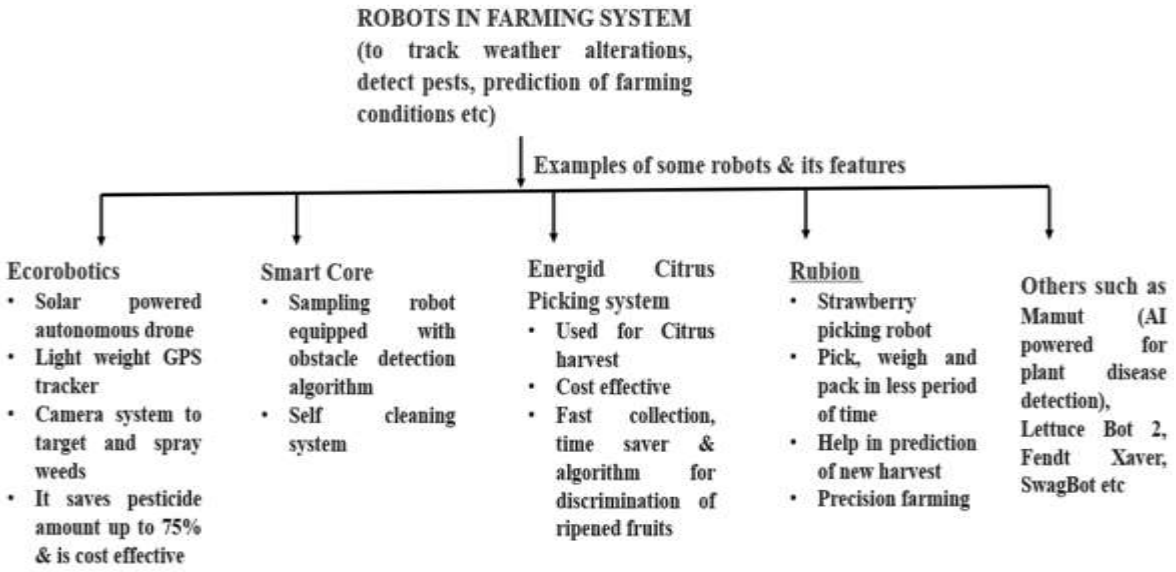

Figure 2: Examples and features of some common robotic systems in smart farming.

1. The Working of a Typical Expert System

- The common system uses a wireless sensor network (WSN) with various sensors such as soil moisture, soil pH, soil NPK, temperature, and humidity sensors to monitor soil parameters.
- The WSN is connected to a microcontroller, Node MCU, USB to UART converter, driver, relay, water pump, LCD display, transformer, and other components.
- The microcontrollers are programmed to perform automatic irrigation based on the soil moisture level and other parameters.
- The expert system uses machine learning techniques to predict the crop variety for sowing according to land suitability and detect leaf diseases.

- The system also uses data analysis to monitor soil parameters and provide insights to farmers.
- The system can be remotely monitored and controlled using a mobile application and a PC localhost database, which can act as the remote eyes and hands for farmers.
- The mobile application, myDevices Cayenne, provides real-time data and alerts to farmers, allowing them to take timely actions to prevent crop damage and improve yield.

Overall, an expert system combines IoT, machine learning, and mobile application technologies to optimize the food production process and improve quality in agriculture[25].

2. **Smart Farming System Equipped with Artificial Intelligence and Internet of Things (IoT):** Artificial intelligence enabled IoT farming system uses diverse sensors as optical sensors, electrochemical sensors, soil sensors, air sensors, etc.) and collect the data from the farms. Collected data is shared via cloud to machine learning systems. It processes the images, videos or other formats of data and with the help of computer vision and expert system algorithms, support the farm management and automated decision making. It can help in optimized crop production in standard conditions and ensure the sustainability, productivity and supply chains.

   Some examples of recently developed AI techniques have been found to exhibit 90-100% accuracy in different agricultural applications. Some examples are as below:

   - **Deep Recurrent Learning:** It is used for the recognition of cow behaviour especially its health care conditions and can detect several pathogen mediated health effects. It measures the data with 85% accuracy[26].
   - **K-Nearest Neighbour:** It us used for spectral, hierarchical and DBSCAN clustering. This AI technique could be used for classify data for irrigation of different crops. It measures the data with 97.1 to 99.8 % accuracy[27].
   - **Augmented Reality with Machine Learning:** It is used for Prawn farm management and helps in adjustment of water level and quality[28], pond status etc. Its accuracy rate is 89.2%.
   - **FCM-KM and R-CNN:** It is used for detection and management of pathogens in Rice crops[29]. It can detect blast and bacterial blight diseases. Its accuracy rate is 96.71%.
   - **Decision Tree, K-Nearest Neighbor and Random Forest Algorithms:** It is used for classification and detection of edible and poisonous mushrooms[30]. Its accuracy rate is 100%.

   One latest machine learning algorithm that uses artificial neural network is Deep Learning. It performs automatically without human involvement and provides better trained data. It is popular in livestock monitoring and assessment of its health parameters. It also helps in forecasting the weather pattern.

VI. PRACTICAL IMPLICATIONS TO AUTOMIZE AGRICULTURE USING PRECISION FARMING

1. We can improve agricultural production using various precision farming techniques such as Global Positioning Systems (GPS), Geographic Information Systems (GIS), Remote Sensing (RS), Yield Monitoring, Variable Rate Application (VRA), Yield Mapping, Site-Specific Management Zones (SSMZ) and Crop Modelling.
2. Improving land management at the field scale by better characterizing soil variability and crop properties within-field through mapping soil and crop properties with high resolutions.
3. Delineating site-specific management zones (SSMZ) to get a better explanation of the actual variation within the field and using SSMZ maps to select which production and management strategies plans are required and where they should be placed.
4. Using grid soil sampling and management zone methods for precision farming to collect soil samples.
5. Using various sensors to estimate single soil chemical and physical attributes to reduce costs and improve management zone delineation.
6. Implementing precision farming techniques in developing countries to increase soil and crop production, reduce costs, increase farm profitability, and reduce environmental risks and desertification processes[31].
7. The precision farming can transform the agricultural domain from being manual and static to intelligent and dynamic, leading to higher production with lesser human supervision.
8. precision farming uses soil moisture sensors to measure the exact moisture level in soil, which enables the system to use appropriate quantity of water, avoiding over/under irrigation.
9. The precision farming uses IoT to keep the farmers updated about the status of sprinklers. Information from the sensors is regularly updated on a webpage using GSM-GPRS SIM900A modem through which a farmer can check whether the water sprinklers are ON/OFF at any given time.
10. The sensor readings are transmitted to a Thing speak channel to generate graphs for analysis, which can help farmers make informed decisions about irrigation and crop management.
11. The precision farming can be extended further to other activities in farming such as cattle management, fire detection, and climate control, which would minimalize human intervention in farming activities.
12. This can be controlled remotely by the farmer, who can switch on/off the pump in order to start/stop the process of irrigation without being present at the farm. This feature can be useful in adverse weather conditions or when the farmer needs to stop the system remotely[32,33].

VII. FARM MANAGEMENT STARTUPS AND COMPANIES IN INDIA USING AI AND IOT

Several startups and companies are using AI and analytics to revolutionize the agricultural sector in India. List of some is given as below for the reference of readers.

1. **Ninja Cart:** It was started in 2015. It is a 'B' to 'B' fresh produce supply chain. They focus on connecting farmers to retailers without any mediator. It uses technology and data science to connect farmers to the market with major objective of avoiding food wastage, information barriers, distribution inefficiency, high input cost, low-quality food and elevating the financial condition of farmers. It uses intelligence tools, machine learning methods and deep learning algorithms for forecasting demand.

2. **Cropin:** It was started in 2010. The company utilizes SaaS-based services and connect to business entities through an intelligent, self-evolving and machine learning system. The company uses big data analytics, AI and machine learning. It also provides decision-making tools, live reporting, analysis, and interpretation mechanisms.

3. **Agribolo:** It was started in 2016. It helps farmers in weather forecasting, best farm practices and uses expert systems with AI and facilitates e-mandi services.

4. **Fasal:** It was started in 2018. It is an AI-powered platform and uses data science and AI algorithms to make on-farm predictions, weather forecasting, irrigation management, management of pathogens and pests etc.

5. **Aibono:** It was started in 2014. It is an AI-powered fresh food aggregator and brings a "Seed-to-plate" platform. It uses predictive analytics and precision farming.

6. **DeHaat:** It was started in 2012. It provides AI-enabled technologies, machine learning and targets high-quality agricultural inputs and financial services. It uses predictive analytics to provide early warning solutions for better production and prediction.

7. **Aarav Unmanned Systems:** It is a drone startup incubated at various premier engineering institutions in the country. Their drone systems provide Agri- solutions such as surveying, mapping, precision agriculture using advanced tools.

VIII. CONCLUSION

It is proved that the AI-based farming production is more efficient, profitable and stable compared to traditional farming methods. The availability of remote sensing tools has enabled better topographical studies and efficient control over crop selection with respect to the habitats. It is important to promote AI and IoT based smart farming system to ensure higher crop yields and address the food security issues. Though the initial cost in setting up the system is little higher and not encouraging to middle income farmers, government promotion schemes can share the burden of financial cost. It will boost the production in agricultural sectors and might be responsible for new revolution. A properly managed system supported by laws and legislation could address the data security and privacy issues and can encourage public Private Partnership and enhance the crop production many folds, which is need of time.

REFERENCES

[1] Subeesh, A., Mehta C.R. Automation and digitization of agriculture using artificial intelligence and internet of things. Artif. Intell. Agric. 2021; 5, 278–291.

[2] Ragazou, K., Garefalakis, A., Zafeiriou, E., Passas, I. Agriculture 5.0: A New Strategic Management Mode for a Cut Cost and an Energy Efficient Agriculture Sector. Energies, 2022; 15: 3113.
[3] Pandey A.K., Mukherjee, A. A review on Advances in IoT-based technologies for smart Agricultural system, in: Pattnaik, P.K., Kumar, R., Pal, S. (Eds.), Internet of Things and Analytics for Agriculture, Volume 3, Studies in Big Data. Springer, Singapore. 2022; pp. 29–44.
[4] Treboux J. and Genoud D. Improved machine learning methodology for high precision agriculture," in Proc. Global Internet Things Summit (GIoTS). 2018 pp. 1-6.
[5] Singh D.K. and Sobti R. Role of Internet of Things and machine learning in precision agriculture: A short review," in Proc. 6th Int. Conf. Signal Process., Comput. Control (ISPCC), Oct. 2021; pp. 750-754.
[6] Gobalakrishnan, N., Pradeep, K., et al. A systematic review on image processing and machine learning techniques for detecting plant diseases," in Proc. Int. Conf. Commun. Signal Process. (ICCSP). Jul. 2020; pp. 0465-0468.
[7] Prabha, D.S, Kumar, J.S. Survey on applications of image processing methods in agriculture sector. Proc. Int. Conf Converg. Tech. Jan. 2014; vol. 4 (1): pp. 997-999.
[8] Jhuria, M., Kumar, A., Borse, R. Image processing for smart farming: Detection of disease and fruit grading," in Proc. IEEE 2nd Int. Conf. Image Inf. Process. (ICIIP). Dec. 2013; pp. 521-526.
[9] Lopez-Riquelme, J.A., Pavon-Pulido, N., et al. A software architecture based on FIWARE cloud for precision agriculture. Agricult. Water Manage. 2017; vol. 183: pp. 123-135.
[10] Kassim, M.R.M., Mat, I., and Harun, A.N. Wireless sensor network in precision agriculture application," in Proc. Int. Conf. Comput., Inf. Telecommun. Syst. (CITS). Jul. 2014, pp. 1-5.
[11] Alreshidi, E. Smart sustainable agriculture (SSA) solution underpinned by Internet of Things (IoT) and arti_cial intelligence (AI), Int. J. Adv. Comput. Sci. Appl. 2019; vol. 10:5: 93-102.
[12] Lakhankar, T., Ghedira, M., Temimi, M., Sengupta, M., Khanbilvardi, R., Blake, R. Non-parametric methods for soil moisture retrieval from satellite remote sensing data," Remote Sens. 2019; Vol: 1 (1): 3-21.
[13] Flores, K.O., Butaslac, I.M., Gonzales, J.E.M., Dumlao, S.M.G., Reyes, R.S.J. Precision agriculture monitoring system using wireless sensor network and raspberry pi local server," in Proc. IEEE Region 10 Conf. (TENCON). 2016; 3018-3021.
[14] Goulding, K. W. T. Soil acidification and the importance of liming agricultural soils with particular reference to the United Kingdom. Soil Use Manage. 2016; vol. 32 (3): 390-399.
[15] Peruzzi, A., Frasconi, C., Martelloni, L., Fontanelli, M., Raffaelli, M. A new prototype to perform precision treatments of activated steaming to kill weed seed before sowing of organic vegetable," in Proc. 1st Int. Conf. Robot. Associated High-Technol. Equip. Agricult. Appl. Automated Syst. Robot. Crop Protection Sustain. Precis. Agricult. (RHEA). Pisa, Italy: Univ. of Pisa. 2012; pp. 49-54.
[16] Futagawa, M., Iwasaki, T., Takao, H. et al. Fabrication of a multi-modal sensor with PH, EC and temperature sensing areas for agriculture application," in Proc.IEEE Sensors. 2009; pp. 2013-2016.
[17] Dan L., Xin, C., Chongwei, H., Liangliang, J. Intelligent agriculture greenhouse environment monitoring system based on IoT technology," in Proc. Int. Conf. Intell. Transp., Big Data Smart City. 2015; pp. 487-490.
[18] Martínez, R., Pastor, J., Álvarez, B., Iborra, A. A test bed to evaluate the FIWARE-based IoT platform in the domain of precision agriculture. *Sensors*, 2016; (16:11): p. 1979.
[19] Rajalakshmi, P., and Mahalakshmi, S.D. IoT based crop field monitoring and irrigation automation," in Proc. 10th Int. Conf. Intell. Syst. Control (ISCO). 2016, pp. 1-6.
[20] Khadatkar, A., Mehta, C.R., Sawant, C.P. Application of robotics in changing the future of agriculture. J. Eco-Friendly Agricult. 2022; vol. 17 (1), pp. 48-51.
[21] Xin, J. et al. Design and implementation of intelligent transplanting system based on photoelectric sensor and PLC. Future Gener. Comput. Syst. 2018; vol. 88, pp. 127-139.
[22] Midtiby, H.S., Astrand, B., Jorgensen, B., Jorgensen, R.N. Upper limit for contextual based crop classification in robotic weeding applications. Biosyst. Eng. 2016. vol. 146, pp. 183-192.
[23] Gonzalez-de-Soto et al., Autonomous systems for precise spraying-Evaluation of a robotised patch sprayer. Biosyst. Eng., 2016. vol. 146, pp. 165-182.
[24] Rahmadian R., Widyartono, M. Autonomous robotic in agriculture: A review," in Proc. 3rd Int. Conf. Vocational Educ. Electr. Eng. (ICVEE). Oct. 2020; pp. 1-6.
[25] Paulchamy, B. et al. Implementation of Proficient Agriculture Using IoT With Machine Learning and Mobile Application, in: 2021 Second International Conference on Electronics and Sustainable Communication Systems (ICESC). Presented at the 2021 Second International Conference on Electronics and Sustainable Communication Systems (ICESC). 2021; pp. 1860–1870.

[26] Shakeel, P.M., Aboobaider, B.B.M., Salahuddin, L.B. A deep learning-based cow behaviour recognition scheme for improving cattle behaviour modelling in smart farming. Internet Things, 2022; vol. 19, Art. no. 100539.
[27] Junior, F.M.R., Bianchi, R.A.C., Prati, R.C. et al. Data reduction based on machine learning algorithms for fog computing in IoT smart agriculture. Biosyst. Eng. 2022; vol. 223, pp. 142-158.
[28] Rahman, A., Xi, M., Dabrowski, J.J., McCulloch, J., Arnold, S., Rana, M., George, A., Adcock, M. An integrated framework of sensing, machine learning, and augmented reality for aquaculture prawn farm management. Aquacultural Eng. 2021; vol. 95, Art. no. 102192.
[29] Zhou, G. et al. Rapid detection of Rice disease based on FCM-KM and faster R-CNN fusion. IEEE Access, 2019; vol. 7: pp. 143190-143206.
[30] Paudel, N., Bhatta, J. Mushroom classification using random forest and REP tree classifiers. Nepal J. Math. Sci., 2022; vol. 3 (1): pp. 111-116.
[31] Belal, A.A. et al. Precision farming technologies to increase soil and crop productivity, In Abu-hashim et al (Eds), Agro-Environmental sustainability in MENA regions, Springer Water. Springer International Publishing, Cham. 2021; pp: 117-154.
[32] Thilakarathna, M.S., Raizada, M.N. Challenges in Using Precision Agriculture to Optimize Symbiotic Nitrogen Fixation in Legumes: Progress, Limitations, and Future Improvements Needed in Diagnostic Testing. Agronomy. 2018; 8, 78.
[33] Yazdinejad, A., Zolfaghari, B., Azmoodeh, A., Dehghantanha, A., Karimipour, H., Fraser, E., et al. A Review on Security of Smart Farming and Precision Agriculture: Security Aspects, Attacks, Threats and Countermeasures. Appl. Sci. 2021; 11:7518.

