AI for Sustainable Farming: Revamping India's Agriculture Framework

Hetal M Patel; Dr. Narayan Joshi
Department of MCA, Dharmsinh Desai University, India

Abstract
Agriculture has remained the foundation for survival of human civilization for centuries and before. It has gone through a number of phases of transformations over the human existence timeline. Traditional farming activities like Land preparation, Sowing, Irrigation, Fertilization, Weeding, Pest and Disease control, Harvesting and Post-harvest activities are done manually with minimal automation tools available. Today also farmers face challenges like low productivity, climate change, pests and disease, and scarcity of resources. Artificial Intelligence (AI) has emerged as a transformative force in modern agriculture, offering innovative solutions to address the growing challenges faced by the farming fraternity. This paper explores various applications of AI in the agriculture sector, considering its potential to improve productivity, sustainability, and efficiency of agriculture practices. The key areas of AI implementation in farming include precision farming, crop prediction, pest and disease detection and control, automated irrigation, seeding and harvesting systems, and soil health monitoring. Advanced machine learning techniques and data analytics enables farmers to make informed - data-driven decisions, optimize resource usage, and reduce environmental impacts. Additionally, AI-driven robots and drones are revolutionizing tasks such as planting, sowing, watering, harvesting, pest management and crop monitoring, leading to labour cost savings and improved yields. Despite of providing numerous benefits, the adoption of AI in the agriculture sector faces a number of challenges, including easy access to technology, data privacy issues, technical infrastructure and the need for skilled labour. The paper discusses challenges, future trends, opportunities, and the potential for AI to shape the future of sustainable agricultural practices at the end. As the scope of AI for the agriculture sector continues to evolve, this
paper will help researchers to explore applications of AI in the agriculture sector in depth and develop context-specific AI solutions to address existing challenges in the farming sector. The paper will also help in exploring socio-economic impacts of adapting AI, and considering farmer's education and training for easy adaptation of AI.

Keywords:
Precision Farming, Yield Prediction, Plant Disease and Weeds Detection, Smart Irrigation, and Sustainable Farming

1. Introduction

India has a farm centric economy, and India's agriculture sector is unquestionably the largest livelihood provider in the country, being a major contributor to the country's GDP. An Economic Survey says that the Indian agriculture sector provides livelihood support to about 42.3 percent of the population and has a share of 18.2 per cent in the country's GDP at current prices [20]. With an increasing population, 1.43 billion currently and projected to surpass 1.66 billion in 2050, demand for quality agriculture products is increasing every day and night. Agriculture and farming have been revolutionized by the use of modern tools and technologies and still can highly benefit from Artificial Intelligence. Some of the key branches of AI are Machine Learning (ML), Deep Learning (DL), Robotics, Natural Language Processing (NLP), Neural Networks, Automated Reasoning, Expert Systems, Image Processing and Computer Vision, Speech Recognition, Data Analytics, Virtual Reality, Augmented Reality, Knowledge Representation, Internet of Things (IoT), Cloud Computing, and Statistical Computing [1]. AI techniques offer some very significant advantages in the agriculture sector - like transforming the way farming is practiced by increasing efficiency, sustainability, and profitability, greater crop production, Resource optimization, Pest and Disease detection, optimizing the supply chain by understanding the market demands, cost reduction, surviving environmental changes, and increasing the overall profit. Agriculture is a

DOI: https://doi.org/10.5281/zenodo.18264417

strenuous and demanding occupation. With rising demand for agricultural production, automation is becoming increasingly required. AI can substantially assist farmers in using smart technologies and applications in overcoming labour costs as well [5].

This paper is organized in total five sections: the first section describes the importance and motivation behind exploring applications of AI in Indian agriculture. Section two discusses the crisis and challenges Indian farmer's face in performing farm activities at the grassroots level. The third section outlines applications of AI and allied technologies for dealing with the farmers' challenges and fostering innovation in the agriculture sector. The fourth section highlights a number of difficulties and obstacles may require to be handled in integrating AI with agriculture. The paper concludes noting benefits, flip side and future avenues of using AI for agriculture.

2. Motivation

The evolution of agriculture has changed human lives in the best possible way across time and space starting from being nomadic hunter-gatherer to - settling down at a place doing farming for reliable food supply to – green revolution with use of most advanced technologies which are still expanding towards good. Digital farming is the need of the time for developing countries like India as according to the United Nations' World Population Prospects-2022 [2]; India's population by 2050 is expected to rise to 166.8 Cr. The share of agriculture in total Gross Value Added (GVA) of the economy has declined from 35% in 1990-91 to 15% in 2022-23 as shown in table 1 [3], due to industrial expansion and reduction in farming land area. These reasons have increased the demand for annual food grain production with added challenges like - Indian agriculture is primarily dependent on natural resources, degradation of land, reduction in soil fertility, increased usage of fertilizers/pesticides to increase farm yield, pest outbreak, climate change, dependency on rainwater, which may cause reduced yields of major crops.

Farmers also deal with other issues like high transportation cost including unavailability of transport vehicles and roads in rural areas, inadequate market infrastructure, Lack of knowledge of market trends, Lack of proper storage facilities, and reduction of farming land due to increasing population and industrial development. Artificial Intelligence (AI) is emerging as a powerful tool to address the challenges of sustainable and efficient farming practice. AI systems can be utilized to improve maintenance of soil health with continuous monitoring, improving crop efficiency, weather forecasting, and AI driven Advisory, Diagnostics, Predictive and Prescriptive applications.

Integration of advanced technologies such as advanced sensors coupled with Internet of Things (IoT) could escalate agricultural production and minimize economic loss. A lot of studies have satisfactorily demonstrated the implication of integrated IoT-smart sensors in monitoring environmental factors such as moisture, humidity, temperature, and soil composition that are critical for crop growth. Greenhouse gases such as Carbon dioxide and Methane are also measured through automated sensors. Smart farming also enables measurement of nitrogen contents in soil that helps farmers to determine the quantity of fertilizers to be used in farm lands [4].

Table.1. The share of Agriculture & Allied Sectors in Total GVA of the Indian Economy from 1990-91 to 2022-23

Year	Share of Agriculture & Allied Sector in total GVA (Gross value added)
1990-91	35
2000-01	26
2010-11	18
2020-21	16
2022-23	15

3. Challenges in Agriculture Landscape: A Farmers Perspective

Indian farmers face a plethora of challenges that affect their farm productivity, livelihoods and the overall agricultural sector in turn. Following are the key observations regarding the challenges that the Indian farmers face:

3.1.High Expenditure and Constrained Financial Support and Farmer Fatalities

The cost of seeds, fertilizers, pesticides, and machinery continues to rise, while the income from farming has not kept pace with inflation. This results in mounting debt for many farmers. Many farmers, especially smallholders, struggle to obtain loans from formal financial institutions due to high interest rates and collateral requirements. As a result, they often turn to informal sources with higher interest rates, leading to a cycle of debt [27].

DOI: https://doi.org/10.5281/zenodo.18264417

Financial stress caused by low income, rising debts, and crop failures has led to a rising number of farmer suicides - self harms in India, especially in states like Maharashtra, Andhra Pradesh, and Karnataka [26].

3.2.The Effectiveness of Government Policy and Subsidy

Intermittent government policies, delayed subsidy payments,andinadequate price support mechanisms often leave farmers in financial distress, as policies do not always align with the ground realities of farming [27].

3.3 Inadequate Access to Advanced Tools and Technology

Majority of the Indian farmers still rely on traditional farming methods due to the high cost, lack of awareness and limited access to state-of-the-art agricultural technology. This negatively affects efficiency of farma-processes and reduces overall productivity [29].

3.4 Fragmented Land Holdings and Low Productivity

Indian farms are often small and fragmented in terms of land area, leading to lower productivity. With an average farm size decreasing over the years due to industrial occupation and increasing housing area caused by increasing population, farmers struggle to adopt modern farming techniques as it costs very high compared to the benefits they are going to get from it [28].

3.5 Irregular Monsoon Cycles and Climate Change

Farmers in India are largely dependent on rainwater for irrigation. But monsoon rains can be fickle or insufficient, leading to crop failures or poor yields. Unpredictable conditions make India's agriculture vulnerable to irregular weather patterns, droughts, floods, and ever-changing climate conditions [29].

3.6 Land Degradation and Erosion

Intensive farming practices in order to gain more profit in less time, overuse of fertilizers, pesticides, and herbicides due to lack of awareness of right amount and timings to be applied on the crops, and deforestation have led to erosion and degradation of land and loss of soil fertility. This reduces agricultural productivity and poses long-term risks to farming sustainability [29].

3.7 Post-Harvest Deterioration

Indian villages have poor crop yield storage conditions. Adding to that limited transportation facilities results in spoilage or pest invasion causing considerable amount of post-harvest losses. Substantial amount of the produce is wasted before reaching consumers [30].

3.8 Farmers Literacy Issue and Insufficient Skilled Workforce

Farmers living in rural India have low literacy rates, which limits their ability to access, understand and accept information on new farming practices and government schemes and policies. As a result, they are not able to bank upon the advantages that AI brings.

Young, educated and skilled generation migrates from rural areas to metros and cities in search of better and decent livelihood opportunities. Such migrations create a labour shortage and labour availability issues for various farming tasks such as sowing, irrigation, harvesting, fertilizing, weeding, and pest control. Often too much dependency on seasonal labourers also goes expensive, unworthy and unreliable.

3.9 Inadequate Extension Support

Agricultural awareness and extension services, which provide knowledge and advice about best farming practices, are often insufficient or poorly disseminated. Particularly in India very few effective and enriched programs are available to farmers [21] [22].

3.10 Pests and Disease

Crop damage resulting from pests and various diseases is a common phenomenon in the Indian agriculture system. Indian farmers often struggle with pest infestations, such as Locusts, Rodents, Insects and bird attacks, which can destroy entire crops. Crop disease like Fungal, Bacterial, Viral, Nematode, and many other types depending on the type of the crop also spoils crops. Either or both, if occur, may result in decreased crop produce, poor crop quality, increased vulnerability to secondary infections, defoliation of plant parts, disruption of photosynthesis and nutrient uptake and hence increased cost [35].

3.11 Plant Stress Mitigation

The most prevalent type of stress the plants face is water stress, either due to drought or water logging. Water stress results may result in another stress like insufficient or excessive nutrients. Water stress can cause impaired plant

DOI: https://doi.org/10.5281/zenodo.18264417

growth, reduce photosynthesis. The stress caused by high temperature and low rainfall may increase toxicity symptoms like making the soil saline.
Saline soil reduces availability of water to the crops resulting in dehydration and nutrient imbalances. Another type of stress is due to over-reliance and over-use of pesticides and fertilizers which does not only harm the environment but also reduces soil fertility in the long run [23].

3.12 Challenges to Quality of Food

Maintaining food and nutrient quality in the crop yields is very a challenging task for farmers. The primary reason is crops being continuously tested by extreme weather conditions added to the issues like weeds, insects and disease. Uncensored use of pesticides and herbicides downscales the food quality while drought and flood limits the food supply chain. Precision farming can help in maintaining crop and food quality by smart irrigation facility and automating weed and disease management [36].

3.13 Price Volatility and Market Instability

Indian farmers often face significant instability in market prices for their farma-products due to market inefficiencies, poor storage facilities, and lack of proper market access. This makes it difficult for them to predict income, which can lead to financial instability [31].

3.14.Health Side-Effects from Pesticides

According to a report of the World Health Organization (WHO), around three million cases of pesticide poisoning occur worldwide each year, resulting in nearly 220,000 deaths. Such statistics make the case of pesticide free organic farming stronger. Restrictions have already been implemented on the use of harmful pesticides and prevent their side effects by different countries [13]. But only putting restrictions is not enough to handle the issue completely. Application of technology may play crucial role here by early detection of crop disease and also deciding right timing and amount of pesticides to be used [40].

3.15 Inadequate Access to Advanced Tools and Technology

Many Indian farmers still rely on traditional farming methods due to the high cost and limited access to modern agricultural technology. This hampers efficiency and reduces overall productivity [29].

3.16 Price Volatility and Market Instability

Farmers often face significant price unpredictability for their produce due to market inefficiencies, unavailability of information at the right time, poor storage facilities, and lack of proper market access. This makes it difficult for them to predict income, which can lead to financial instability [31].

4. Reimagining Agriculture with AI: A Path to Solving India's Farming Issues

Farming and Agriculture can highly benefit by incorporating AI powered intelligent solutions often empowered with smart devices such as robots, sensors and drones. Following are the key areas where AI based farming solutions are being designed and employed for uplifting various agricultural practices.

4.1 Sowing and Harvesting

Sowing, also known as seeding is a process of planting seeds in the farmland. Preparation of the soil is required before sowing. Selecting the right amount and quality of seeds, sowing them, and arranging for a good irrigation facility at the right time is another important task that the farmers need to do in advance. Harvesting is getting the yield produced and getting rewards for the hard work of months.
AI based precision agriculture can enable farmers in making smart decisions about optimal time for planting and harvesting the mature yield. AI Robots and Robotic arms can also be utilized to increase speed and accuracy of planting and harvesting.
AI drones equipped with cameras and sensors can be used to monitor crop health, soil health and appearance and progression of the weeds population in the crops. Self-driving tractors can be used as well to perform tasks like ploughing, seeding, and harvesting. The use of Robots, Drones, and automated tractors can reduce labour costs, save time, prevent damaging of the produce and increase efficiency [32].

4.2 Sowing and Harvesting

Sowing, also known as seeding is a process of planting seeds in the farmland. Preparation of the soil is required before sowing. Selecting the right amount and quality of seeds, sowing them, and arranging for a good irrigation facility at the right time is another important task that the farmers need to do in advance. Harvesting is getting the yield produced and getting rewards for the hard work of months.

DOI: https://doi.org/10.5281/zenodo.18264417

AI based precision agriculture can enable farmers in making smart decisions about optimal time for planting and harvesting the mature yield. AI Robots and Robotic arms can also be utilized to increase speed and accuracy of planting and harvesting.

AI drones equipped with cameras and sensors can be used to monitor crop health, soil health and appearance and progression of the weeds population in the crops. Self-driving tractors can be used as well to perform tasks like ploughing, seeding, and harvesting. The use of Robots, Drones, and automated tractors can reduce labour costs, save time, prevent damaging of the produce and increase efficiency [32].

4.3 Managing and Monitoring Soil Health

Soil health is a vital and critical part of successful and sustainable agriculture practice because "Healthy soil grows healthy crops". Soil health is assured by the availability of nutrients like nitrogen, phosphorus, and potassium that plants need to grow. Apart from that water retention capability of the soil ensures adequate moisture for plant growth. Right pH level and good internal structure assures strong root development to enable efficient water and nutrient absorption [37].

Traditional soil analysis methods often rely on manually collected soil samples and laboratory testing. But these techniques are not only time-consuming and labour-intensive but also challenging for large-scale real-time monitoring. AI along with sensors, remote sensing technology, and big data analysis, is able to collect and process large amounts of real-time soil data. Soil data includes soil moisture, temperature, pH value, nutrient value, texture and organic value, helping farmers to fully understand the soil's health condition [9].

AI models can predict the amount of fertilizers and irrigation required considering the type of the soil. Also they can identify different types of soil degradation like erosion, salinization, as well as biological, physical and chemical degradation by analysing weather patterns, rainfall patterns, land usage patterns and soil sensors data [37].

AI modules have given promising results in achieving robustness in soil water content and soil texture analysis [8]. The need for robust, quick, and accurate soil analysis systems using AI technologies holds a great and promising future for sustainable agricultural practices and efficient natural resource management.

4.4 Smart Irrigation And Precision Spraying

India's diverse and extreme weather conditions play a crucial role in agriculture practices followed by the farmers. Most common but opposite resulting situations are drought and waterlogging. AI systems like sensor-based drip irrigation or Robots and drones with cameras can be used for intelligent spraying to save water to deal with drought. AI systems can be trained to ensure the right amount of water the crop needs at the right time in the heated and dry regions, and to stop supply of water to the farm to deal with water logging. These systems can reduce water wastage; enhance crop growth and lower costs of irrigation by utilizing rain water and managing and controlling water usage for the farmers [38].

Sensors and IoT devices can gather information about soil moisture, weather conditions and plant health. This information can be analysed using various AI algorithms to create predictive models for preparing irrigation schedules considering water needs of the crops based on soil moisture level, availability of rain water and type of the crop as different drops have different water requirements at different time and growing stages. AI based algorithms can also control times and amount of water to be sprayed based on real-time conditions, minimizing water waste by irrigating only where and when needed [33].

Smart spraying systems can also be incorporated to enhance application of water, pesticides, herbicides, and fertilizers. AI powered computer vision models can be used to analyse drone captured images to detect pests, stages of disease and nutrient deficiencies. Drones and automated vehicles can navigate through the farm fields directly to apply precise doses of pesticides or fertilizers as and when required. Such practices help in controlling overuse of chemicals promoting healthier crops, healthier soil and higher yields [36].

4.5 Crop Prediction

Indian farming practices are driven majorly by experiences only. Hence crop predictions are done based on the type of the land, availability of water and fertilizers, accessibility to advanced technologies, and farming activities adapted by the respective farmer. Due to less reach of technology amongst the farmers, crop predictions are not supported by real time data, resulting in crop losses more frequently and uneven availability of food for increasing population index [39].

DOI: https://doi.org/10.5281/zenodo.18264417

Leveraging on different AI techniques such as Deep Learning, Computer Vision, Remote Sensing, Farm Robots and Chat Bots, it is possible to make informed decisions, predict crop yields and schedule plans for activities like planting, harvesting, and pest-disease control [39].

AI based agricultural Decision Support Systems can also predict crop failures due to extreme weather conditions, pests, disease at an early stage allowing farmers to take preventive actions and corrective measures [34]. Crop predictions may be affected by pests and weeds. During the growing season, crop management and quality control are largely dependent on climatic events. AI systems using meteorological and soil data, and accurate schedules for fertilizers and pesticides can help in predicting crop yields more precisely [10].

4.6 Identify and Manage Crop Water Stress

Crop water stress is a condition that occurs when plants do not get enough water as and when needed. When a plant's demand for water exceeds the available water supply, it experiences stress which may result in slow growth, reduced yields, degraded fruit quality and reduced quantity, and increased susceptibility to disease and pests. Plants also need water for photosynthesis, transpiration, growth and well-being. There are a number of types of stress like drought, poor irrigation, reduced water absorption ability due to salination of the soil, and extreme weather conditions like increased or decreased temperature as well as poor or extreme rainfall [40].

The plant evapotranspiration is dependent on various atmospheric parameters such as humidity, wind speed, and solar radiations. Other important factors such as the stage of crop growth, plant density, soil properties, and presence of pests can be taken into consideration while implementing an automatic irrigation system to effectively manage supply of water [17].

Precision farming techniques like smart spraying using robots and drones including remote sensing and soil moisture sensors can be used to identify the water stress earlier. Drip irrigation techniques implemented using AI can be used to deal with drought and scarcity of water. [23].

4.7 Analysing Market Trends and Demands

AI can bring huge implications in predicting market trends and demands to manage the agriculture supply chain. AI-enabled solutions may be developed for analysing weather patterns, effects on soil, and crop cycles to predict supply of agro products. They can also analyse market demands and emerging consumer trends for informed decision making in order to fulfil demands. AI can also predict changes in the market demand considering transportation costs, and geopolitical factors.

AI's role in demand forecasting and supply optimization extends beyond mere prediction. It involves a comprehensive analysis of various factors influencing supply and demand, such as market trends, consumer behaviour, weather patterns, and geopolitical events. By processing and analysing large datasets, AI provides a more holistic view of the supply chain, enabling organizations to anticipate changes and respond proactively [19].

4.8 Chatbots for Farmers

The Indian farmer’s community, especially those in rural areas, lacks digital literacy as most of them are unfamiliar with advanced techniques including AI tools designed to optimize crop yield production, crop disease, soil health, and farm-resources management. This is aggravated by limited access to digital infrastructure and high-speed internet.

ChatBots can play a significant role in advising farmers on best practices for planting, irrigation, use of fertilizers, pesticides and herbicides and managing crop and soil health. Farmers can be guided about new sustainable farming techniques, using farming equipment and adopt precision farming through ChatBots.

An agricultural assistance ChatBots can play a crucial role in addressing various issues in the agricultural sector and have a significant impact on resource conservation, minimizing unproductive tasks, and reducing unnecessary expenses. By providing farmers with accurate answers to their queries, this ChatBots empowers them to make informed decisions in a timely manner [15] [24].

4.9 Weed Eradication

Weeds are unwanted plants and grass that grow with real crops. Weeds are considered like diseases as they compete with crops for the resources that are the source of life for the plants like water, sunlight, space and fertilizers and even oxygen as well. Some types of weeds act as hosts for different pests, diseases and pathogens that can negatively impact growing of the crops. As a result, weeds reduce farm productivity, downgrade crop quality, contaminate harvested crops and in some cases harm livestock as well.

DOI: https://doi.org/10.5281/zenodo.18264417

A significant amount of time, effort, and labour costs are required to perform weed management activities like applying herbicides, tilling, or manual removal. AI-enabled computer vision systems utilizing deep learning algorithms can be trained to distinguish and recognize weeds from the crops. The image sources can be images captured using cameras mounted on drones and tractors or clicked by robots. Similarly, for removal of the weeds also autonomous robots can be used. Robots can be programmed to identify the weeds and remove them by pulling or cutting them down and to target weeds only while spraying herbicides reducing the side effects caused by them to the environment and to the human health as well [16].

5 Challenges Of Integrating AI With Agriculture

Integrating AI with agriculture is like a two-edged sword. Along with the number of benefits it provides, it comes up with lots of challenges also at ground level implementation as discussed below:

5.1 The biggest challenge for the Indian farmers in adapting modern technology is incompetency due to low level of education and lack of technical infrastructure. Hence the farmers are unable to understand and use the latest technologies. A strong technological infrastructure can provide a sufficient amount of digital data and the lack of technological infrastructure adds to lack of data as lot of data is needed for any AI system to work and produce precise results and to become useful for making right predictions [36].

5.2 For huge agricultural regions, it is challenging to find real-time data as it is dynamic in nature. Although collection of location-based data is easy, a resilient machine learning model takes time in getting mature due to time required for data collection and training [25].

5.3 AI applications need to be robust in order to investigate a broad range of possibilities to fit in agriculture problem solving and should be able to adapt to changes in the environment, support real-time decision-making and use the proper platform to collect and access relevant data.

5.4 In order to make technology to be accessible at the farm micro level to the common man, solutions have to be made cost-effective. According to an estimate, there are more than 12 crore small and marginal farmers in India, with an average land holding of less than 1.1 hectares only [11]. Due to this Indian farmer have limited finances leaving no additional funds to be invested in technology. Hence, technical solutions are expected to not affect the overall investment cost of the farmers.

5.5 Farmers in India, in general, relies on traditional farming methods followed since centuries which makes them kind of change resistance. Hence most of the farmers have no risk taking attitude making it difficult to adopt use of technology as a part of farming practices. Farmers remain immune to the advantages that the technology brings. It is highly required now that farmers are convinced, guided, trained and financially equipped to using modern AI technologies.

5.6 The introduction of agricultural robots may also have social and ethical implications; such as concerns regarding job displacement in rural groups closely reliant on labour work. The transition to automated structures requires to be managed cautiously to ensure an honest and equitable distribution of the automation [18].

5.7 The Agri-Tech revolution is bringing innovation to farming practices, with over 6,000 agriculture start-ups and 2,800 Agri-Tech start-ups recognized by DPIIT (Department of Promotion of Industry and Internal Trade). The sector contributes approximately 18% to India's GDP [12] and offers a range of tech-based solutions, including digital finance, micro-insurance, access to agricultural inputs, quality testing, traceability and market connect platforms. But fragmented technological infrastructure, high cost of operations, lack of access to data and limited technical expertise, hamper the scale of reach of these technologies to the farm level.

5.8 Extensive data processing and testing of emerging AI applications on the field is very important as agriculture is affected by environmental factors that cannot be controlled. But AI applications can be tested on the field with real time environment conditions only. This too makes it difficult to implement AI on a larger scale.

5.9 The use of sensors, cameras, and other record-gathering technology in agricultural

DOI: https://doi.org/10.5281/zenodo.18264417

robot's increases concerns regarding information protection, confidentiality and privacy. Farmers may be hesitant to adopt those technologies if they are not assured about the safety of farm records such as crop yields, soil situations, and operational practices information.

5.10 Smart agriculture system has the capacity to transform data into some knowledgeable form to be used by the stakeholders to improve decision-making. However, transforming data into some knowledgeable actions requires real-time data and processing. After the evaluation, decision-making process comes with some limitations including accessibility, scalability, interoperability, and uncertainty [14].

6. Conclusion

Artificial Intelligence based tools and techniques for agriculture have the capacity to go beyond the horizons in order to provide promising solutions to farmers' issues and to assure increased productivity, sustainability, profitability and efficiency. The integration of AI techniques such as Computer Vision, IoT, Machine and Deep Learning, Remote Sensing and Robotics represent a transformative step towards addressing the numerous challenges faced by farming industry as it can be used to optimize the use of farmland, enhance precision farming, monitor plant and soil health, predict environmental changes and side effects of pests, weeds and pesticides. These advancements enable the farmers to make data-driven decisions, optimize resource usage, minimize environmental impacts, maximize the yield production and adapt to the changing environmental conditions. AI also helps in developing more resilient and adaptive state of the art agriculture practices, to meet the global demand for food and balance the food supply chain. As AI is incessantly growing and expanding its scope for diversified applications, with right investments in technology, training, and infrastructure its integration into the agriculture sector can bring more innovation, improved food security and creation of a more sustainable agriculture ecosystem. AI applications hold immense potential to revolutionize the entire agriculture value chain and take India closer to achieve one of the important goals, "Productivity and Resilience in Agriculture" of Vikasit Bharat@2047 mission.

References

[1] Press Information Beuro, Government of India, PIB Delhi. https://pib.gov.in/PressReleasePage.aspx?PRID=2034943

[2] United Nations World Population Prospect 2022, https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf

[3] India Environment Portal, Centre for Science and Environment (CSE), public interest research organization based in New Delhi, http://www.indiaenvironmentportal.org.in/files/file/winter_session_2023/Loksabha-Contribution%20of%20Agriculture%20in%20GDP.pdf

[4] Prem Rajak, Abhratanu Ganguly, Satadal Adhikary, Suchandra Bhattacharya, Internet of Things and smart sensors in agriculture: Scopes and challenges, Journal of Agriculture and Food Research, Volume 14, 2023, 100776, ISSN 2666-1543, https://doi.org/10.1016/j.jafr.2023.100776

[5] Mohd Javaid, Abid Haleem, Ibrahim Haleem Khan, Rajiv Suman, Understanding the potential applications of Artificial Intelligence in Agriculture Sector, Advanced Agrochem, Volume 2, Issue 1, 2023, Pages 15-30, ISSN 2773-2371, https://doi.org/10.1016/j.aac.2022.10.001

[6] H. I. Peyal et al., "Plant Disease Classifier: Detection of Dual-Crop Diseases Using Lightweight 2D CNN Architecture," in IEEE Access, vol. 11, pp. 110627-110643, 2023, doi: https://10.1109/ACCESS.2023.3320686

[7] S. K. Noon, M. Amjad, M. A. Qureshi and A. Mannan, "Handling Severity Levels of Multiple Co-Occurring Cotton Plant Diseases Using Improved YOLOX Model," in IEEE Access, vol. 10, pp. 134811-134825, 2022, doi: https://10.1109/ACCESS.2022.3232751

[8] Awais, M., Naqvi, S.M.Z.A., Zhang, H. et al. AI and machine learning for soil analysis: an assessment of sustainable agricultural practices. Bioresour. Bioprocess. 10, 90 (2023). https://doi.org/10.1186/s40643-023-00710-y

[9] H. I. Peyal et al., "Plant Disease Classifier: Detection of Dual-Crop Diseases Using Lightweight 2D CNN Architecture," in IEEE Access, vol. 11, pp. 110627-110643, 2023, doi: https://10.1109/ACCESS.2023.3320686S Liu, "Wi-Fi Energy Detection Testbed (12MTC)," 2023, gitHub repository. [Online]. Available: https://github.com/liustone99/Wi-Fi-Energy-Detection-Testbed-

DOI: https://doi.org/10.5281/zenodo.18264417

[10] Anitha, P. & Chakravarthy, T. (2018). Agricultural Crop Yield Prediction using Artificial Neural Network with Feed Forward Algorithm. International Journal of Computer Sciences and Engineering. 6. 178-181. 10.26438/ijcse/v6i11.178181. Start-up pup India, Government of India. Innovators for Agriculture and Animal Husbandry

[11] Press Information Beuro, Ministry of Agriculture and Farmes Walfare, Government of India, October 2023, https://pib.gov.in/PressReleseDetailm.aspx?PRID=1966430&reg=3&lang=1

[12] Startup India, Innovators For Agriculture And Animal Husbandry, National Starup Awards 2023, Government of India. https://www.startupindia.gov.in/nsa2023results/innovators-for-agriculture-and-animal-husbandry.html#:~:text=The%20Agri%2DTech%20revolution%20is,approximately%2018%25%20to%20India's%20GDP

[13] S. Qazi, B. A. Khawaja and Q. U. Farooq, "IoT-Equipped and AI-Enabled Next Generation Smart Agriculture: A Critical Review, Current Challenges and Future Trends," in *IEEE Access*, vol. 10, pp. 21219-21235, 2022, doi: 10.1109/ACCESS.2022.3152544

[14] Nitin, Department of Computer Science and Engineering, Indira Gandhi University, Meerpur, Rewari, Haryana, India Satinder Bal Gupta Department of Computer Science and Engineering, Indira Gandhi University, Meerpur, Rewari, Haryana, India. Artificial Intelligence in Smart Agriculture: Applications and Challenges. November, 2023. DOI**:** https://doi.org/10.55003/cast.2023.254427

[15] Patha Druva, Nelki Sainithin, Muppa Manisai, K. Sreelatha. Dept. of Electronics and Computer Engineering, Sreenidhi Institute of Science and Technology, Yamnampet, Ghatkesar, Hyderabad, Telangana, India Sreenidhi Institute of Science and Technology, Hyderabad, Telangana, Indiahttps://doi.org/10.22214/ijraset.2023.53180

[16] Eli-Chukwu, N.C. 2019. Applications of Artificial Intelligence in Agriculture: A Review. *Engineering, Technology & Applied Science Research*. 9, 4 (Aug. 2019), 4377–4383. DOI:https://doi.org/10.48084/etasr.2756

[17] Tanha Talaviya, Dhara Shah, Nivedita Patel, Hiteshri Yagnik, Manan Shah, Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides, Artificial Intelligence in Agriculture, Volume 4, 2020, Pages 58-73, ISSN 2589-7217, https://doi.org/10.1016/j.aiia.2020.04.002

[18] Singh, Prajyendu & Sharma, Harshit & Kuntal, Preeti. (2020). Agricultural Robots for Harvesting and Planting. Turkish Journal of Computer and Mathematics Education (TURCOMAT). 11. 1112-1118. 10.61841/turcomat.v11i1.14410

[19] Elufioye, Oluwafunmi & Ike, Chinedu & Odeyemi, Olubusola & Usman, Favour & Mhlongo, Noluthando. (2024). AI-Driven predictive analytics in agricultural supply chains a review: Assessing the benefits and challenges of AI in forecasting demand and optimizing supply in agriculture. Computer Science & IT Research Journal. X. 1-10. 10.51594/csitrj.v5i

[20] Economic Survey 2023-24, Government of India, https://agritech.tnau.ac.in/govt_schemes_services/pdf/Economic%20Survey%20Complete%20PDF.pdf

[21] Sharma, Yogita & Priyadarshi, Shubham. (2024). ARTIFICIAL INTELLIGENCE IN INDIAN AGRICULTURE

[22] Dr. Mukesh Ranga, Institute of Business Management, CSJM University, Kanpur, An Assessment of Impacts of AI Revolution on Agriculture in India, ALOCHANA JOURNAL (ISSN NO:2231-6329) VOLUME 13 ISSUE 2 2024

[23] Chandel, Narendra & Chakraborty, Subir & Rajwade, Yogesh & Dubey, Kumkum & Tiwari, Mukesh Kumar & Jat, Dilip. (2021). Identifying crop water stress using deep learning models. Neural Computing and Applications. 33. 10.1007/s00521-020-05325-4

[24] Anusiya M.1, Buviya R.2, Deva Dharshini M.3, Revathi S.4, Dr.M.Kumar.5 Associate Professor, Chettinad College of Engineering and Technology, Karur (TN), India. Advanced Agriculture ChatBot, 2024 IJCRT, Volume 12, Issue 4 April 2024

[25] AI in agriculture: Opportunities and Challenges, Grain Data Solutions, https://graindatasolutions.com/data-science-artificial-intelligence-applications-agricultural-practices-opportunities-challenges/

[26] Dominic Merriott, Factors associated with the farmer suicide crisis in India, Journal of Epidemiology and Global Health, Volume 6, Issue 4, 2016, Pages 217-227, ISSN 2210-6006, https://doi.org/10.1016/j.jegh.2016.03.003

[27] Deveshwar, Aarti & Panwar, Saloni. (2024). Overview of Agricultural Subsidies in India and Its Impact on Environment. Current World Environment. 19. 393-403. 10.12944/CWE.19.1.33.De, L. C., Tulipa De, R. K. Pamarthi and Singh, R. K. 2019. Agri-

DOI: https://doi.org/10.5281/zenodo.18264417

Horticultural Interventions for Doubling of Farmer's Income.*Int.J.Curr.Microbiol.App.Sci*. 8(12): 1414-1425. doi: https://doi.org/10.20546/ijcmas.2019.812.171

[28] De, L. C., Tulipa De, R. K. Pamarthi and Singh, R. K. 2019. Agri-Horticultural Interventions for Doubling of Farmer's Income.*Int.J.Curr.Microbiol.App.Sci*. 8(12): 1414-1425. doi: https://doi.org/10.20546/ijcmas.2019.812.171

[29] Ramanna Havinal, 2020, The Role and Potential of Information Technology in Agricultural Development, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 09, Issue 07 (July 2020)

[30] Food and Agriculture Organization of United Nations, Post-Harvest Losses, https://www.fao.org/4/t0522e/t0522e04.htm

[31] National Bank for Agriculture and Rural Development, Volatility in TOP and Role of Agri Value Chain, June 2023, Issue No: 02, https://www.nabard.org/auth/writereaddata/tender/pub_270623091211322.pdf

[32] Manas Wakchaure, B.K. Patle, A.K. Mahindrakar, Application of AI techniques and robotics in agriculture: A review, Artificial Intelligence in the Life Sciences, Volume 3, 2023, 100057, ISSN 2667-3185, https://doi.org/10.1016/j.ailsci.2023.100057.

[33] K. Lochan, A. Khan, I. Elsayed, B. Suthar, L. Seneviratne and I. Hussain, "Advancements in Precision Spraying of Agricultural Robots: A Comprehensive Review," in *IEEE Access*, vol. 12, pp. 129447-129483, 2024, doi: 10.1109/ACCESS.2024.3450904

[34] M. J. Hoque *et al*., "Incorporating Meteorological Data and Pesticide Information to Forecast Crop Yields Using Machine Learning," in *IEEE Access*, vol. 12, pp. 47768-47786, 2024, doi: 10.1109/ACCESS.2024.3383309

[35] [35] Karthik, A. Ajay, A. Singh Bisht, T. Illakiya and K. Suganthi, "A Deep Learning Approach for Crop Disease and Pest Classification Using Swin Transformer and Dual-Attention Multi-Scale Fusion Network," in IEEE Access, vol. 12, pp. 152639-152655, 2024, doi: 10.1109/ACCESS.2024.3481675

[36] Indian Council of Agricultural Research, Annual Report 2023-24, https://icar.org.in/sites/default/files/2024-09/ICAR%20Eng%20AR_2023-24%20for%20web.pdf

[37] Lloyd Miner, Grace & Delgado, Jorge & Ippolito, Jim & Stewart, Catherine. (2020). Soil health management practices and crop productivity. Agricultural & Environmental Letters. 5. 10.1002/ael2.20023.

[38] TY - JOUR AU - A, Srinivas AU - Sangeetha, J PY - 2021/01/01. SP - T1 - Smart Irrigation and Precision Farming of Paddy Field using Unmanned Ground Vehicle and Internet of Things System VL - 12 DO - 10.14569/IJACSA.2021.0121254 JO - International Journal of Advanced Computer Science and ApplicationsER.

[39] Md. Abu Jabed, Masrah Azrifah Azmi Murad, Crop yield prediction in agriculture: A comprehensive review of machine learning and deep learning approaches, with insights for future research and sustainability, Heliyon, Volume 10, Issue 24, 2024, e40836, ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2024.e40836.

[40] Lehouel, K.; Saber, C.; Bouziani, M.; Yaagoubi, R. Remote Sensing Crop Water Stress Determination Using CNN-ViT Architecture. *AI* 2024, *5*, 618-634. https://doi.org/10.3390/ai5020033

[41] TÜRKOĞLU, MUAMMER and HANBAY, DAVUT (2019) "Plant disease and pest detection using deep learning-based features," *Turkish Journal of Electrical Engineering and Computer Sciences*: Vol. 27: No. 3, Article 6. https://doi.org/10.3906/elk-1809-181

DOI: https://doi.org/10.5281/zenodo.18264417