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A Review on Application of AI & ML Techniques in Indian Agriculture Sector

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Abstract--

Keywords*-- Artificial Intelligence (AI), Machine Learning (ML), Indian Agriculture, Precision Farming, Crop Monitoring, Supply Chain Management. Agriculture remains a cornerstone of the Indian economy, contributing significantly to employment, food security, and export earnings. However, the sector faces persistent challenges such as climate change, declining productivity, water scarcity, fragmented landholdings, and limited access to markets and finance. In this context, emerging digital technologies—particularly Artificial Intelligence (AI) and Machine Learning (ML)—offer transformative potential to enhance agricultural efficiency, sustainability, and profitability. This review paper examines the application of AI and ML techniques across the entire agricultural value chain in India, including planning, crop selection, soil preparation, precision farming, monitoring, harvesting, post-harvest management, and supply chain optimization. The study highlights real-world initiatives such as AI-enabled sowing advisory systems, precision agriculture using drones and sensors, soil fertility assessment tools, AI-based quality grading, and digital Agri-logistics platforms. Successful implementations like the Saagu-Baagu project and emerging Agri-fintech and Agri tech startups demonstrate the practical viability of these technologies. The paper also discusses key challenges hindering large-scale adoption, including high costs, lack of awareness, infrastructure limitations, and the complexity of diverse climatic conditions. The review concludes that while AI and ML hold immense promise for revolutionizing Indian agriculture, inclusive deployment strategies, policy support, farmer education, and affordable technology models are essential to ensure widespread adoption and sustainable agricultural growth.

I. INTRODUCTION

The agriculture sector plays an important role in India's economy and food security. It's one of the major contributors of our GDP. Its share has been declining due to growth in other sectors but still the largest workforce of our country is employed in this sector. Ensuring food security of population is very important for overall stability of a country. In India, staple products such as rice, wheat pulses and vegetables are produced on a large scale. Due to diversified climate conditions, India produces fruits, spices, cash crops such as sugarcane and cotton other than cereals. It is one the significant generators of export earnings for the country.

India is one of the major exporters of spices, tea, coffee, fruits etc to international markets. Many industries such as textiles, pharmaceuticals are depending on the agriculture sector for raw materials. The growth of the agriculture sector is closely linked to the overall growth of rural development and other businesses such as Agri-business, rural entrepreneurship etc. Our nation's culture is rooted in agriculture as many traditions and festivals are linked to agriculture.

Despite its importance, there are many challenges such as climate changes, outdated farming practices, water scarcity, low productivity, sub-optimal farm mechanisms, affordable finance, direct market access etc. According to the Economic Survey Report 2022-23, the agriculture growth rate has fallen to 3 per cent in 2021-22 from 3.3 per cent in 2020-21 and it also points out that the sector needs "re-orientation" in the backdrop of challenges. The adoption of modern technologies such as Artificial intelligence (AI) and Machine learning (ML) along with IoT, block chain and cloud computing can enhance the productivity and efficiency of the agriculture sector.

AI and ML techniques can be deployed in many activities of the cultivation process of a crop to optimize output. The cultivation process of the crop is broadly divided into - Planning, Cultivation and monitoring, harvesting and trading.AI and M L techniques along with IoT and Block chain can be used in all stages of cultivation of crops. AI techniques such as automated systems can be used for many tasks related to farming (Talaviya et al,2020). ML techniques can be implemented in all stages of the farming and help farmers to reduce their losses (Meshram et al,2021).

Saagu -Baagu (agricultural advancement) project launched in 2021, is the first kind in India of public private collaboration with Telangana state government, world economic forum, Agri tech industry and the start-up companies under state initiative of AI4AI (AI for agriculture innovation). Through this project Chilli farmers from Khamman,Telangana are able to receive the fast-track quality report of Chilli which checks the chemical content, moisture and physical content using an AI algorithm. It has impacted 7000 Chilli farmer's by providing them access to AI based agritech for soil testing, quality testing and e-commerce.

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AI and ML tools along with Industry 4.0 tools such as cloud computing, IoT, block chain has transformed many sectors and there are lot of potential to revolutionize Indian agriculture sector.

II. Systematic Agricultural Planning

A systematic approach for agricultural planning can be broadly divided into:

- *Financial Planning:* Financial planning is the crucial part of successful farming. It includes budgeting, risk management, cash flow management, income projection etc. Big data, IoT, and Fintech are essential technologies used for good-sized statistics and assist agricultural practitioners in recognizing farming practices and making specific decisions (More et al, 2022). Agri-Fintech companies can give farmers customized solutions to tackle their finances. Agri-Fintech refers to those financial companies which use technology such as AI, IoT, block chain to finance farmers and value chain. They have a data driven approach, market linkages, partnerships and lending strategies to increase the profitability of the farm. These companies have huge potential in Indian markets as 126 million small farmers are not able to obtain the credit easily despite having priority sector lending. There are some Agri-fintech companies in the Indian market such as Jay kisan, Mumbai based Agri-Fintech startup company provide loans to small farmers to purchase farming equipment at interest rates from 8% to 24%. They provide the loan against the productive assets which repossessed in case default and collected data of farmers used for credit score.
- *Crop selection:* Crop selection is an important decision in agriculture and it has a direct impact on the success and profitability of farming. Crop selection is dependent on climate, Soil type, water availability, market demand etc. The paper on "Machine Learning Approach for Crop Selection based on Agro-Climatic Conditions'(Vishwa et al,2019) proposes an algorithm named crop variety selection method (CSVM) to predict the yield of crops. It has three parts - Crop selection, market price and crop variety selection. Artificial neuron networks are used to predict yield rate of the crop. After selecting the crop and checking the crop will give maximum profit for the current market and environment. Then, check which variety of crop will be suitable for the current season. By collecting the data of growth rate variety of a crop, AI can help to identify the variety of the crop that are less prone to disease and well adapted to weather condition. Seed-X is a company which uses AI to collect genomic information of the seeds and produce seeds which give optimized results.
- *Soil Preparation:* Soil preparation is the crucial step which includes plowing debris cleaning, leveling, harrowing etc. One of the important steps after this is testing soil to determine the nutrient level, pH and texture. Many decisions such as crop selection, fertilizer and soil amendment are dependent on it. AI & ML tools can be used to monitor the soil quality and farmers able to get recommendations about crops and fertilizers and nutrients for suggested crops. Brazilian startup company named InCeres developed a app which predict the fertility of the soil based on AI analysis of the chemical content, weather condition, satellite images showing plant growth rate and crop type. This app conducts the analysis of the soil in a cost effective and profitable way for the farmers. The paper "An AI solution for Soil Fertility and Crop Friendliness Detection and Monitoring" (Varshitha et al,2021) proposes an approach based on Deep learning, AI techniques and IoT features for Indian soil. This algorithm suggests the soil quality and also gives recommendations for the right crop to be sowed. The recommendation for fertilizers and nutrients also provided as per crop. The recommendations are sent on the farmer's phone and it's a cost-effective process for farmers.

Effective Farming and Appropriate Monitoring

Effective farming and appropriate monitoring of crops is the way towards sound agricultural practices. The key steps include effective farming and monitoring are:

- *Sowing time:* It refers to the appropriate time to sow seed in the soil and to harvest a good crop. The sowing time depends on various factors such as climate conditions, soil condition, crop variety, market demand etc. Microsoft has developed an AI -sowing App in collaboration with International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) for Indian farmers. Around 4000 farmers from Andhra pradesh and Karnataka provided insights of sowing time for the kharif crop cycle (rainy season). Using ML Algorithm based on the variables such as climate condition, moisture content, pH level, and nutrient content of soil able to offer insights to farmers regarding best time to sow, water and fertilize their crops (Elbasi et al,2023).
- *Precision farming:* The farming used the modern technology and farm management based on information technology, data collection and analysis of soil, crop health and environmental parameters using sensors, drones, satellite images etc, usages of Automated machine and robots, precision irrational based on sensors, crop monitoring and health management using drones and satellite images.

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Application ML algorithm Regression analysis is used to predict the crop yield based weather patterns, soil condition, irrigation management. The models can be built by accessing past years data to predict the yield of crops. Decision trees can be used to classify the variety of crops based on growth and optimal yield. Deep Learning techniques based on neural networks can be used to classify images captured from drones and satellites. German Federal Ministry for Economic Affairs and Energy has recently funded the large scale NaLamKI initiative, which aims at developing a cloud based Software as a Service (SaaS) platform with open interfaces for providers from the upstream and downstream sectors of agriculture, industry, and service providers for special applications in crop production and also aims at the creation of a dataset by the fusion of sensor data from machines, remote sensing (satellites and drones), soil, weather and other existing data sources so that agricultural processes like irrigation, fertilization, or pest control can be optimized thanks to the application of advanced AI methodologies(Linaza et a1,2022). Application of Drones in Indian agriculture has a lot of potential, it provides real time image and high-quality aerial image compared to satellites. Applications of drones are localizing weeds and diseases, determining soil properties, detecting vegetation differences and the production of accurate elevation models (Gupta et al,2022). In Rajasthan, locust swarm attack of crops was tackled by spraying pesticides using drones. KissanGPT is an AI chatbot for Indian farmers launched in March 2023 which provides guidance to farmers about irrigation, pests control and crop cultivation.

III. Harvesting And Supply Chain Management

Harvesting and supply chain management is the one critical component of agriculture and involves many procedures to ensure efficient production and distribution of the product to the end customer or market. These processes involved are timing of the harvesting, post -harvest handling, storage, quality control, transportation, processing, distribution etc.

- *Timely harvesting:* AI can be applied for timely harvest by processing the image of the color and shape of the crop and determining the maturity of the crop. This in turn determined the correct time for harvesting. In 2025, AI-driven timely harvesting in India is a critical component of precision agriculture, shifting from traditional manual estimation to data-led decisions that maximize crop quality and profitability. By integrating satellite imagery, IoT sensors, and machine learning, farmers can now identify the exact peak maturity window for their crops.
- *Post- harvest processing and storage:* Once the harvesting is completed, crops need to be handled properly to prevent spoilage and stored properly. Post-harvesting crops can be graded and sorted using AI technique. Integration of AI technique with IoT based sensors, block chain can be deployed for monitoring the storage system of crops especially cold storage system.AI-powered robots are being deployed to address labor shortages. These machines use computer vision to distinguish between ripe and unripe produce, performing non-destructive harvesting for crops like legumes.
- *Quality Control:* It includes the inspection, testing and certification of the agriproduct. The traditional way of performing the quality control is very time consuming and it impacts the profitability of farmers. To tackle this problem, ML and computer vision enabled quality checking of agriproducts are paving their way. By training the ML models on a large training dataset, computer vision is able to recognize the patterns and provide accurate quality checks based on visual features. Startups like AgNext and Intello Labs use computer vision to analyze and grade the quality of harvested produce (fruits, grains, vegetables) in real-time, helping farmers secure better market prices.
- *Supply chain management:* AI can minimize the delays and losses in India's Agricultural supply chain by providing real -time data, demand forecasting and route optimization for improving logistics. A technology platform DeHaat links the small holder farmer with institutional buyers. It helps farmers to make smart decisions where to sell the crops and when to sell the crops so that losses can be reduced due to market fluctuation and hence increase the profitability. It also helps to streamline the supply chain by managing the logistics and storage and reducing the waste. To facilitate logistics to farmers, the government introduced the Kisan Rathe mobile application which helps farmers , Farmer produce organizations and trader hiring for transportation of agriproduct. The app uses data-driven algorithms to manage a massive network of over 5 lakh trucks and 20,000 tractors. AI helps in matching farmers' transport requirements with available vehicles in real-time to ensure the timely movement of perishable goods and reduce post-harvest losses. The app is supported by AI based chatbot Kisab - e- Mitra which assists farmers in multiple regional languages able to handle 20000 query regarding government schemes at time and providing real time support.

The study found that the use of Digital platform and AI in Indian Agro-Logistics has a very viable future for improving operation efficiency, cost. cutting, and quality control of products in the chain of supply (Lakhotia,2024)

IV. CHALLENGES

The main challenge in integrating machine learning and AI into agriculture is not the lack of expertise among agricultural scientists, but rather the variability in physical environments. These variations make testing, validating, and deploying these technologies more complex. While human intervention can often address problems with greater precision than AI, the goal is to alleviate the labor-intensive aspects of farming, and here, AI and machine learning offer significant potential—from soil preparation to post-harvest processing.

From a farmer's point of view, AI may seem like something only relevant in the digital realm, with little application in the actual field. The lack of awareness about AI's benefits, combined with high implementation costs, often creates barriers to adoption. Small landholders face challenges such as irregular terrain, making it difficult to use precision agriculture tools effectively. Since many small-scale farmers can't afford expensive AI technologies or unmanned aerial vehicles (UAVs), they continue with traditional farming methods. In contrast, larger farming operations—those with over 5 hectares of land—are more likely to embrace precision agriculture and even offer these technologies for rent through custom hiring services.

V. CONCLUSION

The review highlights that artificial intelligence (AI) and machine learning (ML) have immense potential to transform the Indian agriculture sector by improving productivity, resource-use efficiency, and decision-making across the entire agricultural value chain. Applications such as crop and soil monitoring, yield prediction, pest and disease detection, precision irrigation, and post-harvest management demonstrate how data-driven technologies can support sustainable and climate-resilient farming practices.

However, the large diversity in agro-climatic conditions, small and fragmented landholdings, limited digital infrastructure, and low awareness among farmers pose significant challenges to widespread adoption. High implementation costs and the need for reliable field-level data further restrict the use of advanced AI-driven tools, particularly for small and marginal farmers.

These constraints indicate that technological capability alone is insufficient without supportive policies, farmer education, and accessible deployment models.

To realize the full benefits of AI and ML in Indian agriculture, collaborative efforts among researchers, policymakers, technology developers, and farming communities are essential. Promoting affordable solutions, strengthening digital literacy, encouraging community-based and custom-hiring models, and integrating local knowledge with AI systems can bridge the gap between innovation and practical adoption. With targeted investments and inclusive strategies, AI and ML can play a pivotal role in ensuring food security, enhancing farmer livelihoods, and achieving sustainable agricultural growth in India.

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