

Artificial Intelligence (AI) and Machine Learning (ML) for Sustainable Agriculture

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ABSTRACT

Agriculture is backbone of our nation's economy. It is the main source of livelihood for about the majority of the population of India, particularly in rural areas. With the advancement of technology this sector is revolutionizing at fast speed. Artificial intelligence is playing a vital role in transformation of agriculture to Smart Agriculture. Artificial intelligence (AI) uses various sub-domains as Machine Learning (ML), Deep learning (DL), Internet Of Things (IoT), Big Data etc to enhance the production of agriculture. With growing population, It is essential to increase the productivity of agricultural and farming processes to improve yields and cost-effectiveness with new technology. In particular, AI & ML can make agricultural and farming industry processes more efficient by reducing human intervention through automation. AI can help farmers in growing the crop, Watering and fertilizing according to need and detecting the health of crop with precision so we can also call it as Precision Farming. It Justifies that smart agriculture can give a good solution for today's problem. This article will discuss recent AI & ML technologies and their current role in the agricultural sector, their potential value for future farmers and the challenges that AI & ML faces in implementation.

Keywords: Artificial intelligence, Machine learning, Internet of Things, Big Data, Precision Farming, Smart Agriculture

INTRODUCTION

India is an agricultural country as agriculture and its associated activities are the main livelihoods for 80% of rural India's population. Therefore, it is the core of India's economy. Agriculture activities produce food, energy, and medicine and many more things to mankind. With the global population projected to exceed 9 billion by 2050, it will be critical to optimize agricultural production and food supply chains to more efficiently produce and deliver food, fiber and fuel to meet growing [1]. At present time, the agriculture sector is facing several challenges such climate change, increasing population, increasing labor shortages, land and water constraints, increasing urbanization, environmental degradation etc. So these big challenges can be dealt with by adopting latest technologies such as Artificial Intelligence (AI), Machine Learning (ML), Internet of Things (IoT), Cloud Computing, Big Data, GPS technology, satellites, Drones, Robots. AI & ML are new digital revolution to agriculture after Green Revolution. These technologies help to get information about soil, weather, climate, crop, etc which is used for further decision making.

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

Artificial Intelligence

The term Artificial Intelligence also shortly known as AI is combination of two words Artificial (means man made) and Intelligence (means thinking ability). So Artificial Intelligence is the man made ability of machines to think or take decisions. So Artificial intelligence (AI) is technology that allows machines to

simulate human intelligence. We are used to AI examples as chatbots, virtual assistants and self-driving cars in present time. AI, started with Alan Turing's work in the 1950s, but the term "Artificial Intelligence (AI)" was given by John McCarthy in 1956 at the Dartmouth Workshop, marking the formal birth of the field. Early AI was focused on symbolic reasoning and logic, but present AI can be used to help make decisions, solve problems and perform tasks that are normally accomplished by humans. AI systems learn how to do so by processing massive amounts of data and looking for patterns. First, a vast amount of data is collected and applied to models, which use the information to recognize patterns and make predictions in a process known as training. Once algorithms have been trained, they are deployed within various applications, where they continuously learn from and adapt to new data. So in this way, AI systems learn to perform complex tasks such as image recognition, language processing and data analysis with greater accuracy and efficiency as human.

Machine Learning

Machine learning (ML) is a branch of artificial intelligence (AI) that enables computers to learn and make predictions or decisions without being explicitly programmed, by analyzing data and identifying patterns. So Machine learning focuses on developing algorithms that can learn from data and improve their performance over time. Data is the foundation of machine learning (ML). Without quality data, ML models cannot learn, perform, or make accurate predictions. Machine learning is used in various applications, including image and speech recognition, natural language processing, and recommender systems.

Types of Machine Learning-

1. **Supervised Learning:** Algorithms learn from labeled data (where the input and output are known) to make predictions. Common Algorithms of this type are- **Linear Regression, Logistic Regression, Support Vector Machines (SVM), Decision Trees, Naive Bayes, K-Nearest Neighbors (KNN)** etc.
2. **Unsupervised Learning:** Algorithms learn from unlabeled data to discover patterns and structures. Common Algorithms of this type are- **K-means Clustering, Principal Component Analysis (PCA), Association Rule Mining** etc.
3. **Reinforcement Learning:** Algorithms learn through trial and error to achieve a specific goal. Common Algorithms of this type are- **Q-learning, SARSA** etc.

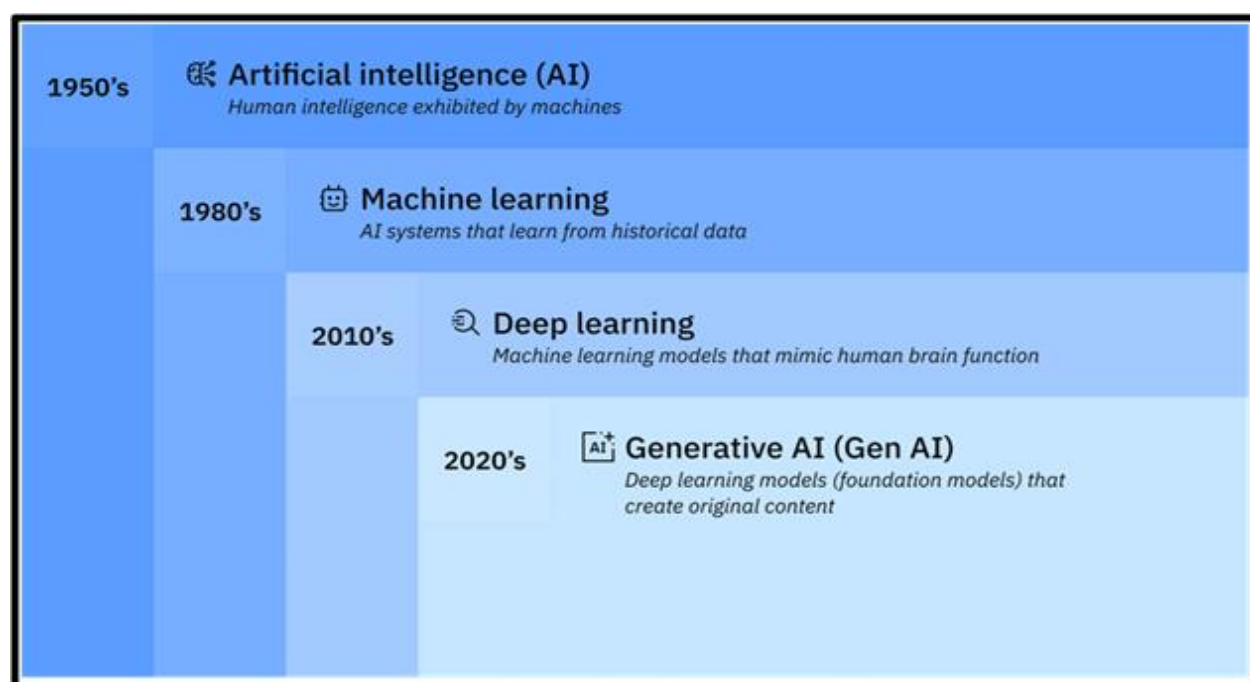


Fig 1-Relationship Between AI, ML, DL & Gen AI

ROLE OF AI & ML IN AGRICULTURE

As we know that Agriculture life cycle starts from land preparation for the crop followed by seed sowing, irrigation, weeding, fertilizer, disease detection & management, harvesting, post-harvest processing, storage and marketing. Various AI techniques have the potential to affect and improve all the phases of the life cycle, some of which are already available and some still need to be worked on. In an ideal smart eco system, a farmer would be guided by an artificially intelligent assistant that would suggest the most appropriate date and method to prepare the land based on the GIS and remote sensing data of that region [2]. The Internet of Things (IoT) is a system consisted of computing devices, mechanical machines and various objects that are interrelated, and each is provided with a unique identifier and possesses the capability of data transfer. IoT is an advancement built on several existing technology, such as wireless sensor networks (WSNs), cloud computing and RF identification. IoT can be applied in manifold fields, such as monitoring, precision agriculture, tracking and tracing, greenhouse production and agricultural machinery [3]. AI and machine learning are transforming agriculture, enabling precision farming optimizing resource usage, and improving crop health and yield through technologies like crop monitoring, disease detection, and automated tasks.

Crop Monitoring:

Standard farming past times requires that farmers need to visit the agriculture sites frequently throughout the crop life to have a better idea about the crop conditions. But by AI & ML, smart agriculture 70% of farming monitoring work can be done by AI & IoT. So AI plays a vital role here to check growth of crop without visiting.

AI-powered systems, including drones and satellite imagery, monitor crop health and growth, enabling early detection of problems like diseases, pests, and nutrient deficiencies.

Soil Management :

The important factor of agriculture field assessment such as soil status prediction, soil salinity, soil pH level, Soil nitrogen level prediction, temperature update, humidity prediction and crop yield prediction and many more application in today world [4]. AI and ML algorithms analyze soil data (moisture, pH, nutrients) to optimize irrigation and fertilization, leading to efficient water and fertilizer use. Devices like fertility meter and PH meter are set up on the field to determine the fertility of the soil by detecting the percentage of the primary ingredients of the soil like potassium, phosphorous, nitrogen[5].

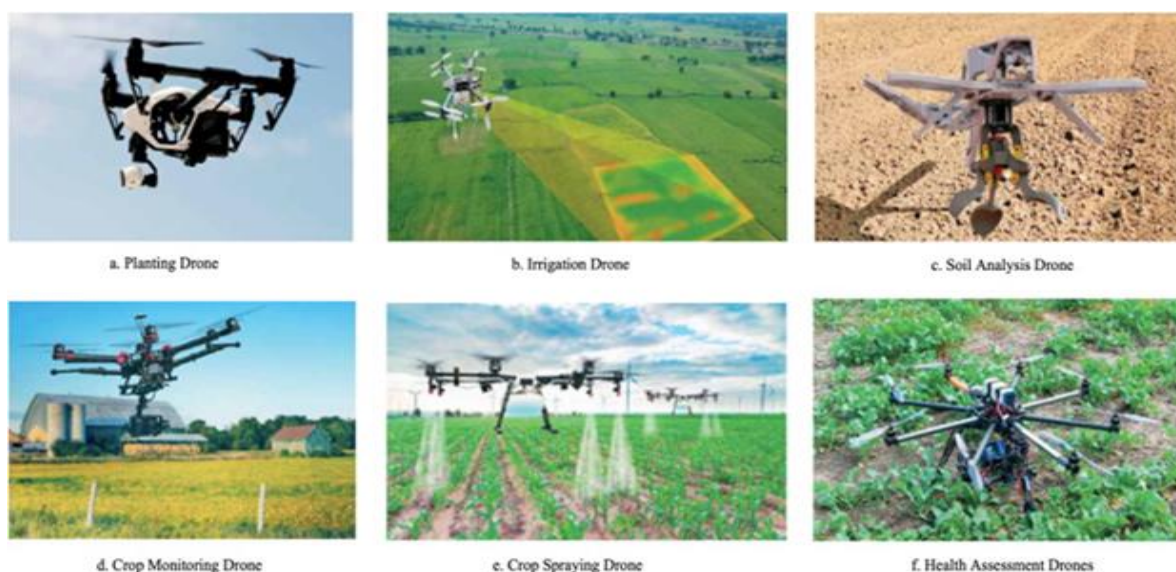


Fig 2- AI & ML IN Agriculture [5]

Water Management

The agriculture sector consumes most of the available freshwater resources and this percentage is increasing rapidly with the population growth and with the increase in food demand. So, its need of the time, to come up with more efficient technologies in order to ensure proper use of water resources in irrigation. The manual irrigation, which was based on soil water measurement was replaced by automatic irrigation scheduling techniques[5]. AI & ML based methods can be helpful for water or irrigation management of a crop. The IoT based sensors will sense water level in the soil and according to results informs the farmers about water level of crop. So this technique basically saves wastage of water also, because irrigation will be done according to need of the crop.

Predictive Analytics

Machine learning models can predict crop yields, optimize planting schedules, and forecast potential problems, allowing farmers to make informed decisions. Yield prediction, one of the most significant topics in precision agriculture, is of high importance for yield estimation, matching of crop supply with demand, and crop management.

Weed Detection

Weed detection and removing is another significant problem in agriculture which required skilled labor. Again, ML algorithms in conjunction with sensors can lead to accurate detection and discrimination of weeds with low cost and with no environmental issues and side effects. ML for weed detection can enable the development of tools and robots to destroy weeds, which minimize the need for herbicides [6].

Disease Detection

AI algorithms can analyze images and sensor data to identify diseases in a crop. So enabling timely treatment of the crop can be done by pesticides. So this will reduce the excess use of pesticides by timely information. Usually, remote sensing imagery covers large areas and, hence, offers higher efficiency with lower cost.

Pest Management

AI-powered systems can identify and track pest populations, allowing for targeted pest control measures and reducing the environmental impact of pesticides.

Automated Agriculture Activities:

Agricultural work is hard, so labor shortages is obvious in farming. AI-powered automated robots and drones can be helpful this. Automated farm machinery like driverless tractors, smart irrigation robots, fertilization robots, IoT-powered agricultural drones, smart spraying, harvesting robots etc are just some examples. Compared with any human farm worker, AI-driven tools are more efficient and accurate and it will reduce labor costs as well.

Robotic Harvesting and Planting

AI-powered robots and drones can automate tasks like harvesting, planting by improving efficiency and reducing labor costs.

Data Analysis Recommender Systems

AI algorithms can process large amounts of data from various sources (sensors, satellites, weather stations) to provide farmers with valuable insights. AI-powered systems can provide farmers with personalized recommendations for crop management, fertilization, and pest control.

Livestock Management

Animal (livestock and aquatic) production is a crucial part of agriculture, not only because it provides food and dairy products, but it also supplies other high-quality goods, such as wool and leather. Sensor-based animal wearables, computer vision systems, and other detection devices can capture the status of animals and environment in real time, which can be analysed afterwards with the aid of AI-based mechanisms to control and predict animals' health, welfare, production, etc[7].

Benefits of AI & ML in Agriculture

Increased Efficiency

AI based technologies can be helpful in each and every step in life cycle of a crop. AI & ML can automate tasks, optimize resource usage, and improve overall farm efficiency.

Reduced Costs

AI based technologies can be helpful for farmers to reduce costs by optimizing resource usage, automation of activities, minimizing waste and improving yield. Most importantly by automation of activities labor cost is saved as agriculture is labor based activity and lack of labor was a big issue due to this sometimes yield of crops get affected.

Improved Sustainability

AI can help farmers adopt more sustainable practices by optimizing resource usage and reducing the environmental impact of agriculture.

Enhanced Food Security

As population is increasing at fast pace, obviously food demands will increase in future. By improving crop yields and reducing food waste, AI can contribute to global food security.

Challenges in Smart Agriculture

Despite the promising potential of Artificial Intelligence (AI) in agriculture, the practical application of AI-based techniques faces several challenges. Understanding and addressing these challenges are crucial for successful implementation and adoption of AI technologies in the agricultural sector.

Limited Access to Technology:

One of the primary challenges is the limited access to AI technology, particularly among small-scale and rural area farmers. The high costs of acquiring and implementing AI solutions, including hardware, software, and data connectivity is a big issue.

Data Quality and Availability:

AI algorithms heavily rely on high-quality and extensive datasets for training and decision-making. In agriculture, the availability of accurate and diverse datasets can be a challenge. Issues such as inconsistent data quality, limited historical records, and variability in data formats pose obstacles to the development of robust AI models.

Interoperability and Standardization:

The agricultural sector comprises a variety of equipment, sensors, and software solutions from different vendors. Ensuring interoperability and standardization of AI-based technologies is a significant challenge.[3]

The lack of standardized data formats and communication protocols hinders seamless integration of AI tools into existing farming practices.

User Acceptance and Education:

Farmers may face problems to adopting AI technologies due to a lack of understanding or familiarity. The complexity of AI systems and the need for specialized knowledge may be obstacle for users from embracing these tools. Effective education and training programs are essential.

Data Privacy and Security Concerns:

Agriculture involves sensitive data related to crop performance, soil conditions, and farm management practices. Concerns about data privacy and security

are significant barriers as farmers may be hesitant to share their data due to fears of misuse or unauthorized access.

Ethical Considerations and Bias:

As AI algorithms learn from historical data, there is a risk of perpetuating biases present in that data. In agriculture, this could lead to biased recommendations or decisions, impacting resource distribution and outcomes. So ethical considerations and ensuring fairness in AI applications

is crucial to building trust and adoption of AI in agriculture.

Scalability and Adaptability

The rapid evolution of both AI technologies and agricultural methods requires flexible solutions that can accommodate new data sources, sensors, and innovations.

CONCLUSION

In summary, the integration of AI & ML in agriculture produces benefits, ranging from improved agricultural production and resource allocation to the better detection of diseases and pests and reduced environmental impacts. These advancements pave the way for a more sustainable and adaptable agricultural sector, ready to meet the demands of the future. This paper discusses the various contributions of AI & ML in Smart Agriculture. This also covers the challenges that new technologies face for proper implementation in present scenario. AI in agriculture therefore has a very promising future to cover the needs of future population. Future research efforts should be focused on creating affordable and scalable AI & ML solutions for regions with limited resources, ensuring that the benefits of the technology reach small scale farmers. Side by side we need to be cover up present challenges of AI & ML in agriculture sector.

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