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Artificial Intelligence (AI) and its Application in Agriculture

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Artificial intelligence (AI) holds the promise of driving an agricultural revolution at a time when we must produce more food using fewer resources and has begun to play a significant role. The main idea behind AI is to create technology that works similarly to the human brain. With the help of AI, it is possible to gather vast amounts of data from government and public websites, analyse it, and give farmers answer to many complex issues, as well as a smarter way of managing inputs by accounting all the variabilities within the field, resulting in higher yield. AI can also gather market trends, annual production, and customer needs, which will help the farmers to maximise agricultural returns through the use of inputs more efficiently. The automated irrigation system will reduce the manpower and time consumption in the process of irrigation. It also helps in significantly conserving water.

1. Introduction

In India, the agricultural sector provides employment to 50% of the country's workforce and accounts for 18% of the country GDP. According to Food and Agriculture Organization, the global population will increase by 9.8 billion by 2050, of which 2/3rd of the world's population will be living in urban areas. However, only 4% of additional land will come under cultivation by then. The increasing urban population will put more burdens on agriculture by reducing the labour force. In the next 30 years, the total production needs to be increased by 70% to meet the world's food demand. The reducing natural resource availability, climatic changes and other man-made and natural threats put this objective in imperil. To meet the increasing food demand of the burgeoning population, the big question now is, how to get most from every acre? The application of Artificial intelligence (AI) in agriculture would automate several processes, reduce risks and provide farmers with comparatively precise, easy and efficient advice for farming.

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AI is a branch of computer science that focuses on developing intelligent devices and algorithms that allow computers to mimic human intelligence. This invention is created by studying how the human brain thinks, learns, makes decisions, and functions when seeking to solve a problem, and then developing smart software, gadgets, and systems based on this knowledge. Like the human brain, these intelligent devices are loaded with training data and then give us the desired result for every valid input. Agriculture today stands armed with drones and robots programmed to gather data from production fields to advance precision agriculture or 'smart farms'. Further, interconnected technologies and high performance analytics are helping farmers in understanding real time data. Farmers are drawing insights like how to increase crop yield, input use efficiency, improve farm management, make environment friendly decisions on the level of resources needed and where to apply them. Farm productivity is set to increase in times to come as cognitive computing in agriculture continues to grow. This is transforming ordinary farms into digitally controlled 'smart' farms. Smart farming refers to managing farms using modern information and communication technologies to increase the quantity and quality of products while optimizing the human labour required. Digital agriculture refers to agricultural practices that digitally collect, store, analyze and share electronic data and information along the agricultural value chain. AI encompasses a wide range of fields, including Machine Learning (ML) and Deep Learning (DL).

1.1. Machine Learning

The ability to learn anything without being explicitly programmed is referred to as machine learning (ML). It is a subset of AI that use techniques (such as deep learning) to allow the machine to classify and predict things like food grading and agricultural yield predictions (Figure 1). ML and soft computing methods with pattern recognition via image and video (drone cameras, satellite imagery) data processing are commonly utilized around the world in monitoring and managing various farm operations and predicting disease/pest incidence, water and nutrient deficiency, weather forecasts, time of application and optimum dose of chemical sprays, time of harvest, a life of produce, and so on.

1.2. Deep learning (DL)

DL is a subset of ML with algorithms inspired by the structure and function of the brain called Artificial Neural Networks (ANNs). Through DL, a machine will learn through its own data processing, and it is the most popular and fastest-growing AI approach. The possibility of advancing AI research and applications to considerably higher levels and with much more accuracy has been signalled by DL algorithms. The process of learning in DL is deep since the structure of an ANN comprises several input, output, and hidden layers (Figure 1). Each layer contains units that convert input data into information that the following layer can utilise to perform a specific prediction task. We can resolve extremely complex issues using DL, especially ones with a large number of features, because in DL more complex models are used, which allow extensive parallelization. This technology is used successfully on picture data for segmentation, resulting in considerably more accurate nutrient deficiency/toxicity, disease/variety, moisture stress identification as well as crop yield estimation and forecast.

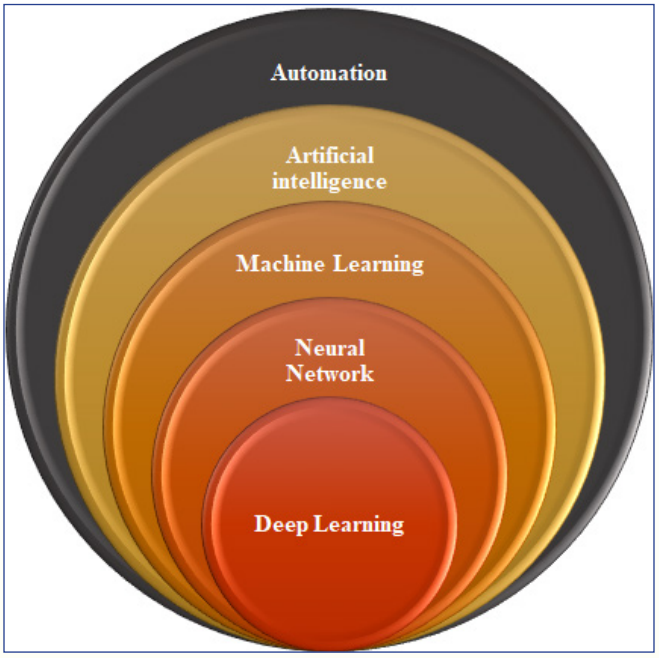

Figure 1: Relationship between AI, ML, NN, and DL

1.3. Artificial Neural Network (ANN)

An artificial neural network (ANN) is a processing algorithm or hardware that is inspired by the design and operation of the human brain. Self-organization and adaptive learning are extraordinary abilities of neural networks. ANN undergoes the process of learning. Learning is the process of adapting to the change in itself as and when there is a change in environment. There

are two types of learning techniques: supervised and unsupervised.

2. Drivers of AI Solutions

Data is one of the primary drivers of AI solutions, where three factors driving are. the volume of available data, its quality, and costs incurred in data generations as well as its maintenance and security (Figure 2). Rapid improvement of technology, availability of low cost efficient sensors (soil, water, humidity, light, temperature), specialized software solutions that target specific farm types or applications, internet connectivity, location identifiers (GPS, Satellite), autonomous tractors & robots and data analytics solutions (Figure 3) are another reason for fast adaption of AI in agriculture. Armed with these tools, farmers can monitor field conditions and make strategic decisions for the whole farm or a single plant without even needing to step foot in the field. The driving force of smart farming is IoT— connecting machines and sensors integrated on farms to make farming processes data-driven and automated for better and cost efficient farming systems.

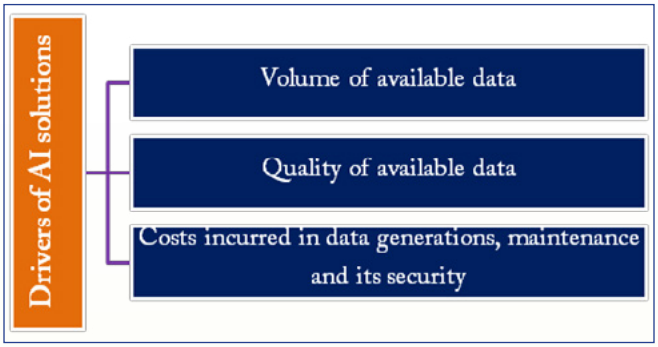

Figure 2: Drivers of AI solutions

3. Why AI is important in Indian Agriculture

• Low irrigation efficiency (approximately 38%) leads to increased groundwater depletion, and environmental pollution (Naya et al., 2020)

• Large post-harvest losses especially in perishable commodities like fruits, and vegetables. Significant losses were also reported in food grains procurement, storage and distribution.

• The decreasing labour force in agriculture over the year and youth are not attracted to agriculture (Nayak et al., 2019; Vijayakumar et al., 2021c)

• Climate change like increasing temperature and changing rainfall patterns are adversely affecting agriculture productivity (Jinger et al., 2016)

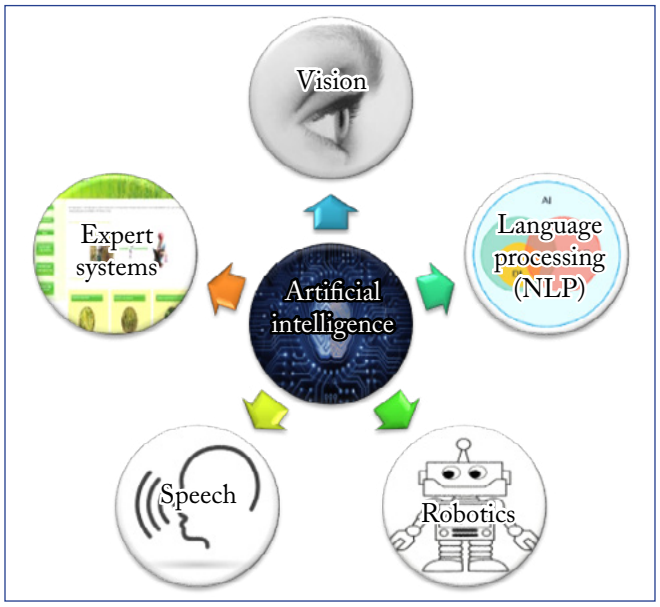

Figure 3: Components of Artificial intelligence

• Increasing incidence of biotic and abiotic stresses (Saravanane et al., 2021)

• Land degradation

• Increasing population and food grain demand

• Low input use efficiency (fertilizers, and other pesticides)

• The increasing rate of pesticide resistance

• Increasing load of pesticides residue in food

• The use of AI in agriculture, will attract youth, reduce drudgery and save precocious natural resources.

Agriculture needs to be smart to address these problems along with increased production by using labour and resource saving techniques and devices. The use of AI brings smart farming into reality. Farmers are eager for this technology to relieve some of the inevitable challenges in agriculture.

4. AI Application in Agriculture

4.1. Identification of optimal mix for agronomic products

The common problem in many developing countries is managing the agricultural land as a single unit without considering the variability within the field which leads to low input use efficiency, increased environmental pollution and reduced returns to the farmer (Vijayakumar et al., 2021b). To overcome this, site specific management

of crops is very important, and it demands a huge amount of data/information. The IoT and AI can give farmers massive amounts of information in real time, such as weather, temperature, humidity, and market price, as well as propose the best mix for any specific condition by fully understanding local resources.

4.2. Crop and varietal selection

Emerging technologies have aided in the best crop selection and have even improved the selection of hybrid seed options that are best suited to the needs of farmers based on many characteristics such as soil condition, weather forecast, type of seeds, and infestation in a specific location, among others. AI can determine itself using the data available on the internet, how seeds react to different weather conditions and soil types.

4.3. Monitoring of crop health

Various plant sensors have been developed to track plant growth as well as identify plant illnesses. Crop health monitoring (nutritional disorders, insect/disease damage), irrigation equipment monitoring, weed identification, livestock and animal monitoring, and disaster management now can be done with the use of UAVs in agriculture (Vijayakumar et al 2020; 2021a). This helps in identifying the problem even before the plant produces a visual symptom of deficiency or infection.

4.4. Smart irrigation or Automation of irrigation

Irrigation is a highly labour intensive operation especially in high water demanding crops like rice, sugarcane, banana, etc (Vijaya Kumar et al 2018). Automation in agriculture is gaining importance across the world. With the use of sensors (moisture, temperature, humidity), IoT devices, and machine learning techniques irrigation systems can be automated to suits varying crops, soil, climate conditions, etc. Automation of irrigation system improves irrigation efficiency, crop yield, quality of economic produce and save irrigation water, time, cost and electricity. Smart irrigation technology increases agricultural production without involvement of large number of manpower by detecting the level of water, temperature of the soil, nutrient content and weather forecasting. However, sensor installation plays a critical role in the successful implementation of an automated irrigation system. Sensors should be placed in the root zone of the crops (ensuring that there are no air gaps around the sensor) where the crops extract water. This will ensure that the crops have an adequate quantity of water. Soil moisture sensors and raindrop sensors, which were buried in the root zones of the crops and powered by solar panels, were controlled via a wireless internet network. The raindrop sensor and soil moisture sensor send SMS to the farmer's cell phone using the GSM module, informing them of the moisture content in the soil. As a result, the farmer can use SMS to turn on and off the water supply. Similar work has been initiated in IIRR, Hyderabad for enhancing WUE in rice.

4.5. Insect pest and disease management

Each year, pest damage account for ~20-40% of the crop loss in India. Speedy accurate identification and taking corrective steps using real time data could minimize the yield loss. The sensors in the field or drones are connected to onboard electronic systems, which transmit the data to an internet server, where images are processed, insects and diseases identified and counted. Depending on the severity of the infestation, the use of agrochemicals may or may not be required. The farmer receives a ready-made report and remedies on his smartphone. Such connected applications are helping farmers to apply the right amount of agrochemical, at the right time to combat pests and diseases in a more cost-effective manner and avoid excess application of pesticides which will, in turn, reduce the pesticide residue in final economic produce (Vijaya Kumar et al 2020; 2021b).

4.6. Automation

The problem of labour scarcity in agriculture, especially during the peak period of the season leads to a rise in wages, thereby, increasing the input cost (Vijayakumar et al., 2021c). Labour shortage has reportedly led to huge revenue losses in key crops like vegetables and fruits. Agricultural robots are poised to become a highly valued application of AI in this sector. Machine vision technologies and robotics, have potentially revolutionary applications in agriculture. New robotic harvesters can 'sense' and perform an array of tasks such as harvesting delicate fruits and berries, weeding, pest control (Figure 4). Independent robots, are capable of sensing processing and performing a spectrum of functions in the field that too at a higher volume and faster pace as compared to human beings. Some of their examples include Oz, Agriboot, SITTIA etc. Other robots can uproot or burn the weed plants using lasers.

4.7. Predictive analytics

AI systems are providing predictive insights such as which crops to grow in a particular season and location. It is also guiding the farmers about optimal dates of

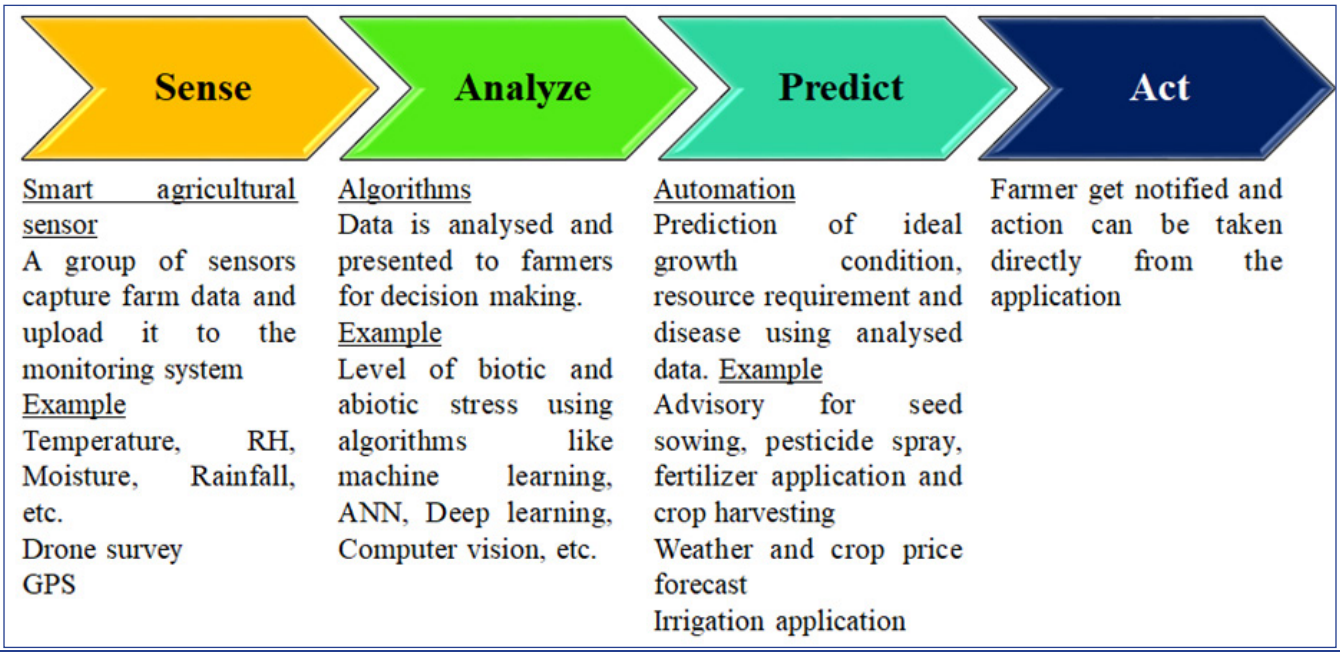

Figure 4: Steps in smart agriculture

sowing and harvesting in a specific area, thereby reducing damages and improving crop yields. Predictive analysis in agriculture is not limited to the cultivation of crops. It is used in insect pest and disease forecast, market demand and price forecast. For example, the Karnataka government has started a price forecasting project for agricultural commodities using historical data and short-term arrivals. Similarly, predictive analytics enabled by AI could potentially warn of rising disease and insect attacks, allowing for more strategic application of agrochemicals and lowering total requirements.

4.8. Precision weed control

Precision weeding and spraying of herbicides with the help of sensors and other means embedded in robots and drones will help in preventing ongoing challenges such as the development of herbicide resistance and increasing pesticide residue in final economic produce and higher production cost (Vijayakumar et al 2020). It applies herbicide only where it is needed. See & Spray agricultural machine developed by Blue River Technology uses computer vision to monitor and precisely spray herbicide on the weed plants. The robots were guided along the row structure to remove weeds and distinguish the single crop from the weed plants using vision-based technology. Two visual systems were incorporated into the robot. The first was the gray-level vision, which was used to construct a row structure to guide the robot through the rows, and the second was colour based vision, which was the most crucial and was used to distinguish a single weed from the others. A robotic weed killer is known as the VIIPA (Variable Injection Intelligent Precision Applicator) apply automatically the right dose of herbicide required to control the weed on the farm at rapid speed. This makes the application of agrochemicals and water very economical.

4.9. Precision agriculture

Precision agriculture reduces the pressure of agriculture on the environment by allowing more efficient use of agricultural resources. Using advanced technologies such as satellite surveillance, sensor, and unmanned aircraft surveillance of fields, engineers have been able to train AI systems to optimise the use of inputs on a precise level, i.e. apply just the right amount of agrochemical, only in the part of the field that requires it, thus maximising yields while conserving resources (Vijayakumar et al., 2021b).

A few of the technologies that enable precision farming are given below:

- High precision positioning system
- Automated steering system
- Geo-mapping
- Sensor and remote sensing
- Integrated electronic communication

• Variable rate technology

4.10. Supply chain management

It is not always feasible to foresee exactly how much and when a certain crop will be available, regardless of who is involved in agriculture. This, combined with shifting consumer demand, might result in serious supply challenges. Data-driven AI solutions might ease some of the challenges that develop in the supply chain. Because it provides better visibility regarding the crops and harvest each season. This is true not just for farmers, but also for everyone else in the supply chain, including distributors, packagers, retailers, and others advancement will be aided by the information derived from AI.

5. Advantages of AI

• Decrease the uncertainty and risk in agriculture operations and production

• Enhance the preparedness of farmers to handle the different types of crisis (climate, market, input, etc.)

• Prediction of future situations and issuing advisories for sowing, pest control and commodity pricing

• Increased income and providing stability for the agricultural community.

• Site-specific management of crops

• Saving of input resources and increased efficiency of input applied. Efficient use of nutrients or pesticides is reducing the use of inputs, thereby saving costs and reducing harmful runoff into the environment (Vijayakumar et al 2020; 2021).

• Real-time information of crops helps the farmers to make early interventions to reduce the damage to crops.

• Spatial and temporal evaluation of individual plots or plants is possible after the advent of these technologies.

• Precision agriculture could be greatly aided by AI, the Internet of Things (IoT), and sensor technology.

• AI, in conjunction with remote sensing technology, can play a crucial role in implementing Climate Smart Agriculture on a large scale.

• Some AI techniques, such as Mobile based Recommendation Systems and Expert Systems, can significantly enhance the adoption rate of agriculture technologies such as high yielding or disease resistant varieties, new farm equipment, and so help farmers earn more money (Vijayakumar et al., 2022).

• Smart irrigation involves providing the right quantity of water, at the right place at the right time for the right crop

• Improving Disease Detection & Crop Protection using AI/ML

• The best thing AI will do for agriculture is eliminating drudgery and boredom from many agricultural activities, allowing us to focus our time and energies on developing a wide range of creative AI advances that outperform human talents.

• Non-literate farmers can benefit from AI techniques such as auto-translation between various languages, text to speech, and speech to text in Indian languages, which can assist them in retrieving the necessary information and knowledge generated by agricultural research and education systems around the world.

• Given India's multilingual society and the fact that the majority of farmers are illiterate, this technology has the potential to greatly assist farmers in gaining access to critical information.

6. Challenges in Developing and Adopting AI in Agriculture

• Unclear privacy, security and ethical regulations (Vijayakumar et al 2021)

• Inadequate availability of AI expertise, manpower and skilling opportunities

• The low intensity of AI research

• Lack of enabling data ecosystems

• High resource cost

• Low awareness for adopting AI in business processes

• Lack of sound database: Only if they have a lot of information/data about the world can machines act and react like humans. It's difficult and time-consuming to inculcate common sense, logic, and problem-solving abilities in robots without a solid database.

• The majority of farmers in developing nations are small and marginal landholders and their financial risk-bearing capacity is generally very low (Nayak et al., 2020). The cost involved in implementing AI in agriculture is beyond the affordability of Indian farmers at present. Therefore state supported mechanisms can make it possible and also community based implementation will be cost effective.

• Although AI has a wide range of applications in agriculture, there is still a lack of expertise with high-tech machine learning solutions at most farms throughout the world.

• To train robots and produce exact predictions, AI systems require a large amount of data. Though spatial data can be easily acquired in the case of huge agricultural areas, temporal data is difficult to get. Because data infrastructure takes time to grow, it takes a long time to develop a reliable machine learning model. This is one of the reasons why AI is used more in agronomic items like seeds, fertiliser, insecticides, and other agronomic products than in in-field precision solutions.

• Extensive testing and validation of emerging AI applications in the field are very important as agriculture is affected by environmental factors that cannot be controlled, unlike other industries. It is highly required now that farmers are trained in modern AI technologies. This will ensure that the technologies are used and continue to improve. The next step in this direction is to combine more complex machines, improve contextual data collection techniques and highly developed software.

7. Conclusion

AI is a modern digital frontier that will have a massive impact on the world, transforming the way we live and work. Agriculture has undergone a transformation as a result of AI. The World Economic Forum is considering AI as the lynchpin of the Fourth Industrial Revolution. AI-related inventions are booming, shifting from theory to commercial application. Climate change, population expansion, employment concerns, and food security issues are just a few of the issues that this technology can solve.

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