ROLE OF ARTIFICIAL INTELLIGENCE IN AGRICULTURE

Abstract

The early food demands of humans during stone age are met by foraging and hunting. Later there is a transformation which resulted in the collection of seeds and growing plant species. This slowly resulted in the system called agriculture. The enormous rise in population during 1950s had resulted in the food crisis. The green revolution in agriculture enhanced crop yields to greater extent which ultimately resulted in self-sufficiency of food grains. But again, the pace of the rising population had been picked and the percentage rise in production levels had been gradually saturated. In order to feed the future populace, there is need for transformation in agriculture. The recent advance in science resulted in application of artificial intelligence in many sectors, but exploitation of its potential in the field of agriculture is still in progress. Artificial intelligence can be used in carrying out several operations starting from seeding, irrigation, detection of diseases, spraying, regular monitoring of crop growth, harvesting, drone technology with several applications and dissemination of information. The collective functioning of these ai based technologies can transform agriculture due to which the Ai is considered as a boon for farmers.

Keywords: Green revolution, Self-Sufficiency, Artificial Intelligence and Drone Technology.

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I. INTRODUCTION

The food demands of the early humans are met by hunting or gathering food material by moving across the forests. But as the time passed, they discovered fire and foraging activity of food collection cannot meet their needs. This slowly led to their collection of plant seeds and domestication of the plant species which is the early agricultural activity carried out by early humans to feed themselves. Later, they carried out those seeds along with them and this is how the seeds have moved from one place to the other. In addition to the activities carried by humans, the impact of biotic and abiotic factors like climate, temperature, rainfall, the incidence of pests and diseases etc led to the development of new crop species. This is how the primary and secondary centres of origin for crop species have been identified. Later on, humans started manipulating the soil according to the requirements of crop growth. This is the time till where the pace of population growth is at par with the rise in food production. The enormous population rise in the period of the 19th century resulted in the food crisis. This crisis had been resolved by the green revolution which has been termed as the one of the golden phases of agriculture. Once after the green revolution during the 1960s, India had achieved self-sufficiency in food grains. Due to the geometrical rise of population and the arthematic rise in food production the sustainability of future food production is at stake. Apart from the global population rise, the uncontrolled climate is intensifying the situation. In order to overcome this crisis, there is need for drastic changes in the traditional practices of agriculture being followed. In the meanwhile, the advancement of science had led to the use of artificial intelligence in industrial sector which had brought tremendous developments. Even though agriculture had witnessed the impact of artificial intelligence, it is not surprising that it is one of the sectors that had limited impact till now. In order to cope up with the changes and meet the future diet requirements of the huge populace, there is need for transformation in agriculture from traditional practices dependent to technology and innovation based. In addition to the technology- based practices, precision-based practices will be an added advantage to the agriculture community which is possible by the use of artificial intelligence. This revealed the existence of a large number of bottlenecks which can be filled by the use of artificial intelligence.

The term "Artificial Intelligence" was first introduced in the year 1955 by John McCarthy. Earlier, most of the applications of AI had been limited to areas in computer science but with advancement of technology and ease of its availability it had spread its wings into a variety of domains such as education, healthcare, finance, manufacturing and agriculture etc. The GOSSYM was the first AI based application attempted by McKinion and Lemmon in the year 1985.It is an expert simulation model System which is used to optimize cotton production under the influence of irrigation, fertilization, weed control-cultivation, climate and other factors. Agriculture, an essential consideration of any country, majorly of India which is called as an agrarian country is still facing many challenges currently. Furthermore, the global population is expected to reach about 9 billion by 2050 (**Poore and Nemecek, 2018**). In addition to the enhancing the production levels, efficient use of resources is one of the major constraints faced by the Indian agrarian community. Among several resources being used, water is a vital component for metabolic processes in humans and also for the plants. There is need for enhancing the water use efficiency. Next to water, fertilizers are major inputs being used. The excessive uses of fertilizers not only enhancing the cost of cultivation but also the damaging the Agri-ecosystem. There is also a need to monitor the

usage of herbicides, pesticides and fungicides. In order to find a common solution to all the concerns considered, AI has been identified as a one stop solution.

II. NEED AND IMPORTANCE OF AI IN AGRICULTURE

The availability of labour force is a major problem faced by the agrarian community. The agricultural workforce availability in India had been decreased from 59.1% in 1991 to 54.9 in 201.It is also estimated there is going to be a drastic decline to 49.9% in 2033 and 25.7% by 2050 **(Tiwari *et al.*,2019).** This has ultimately raised the wages of farm labour which increased the cost of cultivation impacting the farmers. It is solved only by adopting the mechanisation and AI based field operations. In addition to the problem work force, it is identified that mechanisation can save various inputs like seeds and fertilizers up to 15–20% and labour requirement and operational time by 20-30%. The cropping intensity and the productivity can also be enhanced to 5-20% and 10-15% respectively **(Tiwari *et al.*, 2019).** Due to the impact of above aspects, over the period of time there is shift in power source used by agriculture which is towards mechanical and electrical sources. In India there is a drastic reduction of animals as a source of power which is indicated by reduction from 93% in the 1960s to 12.6% in 2010-11. It is also estimated by the year 2032-33, the use of animals as power sources will be reduced to about 4.1% of total farm power **(Tiwari *et al.*, 2019).** In indicated the need for mechanisation in agriculture. The AI based farmed practices can result in paradigm shift in the agriculture.

III. SMART FARMING

The way of enhancing the accuracy and precision of the farm operations is termed as the Smart farming. It is also referred with several other names such as Agriculture 4.0, Digital Farming and Precision farming etc **(CEMA. Digital Farming).**

Among the technologies available for present-day farmers are:

- **Sensors:** Soil, water, light, humidity, temperature management
- **Software:** Specialized software solutions that target specific farm types or applications agnostic IoT platforms
- **Connectivity:** Cellular, LoRa
- **Location:** GPS, Satellite
- **Robotics:** Autonomous tractors, Processing facilities
- **Data analytics:** Standalone analytics solutions data pipelines for downstream solutions.

IV. GROWTH DRIVEN BY INTERNET OF THINGS (IOT)

Agriculture is a stream where the operations based on several factors like climate, onset of monsoons, availability of labour and inputs etc. In order to predict the future results or to suggest regarding time of agricultural operations needed to be taken there is need to study the data related to those operations. The data produced here is very huge including both structured and unstructured format, which is related to historical weather pattern, soil reports, new research, rainfall, pest infestation, images from Drones and cameras and so on. The Internet of things (IOT) is the thing which allows the linkage of all the devices and

equipment's from which the data is generated, processing the data and gives the decisions regarding the operations needed to be taken as output **(Kumar & Periasamy, 2021).**

Applications in smart framing

1. **Robotics in agriculture:** The need for the robotics in agriculture sector had been increased due to various concerns like high aged population in agricultural workforce, disinterest of younger generations in agriculture and lack of employment opportunities for educated youth which are going to be to enhanced in future days **(Sahi ,2015).** The increased interest in agriculture robots is reflected in-terms of rise in global investment from $817 million in 2013 to more than $16 billion by 2020 **(Hajjaj and Sahari,2016).** The various applications of robots in agriculture as follows.

   - **Weeding robotic systems:** Weeding is the agriculture operation agricultural labour which needed about 40% of the total labour **(FAO,2006).** The system drops on demand in weeding in which the robots identify the weeds in between the plants and drop the weedicides on the weeds. This achieved 100% effectiveness which is highest among chemical robots **(Utstumo *et al*., 2018).** The weeding robots are already under the development and some of the robots are also available in markets.

   - **Seeding by robots:** Seeding is the basic operation of agriculture which is very important for the successful establishment of crop. The plant density is the vital factor impacting the yields. In order to maintain optimum plant density there is need to maintain optimum spacing and sowing should be done at the optimum depth which will result in proper germination. The use of robots will enhance the precision in depth of sowing and spacing between the plants.

   - **Phenotyping:** The term plant phenotyping refers to the regular observation of morphology and various traits contributing to the crop yield. The robots used can be of fully autonomous or semi-autonomous. One of them is Bonirob an autonomous robot which is based on multisensory data fusion in measuring the traits population density, plant distribution, plant height, stem thickness etc **(Ruckelshausen,2009).** Illumination is identified as the major problem being faced in phenotyping using robots. It has been solved to a certain extent by artificial lighting **(Bao.,2019).**

   - **Harvesting:** The robots are used for harvesting of crop produce. In the crops like rice, wheat and corn the crop can harvested at a time using the combined harvesters which reduce the problem. But in case of crops like cotton, fruits and vegetables the produce cannot be harvested at a time due to which the timely harvesting had become the major problem. In order to overcome this there is need for automation which resulted in use of automated harvesting robots. In order to identify the fruits to be harvested stereovision system and laser active vision technology are used. In case of stereo vision system there are two types which are binocular vision system and RGB-D camera method. The binocular method is which is based on optical principles and optimal algorithms to identify 3d position of the target. The RGB-D camera method uses infrared sensors in identifying the fruits to be harvested **(Tang *et al*.,2020).** The preliminary method of laser-based machine vision system for automatic identification of fruits was given by **jimenez *et al*. (1999).** This method uses an infrared laser

ranging sensor to detect the 3D position, radius, and surface reflectivity of each spherical fruit. The laser finder tomato method was used in crops like tomato, cucumber, and grape by **(Kondo *et al*. (2009).**

2. **AI-based irrigation system:** water is considered as one of the vital components which is essential for each and every metabolic process for plants. Agriculture is the major area which with draws about 70% of the global water resources **(FAO 2002; WRI 2005).** As the factors like urbanisation and climate changes are exacerbating the water scarcity which is indicated by the increase of urban population facing water scarcity from 933 million (one third of global urban population) in 2016 to 1.693–2.373 billion people **(He *et al*., 2021).** Smart irrigation is based on the principle of application of water at the right time, in the right amounts, and at the right spot in the field **(Singh *et al*., 2019).** This is possible only by the use of modern equipment like sensors using which, various parameters like soil moisture status, plant water status and weather parameters can be monitored.
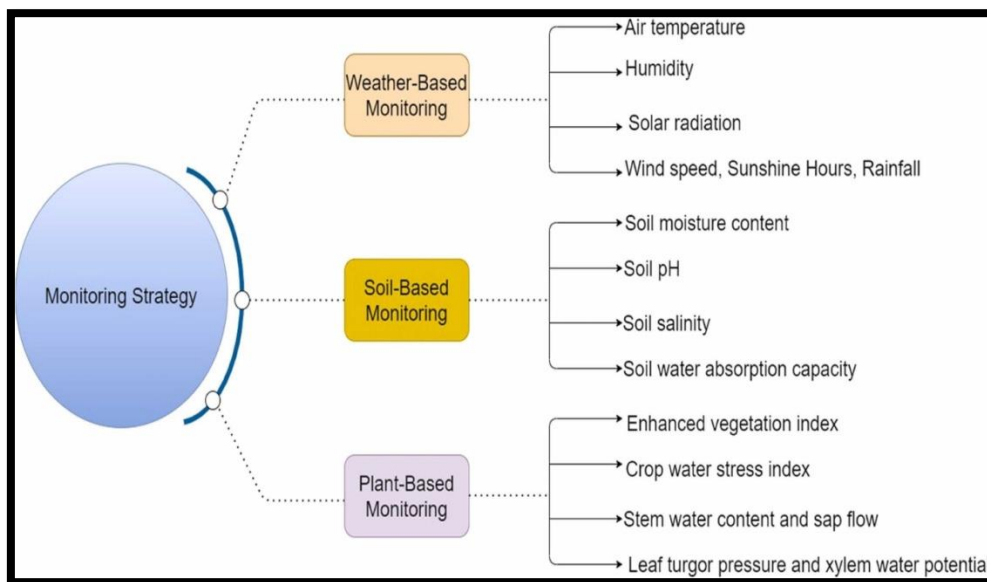
(Source: Bwambale et al., 2022).

Figure 1: Monitoring Methods in Smart Irrigation

- **Soil moisture sensors:** It is one of the parameter which can be used for scheduling irrigation of the crop **(Delgoda *et al*., 2016).**The soil moisture sensors are placed at various depth of the soil by which moisture availability at various levels of the root zone can be predicted based on which the irrigation scheduling can be fixed **(Soulis *et al*., 2015).** Different kinds of sensors that are employed in soil moisture estimation are:

  ➢ Soil matric potential sensors.
  ➢ Volumetric soil water content sensors.
  ➢ Thermos conductivity sensors.
  ➢ Resistance sensor granular sensor matrix **(Bwambale et al., 2022).**

The major limitation of a soil moisture-based irrigation system is that apart from the soil moisture, the various other biotic and abiotic factors also had an impact on the irrigation scheduling. This limits consideration of soil moisture as a sole criterion for irrigation scheduling.

- **Sensors for monitoring weather parameters:** The physiological process of evaopo-transpiration is an unavoidable evil in plants by which water is lost through the stomata. This process is regulated by various factors like humidity, temperature, rainfall, etc. In the case of the real-time weather-based monitoring system, the sensors for these parameters are fixed at weather stations **(Adeyemi et al., 2017).** These sensors were connected to the microcontroller system and the signals were transmitted through a radio frequency module using the LoRaWanTM protocol **(Bwambale et al., 2022).**

- **Plant-based monitoring:** The plant-based monitoring includes direct measurement of leaf, xylem, or stem water potential and plant physiologic monitoring that involves stomatal conductance, thermal sensing, sap flow, and xylem cavitation measurements.

- **Leaf Turgor sensors:** They are used to detect leaf water stress by measuring relative changes in leaf turgor pressure **(Zimmermann *et al*., 2013).** An example of the leaf turgor pressure sensor is the non-invasive leaf patch clamp pressure probe also known as the ZIM-Probe.

- **Leaf thickness sensors: Seelig *et al*. (2012)** observed that irrigation timing based on leaf thickness measurements improved water use efficiency by 25–45% compared to the present irrigation scheduling treatments. These studies suggested leaf thickness variations as a feasible plant-based method for monitoring water status.

  In addition to the above two, Sap flow sensors, Xylem cavitation sensors and Stem diameter variation sensors are also available which can be used for measuring the plant water status

3. **Drone technology:** Among several artificial intelligence-based innovations, the drones termed as UAVs unmanned aerial vehicles (UAV's) is one of the most beneficial one. Agriculture is one of the most promising areas where the potential of drones can be exploited to greater extent in-order to address the major challenges. The usage of drones is dependent on various critical aspects like weight, range of flight, payload, configuration and their costs (Maurya, 2015). The various applications of drones throughout the crop cycle are as follows:

- **Soil and field analysis:** Early soil analysis analysis can be carried out by producing precise 3-D maps.
- **Planting**: It is believed that the use of drones in combination with remote sensing and machine learning can play a key role in overcoming the problem of deforestation **(Bio Carbon engineering: industrial-scale reforestation, 2016)**. These systems shoot pods with seeds and nutrients into the soil, providing all the nutrients necessary for growing crops.

- **Crop spraying:** The drones are used to scan the ground and spraying is carried out in real time for even coverage. The aerial spraying carried out is faster than drones than traditional machinery.
- **Crop monitoring:** In order to carry out the timely operations the crop has to be monitored regularly. In small scale farmers it is possible with humans, but in-case of large it is inefficient in-terms of both monetary and resource basis which is a huge obstacle. The UAVs can cover the huge area for different indices **(Simelli *et al*., 2015).** The drones are equipped with thermal and multispectral cameras by which images are captured and monitoring is made possible **(Bendig *et al*., 2012; Colomina and Molina., 2014).**
- **Irrigation:** The drones equipped with sensors can identify the dry parts of a field.
- **Health assessment:** By scanning a crop using both visible and near-infrared light, drone-carried devices can help track changes in plants and indicate their health and alert farmers.
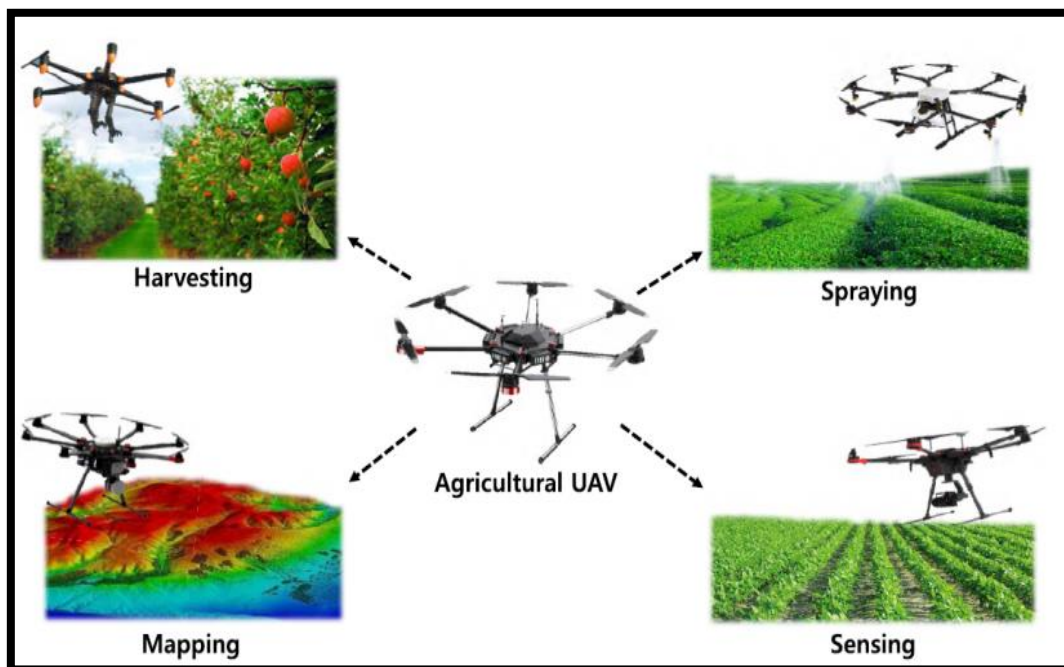
Figure: 2 UAVs carrying out different operations at field level (Islam *et al*., 2021)

4. **AI-mediated weeding:** The presence of weeds in the crop fields can cause huge losses in yields are they compete with crop plants for nutrients and other resources **(Patel *et al*., 2019).** The reports across the world shows that usage of herbicides is the major method opted by the farmers for controlling weeds even though the weeds like cultural and mechanical are practiced to limited extent **(Dilipkumar *et al*., 2020)** which enhanced the usage of herbicides. This enhanced usage of herbicides is not beneficial in economic and eco-friendly terms. This enhanced the need for more target specific approaches for controlling the weeds in crop fields. In mean time, the entry of AI into agriculture and its developments resulted in an approach called the sitespecific weed management (SSWM) which considers the spatial variability and temporal dynamics of weed populations in fields **(Gerhards *et al*., 2002).** Some of precision technologies for weed management are listed below:

- **Patch spraying:** This patch spraying simple map-based GPS controlled using which turn on and of the spraying in the field where the population of weeds exceed the economic thresholds **(Gerhards & Christensen, 2003).**

- **Camera guided physical weeding:** In this approach, Regions of highest green pixel densities are identified and connected to a line for tracking of crop rows **(Tillett *et al*., 2002).** It allows the identification crop rows and can be differentiated from the wed species. This approach control 80-90% of the weeds but it is more beneficial when combined with several other approaches **(Gerhards *et al*., 2002).**

- **Robotic weeding:** The advancement of robotics had spread its wing into the field of agriculture and several prototypes had been developed for weeding and tested in several field crops **(Ruigrok *et al*., 2020).** These robots may use different approaches for controlling the weed such as spraying, physical weed control using hoeing blades, high voltage, laser and flaming. The protypes of the robots developed had a success rate of 80% in differentiating the weed and crop species controlling 96% of weed limiting the damage of crop species to less than 10% **(Gerhards *et al*., 2002).**

5. **Role of AI in disease detection: The** crop production levels impacted drastically depending upon the intensity of disease. In order to feed the future population, there is need to protect every grain produced from disease and pests. There is need and large scope for artificial intelligence for controlling the damage caused by diseases.

- **Disease identification using temperature sensor:** In this case a sensor named DHT11 temperature sensor is used using which temperature of the leaf is measured. The information collected is sent to the cloud flatform using the wifi shield connected to the Arduino UNO board. The temperatures of healthy leaves are recorded and a range is fixed. If the leaf temperature is that particular range it is considered as healthy and if not as diseased **(Rajesh *et al*., 2018).**

- **Disease identification using colour sensor:** The disease causes damage to the pigments in the leaf which will change the colour of the leaf. The colour sensor named TCS3200 RGB. Each colour is assigned with a threshold values and recorded values of the leaves are sent to cloud flatform. By comparing the values, the diseases leaves are separated from healthy ones **(Rajesh *et al*., 2018).**

- **Disease identification using humidity sensor:** The transpiration of the plants is affected by humidity in the atmosphere. When the humidity is high transpiration reduced and when it is prolonged it results in damage to the leaves. The humidity is measured by the sensor named DHT11 **(Rajesh *et al*., 2018).**

6. **Digitalisation of agricultural information:** Apart from the services provided at the farm level, the digitalization and Development of AI based information interfaces made the availability of agricultural information easier. In the current situation the world at our finger tips in-terms of a mobile phone. Even the people without formal education are able to access the services provided through mobile. This resulted in the development of several agriculture based flatforms and apps which are beneficial for farmers. Let us have look at some of them and the services by them.

- **IFFCO-Kisan:** This particular application provides information about latest mandi prices and also provides agricultural tips and advices. It also provides the weather information. The entire information is available in 10 different languages which increases its accessibility and benefits the farmers.

- **Farm bee RML farmer:** It provides the location specific weather pattern and agricultural information based on specific stage of the crop. It also provides the information 450 crop varieties, prices in 1300 markets and weather information 3500 locations.

- **Kisan yojana: this application** provides the information about various government schemes related to the agriculture which are implemented by various states. By using this the farmer can know the basic information of any agriculture scheme being implemented without reaching to concerned authorities.

Similarly, there are many more digital applications which can be used through mobile phones. This enhanced reach out different agriculture information which enhanced the awareness of farmers.

V. ADVANTAGES OF AI IN AGRICULTURE

1. Resource use efficiency and productivity is enhanced.
2. The precision in management practices is enhanced.
3. The use of AI based sensors can result in automation of agricultural operations in advance which will reduce the burden of monitoring for the farmers.
4. The AI based user interface can forecast the need of various agricultural operations in advance, by which farmers can carry out them in time.
5. Based on the previous year data, AI based models can predict the future supply and demands of agriculture products. This will ensure the careful management delivering goods to market just in time by which wastage can be reduced and remunerative prices can be fetched for farmers.

VI. CONSTRAINTS IN ADOPTION OF SMART FARMING

The roots of artificial intelligence had been penetrated into many fields but they are limited to the surface in the case of agriculture. It is because agriculture is an occupation which is carried out by mostly rural households and most of the framers are small and marginal farmers. The use of artificial intelligence in agriculture requires huge infrastructure i.e., unlimited or continuous internet connection, large equipment like machinery, computers, sensors etc. The establishment of the above infrastructure is a huge economic constraint which the farming community is facing. In addition to establishment of infrastructure, its utilisation is a major concern. Apart from these, the literacy and the awareness regarding the use of digital technologies among the farmers is increased but it is limited. In order to exploit the resources of AI, there is need for understanding its operating systems which is limiting its usage.

VII. FUTURE PROSPECTS AND CONCLUSION

The current agriculture community is great need of novel methods like artificial intelligence in order to overcome the hurdles faced by the farmers. AI technologies can benefit the farmers in various means such as, analysing land/soil/health of crop, AI mediated sowing, crop monitoring and pest control using drones, suggestions for farmers in carrying out timely operations etc resulting in higher yield which finally benefits the farming community. It also deals with the major problem faced by farming community which is labour scarcity by mechanisation. There is a huge-lacunae to be filled in the field of agriculture especially in terms of adopting technology and mechanisation which is still untouched. There is huge scope for filling that lacunae by adopting artificial intelligence-based practices in agriculture. This particular change can propel the future growth of agriculture and can lead drastic changes. Based on the above advantages and applications of artificial intelligence in agriculture it can be considered as a boon for agriculture.

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