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ROLE OF ARTIFICIAL INTELLIGENCE IN AGRICULTURE

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ABSTRACT

Agriculture plays an important role in the progress of a nation's economy. The field of agriculture encounters many challenges like disease, weed and pest influx, improper soil management, insufficient drainage and irrigation, and many more. A fast increase in population, shortage of farmland due to urbanization, decline in the availability of natural resources, unpredictable changes in climate, and everchanging market trends are pushing the agricultural production system into a new archetype. Artificial Intelligence (AI) with its laborious learning abilities can play an important role in the agronomics area. Systems are being established to support the agricultural experts by limiting the use of water, pesticides, conserving soil fertility, food security concerns. The algorithms so employed use large sets of data precisely and quickly, protecting the security and privacy of data. These AI-powered farming solutions help a farmer to have more output with less effort, improving the quality, and guaranteeing a speedy go-to-market (GTM) approach for crops. Agriculture has thus changed with the use of AI and its technologies. The current paper explores how the AI-powered techniques can be used in soil management, crop management, weed management, and disease management.

Keywords Agriculture, Artificial Intelligence, Crop Management, Disease Management, Robotics, Soil Management, Weed Management.

1. INTRODUCTION

Agriculture is the foundation of sustainability and progress of any country's economy. From the last two decades, agricultural activities have transformed to food processing activities, production, marketing, distribution of crops and livestock products (Chukwu et al., 2019). Agricultural activities act as a major source of income, improves a country's GDP, trade, provide raw materials to other industries. Agriculture is an ever-changing domain which does not run smoothly from sowing to harvest. All the circumstances cannot be comprehended to a common solution. The key challenges are pest and disease invasion, inappropriate drainage and irrigation, weed control, harvest forecasting, inadequate use of chemicals, and many more.

In order to solve the existing problems in agriculture, many approaches have come forth starting from databases to decision support systems. Among these, systems which employ Artificial Intelligence (AI) have been found to be more accurate and robust. Artificial Intelligence is the development of algorithms to imitate a human especially the human reasoning and learning abilities (Hancock et al., 2020). AI systems work by using vast amount of labelled training data, looking for correlations and patterns, and then using these patterns to make future predictions. It has touched a variety of fields like education, finance,

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automotive, robotics, manufacturing, healthcare, entertainment, travel and tours and many others.

Agriculture is one such field too where AI has been employed. The first application of AI is found in the year 1985 by McKinion and Lemmon (Bannerjee et al., 2018). A cotton crop simulation model was developed using Expert System to enhance cotton yield. The model GOSSYM takes into consideration factors like irrigation, pesticides and fertilizers, weed control, climate etc (Zha, 2020). In India, at present, with approximately 175 farmers of Andhra Pradesh are working in corporation with Microsoft Corporation (Dharmaraj and Vijayanand, 2018). The services being rendered are land preparation, sowing, adding nutrient supplements and fertilizers. As compared to earlier harvests, an average of 30% increase per hectare has been recorded (Khandelwal and Chavhan, 2019).

AI technologies employed collect large volume of structured and unstructured data pertaining to weather pattern, soil reports, rainfall, susceptibility to pest, using drones and cameras for imaging. The AI systems identify and give beneficial solutions to increase crop yield. The main technologies employed use proximity and remote sensing. This helps in the description of soil, beneath the surface at a specific area. An example is hardware like Rowbot which gathers data with robotics to know the best fertilizer to get a better yield (Khandelwal and Chavhan, 2019). Remote sensing on the other hand uses sensors which are built into aerial or satellite systems. Images obtained through drones can help farmers to take intensive care of the crops thus, taking a quick action. Aerialtronics is one of a commercial drone, which employ IBM Watson IoT Platform and Visual Recognition APIs to analyse real time images (Dharmaraj and Vijayanand, 2018). Such computer vision technologies aids in disease detection, field management, crop readiness, crop management etc.

Section 2 of the paper takes a review of the work done by renowned people towards employing AI tools and techniques in the field of agriculture. Section 3 takes a deep insight in the application of AI in agriculture by discussing soil, weed, crop and disease management as subsections. Section 4 briefs the challenges being faced by the AI techniques followed by the conclusion.

2. LITERATURE REVIEW

Chukwu et al., (2019) reviewed application of AI in agriculture through a tabular presentation. A major stress is on the assets and limitations of various AI practices for the management of soil, crop, weed and disease.

Zha (2020) focused on two aspects of agriculture- soil and weed where AI has been employed. The paper addressed the challenges faced by AI to reach every corner and pocket worldwide. Another challenge discussed is the ability of the algorithm to process large set of data accurately and last is the security of the device as well as the data. Use of robotics for various agricultural activities can be found in this work.

Khandelwal and Chavhan, (2019) explored the automation techniques for irrigation, crop health monitoring, recognition of plant stress using machine learning and intelligence and the use of robotics.

Mishra et al., (2020) deliberated the role of IoT and big data analysis in agriculture for greenhouse monitoring, intelligent farm machines, and drone-based crop imaging, supply chain modernization, social media in food industry, food quality assessment and food safety. It presented IoT framework within agri-food industry context and machine learning paradigms and their applications.

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Oliveira et al., (2023) presented a review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology on artificial intelligence technologies applied to agriculture. The study took into consideration 20 diverse AI practices with machine learning, convolutional neural networks, IoT, big data, robotics, and computer vision to name a few. Agricultural areas counted in were crop management and prediction and disease and pest management highlighting countries like India, China and the USA. To conclude, it presented challenges and inclinations in AI for agriculture.

Cosmin (2011) summarised the tendencies of adoption and the expansion of artificial intelligent tools and techniques in agriculture. The primary emphasis is on expert systems, sensors for collecting and transmitting data and robotics. The paper concluded with the challenges of acceptability of new technologies which requires time and investments.

Dahikar et al., (2014) used Artificial Neural Networks for crop prediction. The paper takes into consideration the regional soil parameters like type of soil, PH, minerals, depth, temperature, rainfall, humidity. The data so collected is then analysed using feed forward back propagation ANN. It has been concluded that ANN is an influential tool for modelling and prediction.

3. ARTIFICIAL INTELLIGENCE IN AGRICULTURE

Agriculture as a whole comes with multiple choices and fears owing to seasonal variations, cost variations of farming requirements, damage done to soil after every harvest, crops affected by weeds, pests, and changes in climate. AI driven agriculture practices helps to deal with such uncertainties. AI services involve huge volume of data which is analysed by data engineers and data analysts. The power of AI in agriculture is applied to soil management, crop production, plant diseases, weeds suffocating crops, predictive analysis and is discussed as further.

3.1 SOIL MANAGEMENT

Soil retains water, essential nutrients for apt crop growth. A sound acquaintance with different types of soil, environmental conditions, soil properties (texture, pH, organic matter etc.), use of compost and manure can increase soil fertility and hence crop yield. Soil degradation is a main factor for crop loss and degraded food quality (Chukwu et al., 2019). AI techniques are employed in four key areas to rally soil management which are discussed as (How Can Artificial Intelligence Improve Soil Management? 2023)

3.1.1 Soil Mapping

Soil mapping is creation of three-dimensional depiction of various soil properties as texture, organic matter, pH, nutrients etc. for soil management. AI creates high resolution soil maps to apprehend progressive and spatial deviations in soil. Sensors and GPS technologies provide reliable information to know soil status and take suitable measures to increase soil porosity and aggregation.

3.1.2 Soil Monitoring

Soil monitoring is a procedure to measure and calculate soil quality pointers like soil temperature, soil moisture, salinity, erosion and pollutants. AI with optical sensors and IoT devices collects data using drones to take pictures of soil colour and gradients. This data is sent to the cloud platforms where deep learning algorithms along with computer vision detect and categorize soil hitches and glitches like pests, weeds and pollutants.

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3.1.3 Soil Remediation

Soil remediation is a process to reinstate and increase soil productiveness, water holding, carbon seizure and remove contamination. AI can use reinforcement learning and optimization techniques for soil management like tillage, irrigation, crop rotation. Natural language processing and knowledge graphs provide significant information for soil regulation and recommendation.

3.1.4 Soil Optimization

Soil optimization is a measure of soil performance in terms of crop yield and quality. Predictive analysis, Artificial Neural Networks (ANN), decision support systems forecast soil performance under circumstances of weather and climate change, crop demand and price variations.

The various AI techniques employed include MOM Management-Oriented Modelling to curtail nitrate percolating (Chukwu et al., 2019). It has a simulator to evaluate various alternatives from a given set of evaluators and to find the best fit alternative which matches user criteria. Decision Support System (DSS) aims to diminish soil erosion and alluvial harvest requires large training data.

Artificial Neural Network (ANN) offers many features like it can foretell soil enzyme action, soil properties as structure, texture, moisture, soil erosion, is cost effective (Dahikar et al., 2014). These predictions are estimated by a remote sensing device to conglomerate granular resolution soil maps with hydrographic constraints.

3.2 WEED MANAGEMENT

Weeds are the unwanted plants that grow along with the crop and compete with the main crop for nutrients, water and other resources (Bannerjee et al., 2018). This leads to abridged crop productivity and quality. As per a report if weeds are not controlled can result in 50% reduced yield of dried beans (Chukwu et al., 2019). Use of sprays to hinder the growth of weeds has adverse effect on health as well as environment. AI with image recognition systems can aid farmers and researchers to classify weeds with greater precision and then take suitable actions to check them.

There are various tools like drones, robots which are enhanced by AI to scan the farms, identify the weeds and then apply herbicides, without effecting main crop. Bosch has come up with a Deepfield robot which is a self-directing weed controller that has a GPS antenna, cameras to direct it in the fields and differentiate between weeds and crops like sugar beet (Misra et al., 2020). Another venture by Blue River Technology has tractor propelled machine that uses cameras, computers and AI. The operations are limited to cotton crop only. It uses herbicides to target weeds only thus minimizing the chemical usage in agriculture, thus saving the environment.

AI expert systems like Saloma offer such services with high prediction level but need large data set for usage. Other techniques provided by AI to manage weeds namely, using Invasive weed Optimization (IVO) (Chukwu et al., 2019). Artificial Neural Networks are very economical and have high performance but face challenges while adapting to new data. UAV (drones) can rapidly and competently monitor weeds but are expensive. AI offers Digital Image Analysis which has a high success rate at the cost of time consumption. Learning Vector Quantization provides within a short time period, a high weed identification rate.

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3.3 CROP MANAGEMENT

Crop management includes seed sowing, watching over crop growth, harvesting, storing the harvest. Apart from these marketing, distribution, providing raw material to primary industries is also a part of crop production. AI enabled technologies offer acquaintance and regulation regarding crop rotation, irrigation, nutrient and pest management, ideal harvesting, disease control and other activities.

AI techniques using decision rules can be used to predict drought conditions, weather patterns. Such systems help to choose alternative cropping methods and better yield. PROLOG uses data pertaining to weather, machines, and work force to appraise crop yield and total returns (Chukwu et al., 2019). Predictive analysis works on parameters related to soil and atmosphere. AI based tools using remote sensing, neural networks and machine learning algorithms provide sustainable solutions to proliferate production over a stated area. Another AI tool is a machine named DEMETER which is fortified with a pair of video cameras, a GPS for steering (Schroth et al., 2023). All the operations are computer controlled and they vary from a planned harvesting of the field, navigating through successive rows and removing any hindrance on the way. According to the researchers this robot can harvest up to 40 hectares of land at the cost of fuel consumption. Using Artificial Neural Networks for crop production, researchers have recorded a success rate of above 90% to identify crop nutrition ailment. ANN can predict the crop production depending upon soil dampness and salinity while allowing only soil temperature and texture aspects to be considered (Dahikar et al., 2014). ANN has been useful to precisely foretell rice production but is restricted by climate and is time overriding.

3.4 DISEASE MANAGEMENT

Crop diseases pose a liability to the crop yield, economy of a country and environment. The numerous reasons for crop diseases are physical-wind, temperature, chemical- soil type, biological-genetics. AI based image sensing and analysis techniques identify on field plant diseases with high precision. A sequence of steps includes taking an image of the plant, segmentation of the image, cropping out the infested area and sending it to the laboratory for further analysis followed by determination of disease and taking necessary actions. Such site-specific disease and pest identification provide more resilient crop management (Khandelwal and Chavhan, 2019). Fuzzy logic which is web-based gives good results with high precision but needs access to the internet (Chukwu et al., 2019). Artificial Neural Network also provides high accuracy of prediction but does not combat with the infection found (Dahikar, 2014). Expert systems which are decision based or use internet services to cure diseases offer high performance (Zha, 2020).

4. CHALLENGES FACED BY AI IN AGRICULTURE

Even though AI has provided efficient decision-making systems and extrapolation mechanisms in agriculture, it is still in its budding phase. There exists a lack of awareness of the innovation, technological solutions provided by AI in agronomics all over the world. AI faces many challenges when dealing with these situations. These challenges are summarised as follows (Misra et al., 2020), (Chukwu et al., 2019), (Dharmaraj and Vijayanand, 2018), (Zha, 2020).

1. **Imbalanced accessibility to technical know-how**

   There are certain farmlands where agriculture practices cannot be upgraded with the latest innovations and high-tech developments owing to their locations or other factors. This leads to an uneven and a sluggish implementation of AI processes in

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agriculture across the globe. Absence of internet services in isolated regions and countryside, indeterminacy of enhanced productivity with the embracement AI, expenses involved all pose a challenge for AI based technology.

2. **Multifaceted challenges posed by nature**

   The robotics involved in farming activities have to deal with physical, chemical and biological characteristics of land, weather and other atmospheric conditions. The large volume of data is categorized accurately to decrease the response time and provide pertinent information simultaneously. Farmers and researchers utilizing such cognitive approaches focus on a system capable of accomplishing tasks with minimal efforts but providing maximized output.

3. **Security of devices and data**

   Another major challenge is the security of physical devices like video cameras, robots; drones installed for AI based solutions in farms. Such devices are positioned in the farm lands without any regulation. The data in the device under seize can be extracted by the attacker. The data can also be attacked when it is uploaded to other devices or cloud. The data fiddling operations on cloud servers can be checked by using session jammers, denial of service (DoS), using cryptographic procedures, and identity verification mechanisms. Security issues at different levels should be addressed accordingly to keep data safe and beneficial.

4. **Enormous volume of data**

   An AI system developed for monitoring and prediction analysis must dig into large volume of data often referred as big data to transform this data at hand into relevant information. The success of any such field expert system depends upon its ability to perform using a given implementation procedure within a given time constraint and with high accuracy. The crop specific data could only be collected once per year when the crop is grown. Since the database takes some time to develop, it takes a lot of time to build a strong AI model. So, training and look-up techniques and algorithms should be well-defined.

5. **Adaptability to change**

   There is always a resistance to adapting a new technology as agricultural practices have been passed down from generations in some farming communities. The unfamiliarity with the services and benefits offered by AI makes it difficult to be acknowledged by the farmers. Governments, non-profits, and the commercial sector must collaborate to provide farmers the tools and encouragement they need to implement AI in agriculture in order to overcome these obstacles. Besides offering training, support, and reasonably priced technology, this also entails creating a hospitable regulatory framework that promotes investment and innovation in this sector.

6. **Flexibility**

   An important quality of any good AI system is flexibility. Even though it appears that a lot of advancement has been attained in applying AI methodologies to specific, isolated activities but the interface of subsystems into an incorporated environment appears to be the key theme at the forefront of AI-based robotics technology. The subsystems themselves must be flexible to meet this requirement. Expandable features that can hold additional user data from the field expert should also be included.

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5. CONCLUSION

Artificial intelligence (AI) in agriculture has much remuneration for farmers, such as improved crop monitoring, precision agriculture, and weather extrapolation. The use of modern technological solutions to improve the efficiency of agriculture will reformulate the traditional pattern and constraints of agriculture. Keeping the mind the facts that labour is declining, land available for agronomy is limited, and the gap between total food production and the world's population is growing, AI will initiate an agricultural insurgency. Nevertheless, there are a few challenges that farmers face when using AI, such as the costs associated with implementing AI systems and technical expertise. Robotics and autonomous systems are set to transform global industries. They will have a noteworthy influence on large segments of economy. Robustness in application to tackle with varying external and unexpected situations can expedite real-time decisions and enable efficient collection of contextual data by sequentially leveraging appropriate models. These models need to be more practicable to stretch to a greater extent of farmers across the world. Such cognitive techniques when presented as open source will result in easier and quick acceptance and with more awareness among the farmers.

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