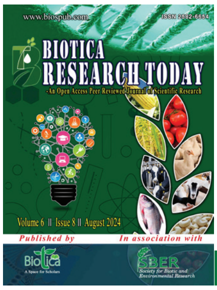

Bio. Res. Today 2024, 6(8):406-409

Biotica Research Today

e-ISSN: 2582-6654

August, 2024

Article ID: RT1711

Popular Article

Growing Smarter: The Role of Artificial Intelligence in Agriculture

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Open Access

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Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?

Saini, D.R., Prakash, P., Kumar, S., *et al*., 2024. Growing Smarter: The Role of Artificial Intelligence in Agriculture. *Biotica Research Today* 6(8), 406-409.

Abstract

To meet ever-growing population demands, there are various revolutions in the agricultural sector to increase quality and quantity of yield with minimum damage to the ecosystem. Now-a-days, there is the 4^{th} wave of revolution regarding precision farming with technological advancement (Agri 4.0) for improvement in quality and yield. The new revolution in agriculture involves the application of the Internet of Things (IoT), DL, ML, Artificial Neural Network, Satellite Imagery, *i.e.*, Artificial Intelligence (AI) in a nutshell, to maintain the field and soil well-being to improve the profitability, safety, efficiency of farming practices and supply chain. The application of AI comprises drones, sensors, robots, satellite images, cameras, GPS technology and data analytic software to detect and to predict weather conditions and helps to make productive decisions. AI has many applications such as weather forecasting, soil and crop monitoring, irrigation scheduling, pest detection, yield prediction, market analysis and so on.

Keywords: Agri 4.0, Artificial intelligence, Drones, Precision agriculture

Introduction

Around 20,000 years ago the first agricultural revolution occurred in the Neolithic era. After that from the past 10,000 years agriculture has gone through many modifications from Agriculture 1.0 to 4.0. The 4^{th} or latest agricultural revolution includes application of artificial intelligence, digital modeling, IoT, cloud computing, satellite imagery for advanced analysis of mega databases to improve the productivity of agricultural practices and farm economy. By 2050 the global population will reach 9.8 billion corresponding to which arable land can be increased to only 4%, where to meet the global food security production must be increased to 70% in the upcoming 30 years (FAO, 2009). Agriculture being a labor intensive and resource exhaustive industry, with sky-rising population and food supply demand, automation of farming is becoming gradually important. Broadly, AI is defined as the simulation of human intelligence in machines that are programmed to make human-like decisions and imitate their actions. This revolution in agriculture through AI has introduced the concept of precision agriculture in crop production by mitigating the factors like climate change, soil infertility and nutrient imbalance, biotic and abiotic stresses, post-harvest risks and health issues in livestock production. AI has a wild contribution from field to plate. The key idea of using AI in farming systems is due to its cost-viability, superiority and adaptability. The tools and techniques associated with AI used in agriculture are drones, robots, satellites, sensors, cameras and other computer-based data analytical software leading to a more sustainable and resource efficient future farming (Figure 1).

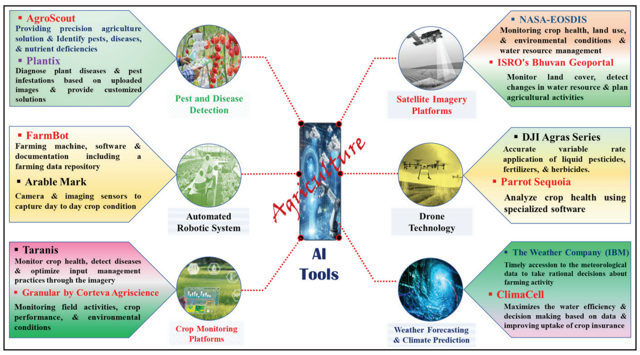

Figure 1: Various AI tools used to monitor agricultural practices, facilitating farmers to optimize resource use, make data-driven decisions and improve productivity

Article History

RECEIVED on 28^{th} July 2024 RECEIVED in revised form 09^{th} August 2024 ACCEPTED in final form 10^{th} August 2024

Satyukt by NABARD, Gamaya for sugarcane farming, AI4 with NITI Aayog are some renowned platforms to farm level analysis and customized digital lending decisions. The global market size for AI in agriculture reached $1.37 billion in 2022 and is estimated to exceed $11.13 billion by 2032 with a CGAR rate of 23.3% in between 2023-2032 (Anonymous, 2023). AI has appeared as a budding technology in advanced agriculture, leveraging digitization to collect, store and further analyze agricultural data, enabling better interpreting and decision-making towards a calculated risk planning.

AI Applications in Agriculture

Now-a-days, artificial intelligence is used for monitoring various primary sources of agricultural databases such as weather forecasting, soil compositing evaluation, crop performance, phenotyping and market trends. AI is applied in agriculture over a lab to land exposure for advancement through a complex set of technical practices via machine learning (ML) including data collection, arrangement and concluding action with deep learning (DL) (Figure 2).

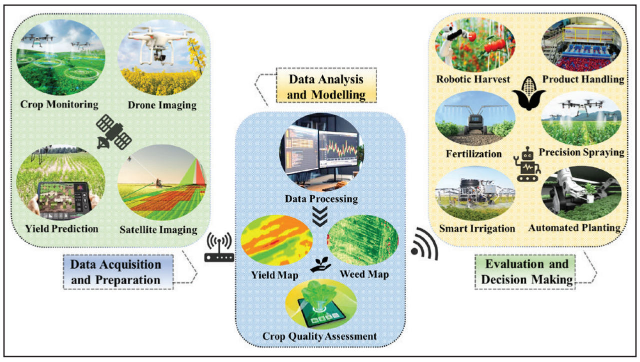

Figure 2: AI in advancing agricultural practices through data acquisition, analysis and decision making

Weather Forecasting

The AI technology is used to track and forecast altered weather and climatic conditions with the help of satellite-based data analysis. AI models assimilate weather data from sensors, weather stations and satellites. By analyzing atmospheric patterns, it provides short-term to long-term forecasts and predicts seasonal weather patterns which help farmers in planning field activities and risk management strategies. Some well-known AI driven weather forecasting platforms are Mausam by Govt. of India, Skymet by IMD, Meghdootam, *etc*.

Improve Decision Making

The significant usages of sensors, satellite images, drones and easier access to data archives helps to make better agricultural decisions like soil reclamation, sowing and irrigation scheduling, crop rotation, harvesting, reduced use of agrochemicals and yield improvement providing an optimal mix for agronomic practices. There is an AI-driven chat-box launched by PM Kisan Samman Nidhi Yojna named ‘Kisan-e-Mitra’ providing the farmers with digital assistance in their own regional languages.

Crop and Soil Monitoring

AI tools help to predict crop and soil parameters such as soil quality, ground-water level, growing periods, nutrient requirements and WUE by analyzing data from various sources. With the help of analyzed data, farmers can plan crop calendars, maintain track of their operations, fertilizer applications, irrigation scheduling and manage their farms more productively (Javaid *et al*., 2023). AI4AI is one of the most successful AI platforms for farm management with a pilot project ‘SaaguBaagu’, developed in partnership with Telangana state government, in its Khammam district, for improving the chili value chain for more than 7,000 farmers. The program results in a 21% increase in chili yield acre^{-1}, 9% and 5% reduction in pesticide and fertilizer usage, respectively and 8% improvement in unit prices due to quality enhancement.

Predict Plant Diseases, Pests and Weeds

AI can predict the attack of insects and pests, identify weeds (VIIPA) and plant disorder and recommend effective control measures by analyzing imagery data from drones, copters and satellites. AI tools can surveil current weed and pest activity, infestation in a specific area and create field maps and feed maps to optimize herbicide and pesticide usage. Prospera, Blue River Technology, Farmbot, Fasal, Trapview, *etc*. are promising AI tools to be used in plant protection.

Harvesting

With the help of AI tools automated harvesting can be done at ideal time without crop losses or damage. AI mediated models can help farmers to predict market demand, market price and ideal time for planting and harvesting. Already, agricultural activities like picking of fruits and vegetables, sorting and grading of the farm produce and trimming of lettuce are carried out by robotics. Harvest CROO robotics is a robotic strawberry picking system and Gramophone by Agstack Technologies provides real time information about harvesting.

Genomic Analysis

The extraction of forward or backward mutations through the changing binding affinity of nucleic acids, information about biological processes with regulation, identification of stress variants, integrated transcriptomic and genomic analysis can be approached by AI applications, such as DeepGAMI.

Phenotypic Analysis

Integrating growth chambers, image sensors, data management, analytical model (PhenoApp) and computer vision improves competence of data collection and analysis in high throughput plant phenotyping. It enables community driven research and data-sharing, providing access to the big amounts of non-destructive sampling data needed for the detailed study of plant phenomes. AI technologies such as of DL and ML are gradually being used to attain and analyze plant images (HALO AI, PlantCV) and data accession in laboratory and field aspects for yield estimation through DL approaches like Yield Spike Segnet (for wheat) (Misra *et al*., 2022).

Market Analysis

AI has a leading role in post-harvest management as well as supply chain management where it can gather data about the crops and harvesting in each season in both temporal and spatial ways. All the stakeholders including producer, distributor, packager, retailer and customer are being provided with an interface to aid in demand-supply equilibrium for optimum profitability. AI can also assemble market trends, periodical production and customer demand, which will alleviate the farmers to maximize agricultural returns through more efficient use of inputs. Jiva Bhumi is a smart and innovative food aggregation solution integrating the products, e-marketplaces and customers with a blockchain technology to collect information in every step of the supply chain.

AI Tools Used in Agriculture

Satellite based System

Satellite data enables the efficient mapping and monitoring of land resources, plant condition, moisture profile, ecosystem, farming events and weather forecasting (Table 1). For example, satellite-based image-processing models SEBAL and METRIC determine evapotranspiration as a residual of a surface energy balance.

Table 1: Various satellite-based software that can be utilized to assist agriculture practices, developed by different space agencies

Software	Agency	Application
Crop SAP	ISRO	Assess crop health, crop yields and agricultural productivity.
Bhuvan	ISRO	Detect changes in land use and plan agricultural activities.
FASALSoft	ISRO	Crop production forecast using remote sensing data analysis for future decision making.
AgroSphere	NASA	Predict crop yield and climate-related risks for sustainability.
LP DAAC	NASA	Utilize MODIS & Landsat, to assess changes in land cover and vegetation over time.
Harvest Crop Yield Prediction Platform	NASA	Aiding in decision-making & resource allocation through crop and food assessment.

Software

Software as a service (SaaS) enables users to connect and utilize cloud-based applications via the internet. It provides total control on the management of land, crop, livestock and market through the compilation of computer science, data science and agricultural sciences (Table 2).

Table 2: Different software/platforms, companies and their applications in agricultural practices

Software	Company	Features/ Application
Farm soft	Tenacious Solutions Ltd	Managing farm fields and packing facilities.
Agroptima	ISAGRI	Include modules for inventory management and storage tracking.
Crop tracker	Dragonfly IT, Inc	Include modules for inventory management and traceability of horticultural crops.
Trimble® Ag Software	Trimble Agriculture	Optimize resource use to regulate efficiency and crop yields.
Climate Field View	The Climate Corporation (Bayer)	Real-time field monitoring, yield analysis, prescription mapping.
Farm Logs	Y Combinator	Analyze field maps, soil samples and weather information.
Agworld	Semios	Identify trends, inputs, to maximize yields and profitability.
Agremo™	Agremo Ltd	Performs analysis from aerial imagery to provide intelligence for agricultural management.

Drones

Drones or unmanned aerial vehicles (UAV) in agriculture provide an advantage in terms of time and labor through their astonishing features. While controlled by computer software or in semi-automated way, drones can be used for studying climate alterations, locating remote areas, identifying pest and disease infestation with severity, spraying of liquid agrochemicals, seeding, irrigation and an overall crop monitoring approach. Some of the advanced drone technologies used in agriculture are Multi-rotor by BAYER, DJI-Agras MG-1, *etc*.

Robots

The stretching landscapes of modern-age agriculture are reshaped by robotics while converging the precision, efficiency and sustainability for future farming. Starting from SGPS-enabled, tele-operated and autonomous tractors and harvesters, the utilization of robotics in agriculture is found in precise application of pesticides and fertilizers, irrigation control, pre and post-harvest crop handling, feeding stations for livestock, textile production, robotic milking stations and dairies, weeding, fruit and vegetable picking, autonomous greenhouse management and so on. It provides large scale benefits like labor cost reduction, resource optimization, data driven decision making, 24×7 service and environmental sustainability along with human resource management.

Sensors

Agriculture sensors gather real time information about crops, field, instrumentation, environment and other factors for a decision-making approach as coupled with IoT to accelerate productivity and minimize financial loss. There are different sensors such as Optical sensors (soil surveillance like natural matter and humidity percentage), electrochemical sensors (soil chemical properties), GPS sensors (livestock tracking and field routing), Temperature sensors (stress prevalence, water availability and harvesting maturity), which are used to monitor agricultural events. Similarly, the soil moisture sensor and raindrop sensor send SMS to the farmer's cell phone using the GSM module, informing them about the moisture content in the soil which in turn can be used for irrigation scheduling.

Cameras

In smart agriculture, for collecting imagery data there are several types of cameras such as RGB cameras (identifying plant morphology, growth patterns), NIR cameras (detecting biotic and abiotic stress conditions), multispectral images (monitoring pest and weeds), thermal cameras (for heat spot and water condition) and hyperspectral cameras (assessment of fruit maturity, nutrient content, disease detection and yield). The high-resolution smartphone cameras are also used for soil erosion measurement, soil profiling, seed phenotyping, identifying weeds, pests and diseases *etc*. Smartphone cameras are easier to use for manual or auto exposure and focus control, image storage, portability and programmability.

Drawbacks of AI Adoption

• AI demands a sound database for ML or DL, which is widely unavailable on a temporal basis.

• The initial and solution cost is very high for the marginal and small farmers.

• In developing countries like India, farmers lack the proper knowledge and skill for using AI.

• The data privacy and security are at risk as it is opened to the cloud. The unethical regulation of databases can be a question raised up against farmers' rights.

• Lack of awareness in AI expertise, adoption of tools and techniques and low intensity of research is a limitation in broad scale.

Conclusion

Today's Agriculture is adorned with automation to gather data from production fields and revealed as advanced precision agriculture or 'smartfarms'. Further, interconnected technologies and high efficacy analytics are helping farmers in assimilating real time databases. Smartphone penetration in each stratum of society including rural farmer belt makes the agricultural app interfaces more accessible to wide audience, leading to the adoption and market growth of AI tapestry. Through the lane of digitization, the paradigm shift of conventional agriculture to smart precision agriculture as a corner stone, is mediated by the correspondence of ML, DL and Artificial Neural Network (ANN) encompassed into the arena of AI for securing sustainable increase in quality and quantity of food production, thus protecting the future of the planet earth against the expected Dooms Day.

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