Emerging Technologies in Agricultural Research: Revolutionizing the Future of Farming

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Abstract

Agriculture continues to be the backbone of India's economy supporting almost 17% of world's population with only 2.4% of world's geographical area and 4.2% of world's water resources. With 1.4 billion people, India is currently the most populated nation on the planet. India achieved great progress in the mid-1960s by implementing green revolution technologies (GRTs), which allowed the country to transition from agricultural primitiveness to contemporary technology. Its potential for horizontal extension is now limited, though, as it has achieved exhaustion. The evergreen revolution (EGR) is desperately needed to meet the growing population's food needs. It can only be accomplished by implementing cutting-edge technology such as block chain management, modeling, robots, drones, automation, artificial intelligence, machine learning, and the internet of things.

Keywords: Digital farming, Internet of Things (IoTs), Modelling, Nutrigenomics, Technology

Introduction

The agriculture sector has experienced spectacular changes over the years to fulfil the rising food demand for the ever-growing world population. The Food and Agriculture Organisation(FAO) of the United Nations systems that, by 2050, there will be9.7 billion people on the earth, challenging to produce 70 further food. The dwindling agrarian land and water coffers on one hand and climate change on the otherhand, make this problem much more delicate. Furthermore, enhancing food production without environmental degradation is another major challenge. Emerging technologies have the potential to revolutionize the agricultureby enabling more effective and sustainable food production. The incorporation of developing technology in agricultural research holds enormous promise for farming's future.Through the integration of precision agriculture, robotics, genetic engineering, Internet of Things (IoT), and controlled environment agriculture, farmers may improve production, optimize their operations, and contribute to resilient and sustainable food systems. Emerging technologies are altering the landscape of agricultural research, providing an enormous opportunity to address the sector's difficulties. Agricultural research can pave the path for a more efficient, resilient and environmentally friendly future of farming by tapping the potential of these technologies, assuring global food security and sustainable agricultural systems.

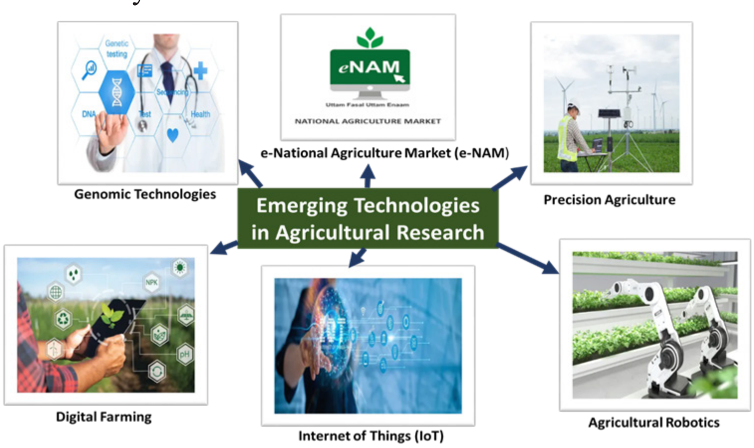

Fig.1.Emerging technologies in agriculture research

Emerging Technologies in Agricultural Research

Innovative agricultural research technologies in today's digital environment are vital to advancing food production and feeding the world's growing population. However, there are a lot of potential and challenges associated with new and innovative technology in the farming community. The following lists a few of the key agricultural sciences technologies.

Precision agriculture

Advanced sensors, satellite photography, and data analytics are used in precision agricultural techniques to give farmers important information on crop health, soil conditions, and pest infestations. Precision farming employs technologies such as GPS, drones, and remote sensing to improve yields, minimize environmental impact, and manage resources more effectively. The Indian government recently employed e-locust tab and e-locust M to contain a locust infestation in Rajasthan's desert regions. In addition to storing data, the technology offered a specific location (GPS), which was helpful for forecasting, warning, and implementing control measures. In a similar vein, ITC Limited has extended its vast e-Choupal network, collaborating with four million farmers to introduce a crop-agnostic integrated solution architecture for a "phygital" system. (Gulati et al., 2023).

Digital farming

Digital farming involves using smart and precision farming techniques consistently, networking the farm both internally and externally, and utilizing web-based data platforms in conjunction with big data analysis. To precisely apply the amount of nitrogen fertilizers needed for the crop plans, a variety of tools have been utilized, including the SPAD meter/Chlorophyll meter, the Leaf Colour Chart (LCC), and the Green Seeker. The government is also promoting the growth of nitrogen-efficient crops like pulses (legumes), which use Biological Nitrification Fixation (BNF) to fix nitrogen in the soil and increase crop productivity. Additionally, the government is funding the development of precision irrigation technologies, such as satellite crop-monitoring systems that determine the precise amount of irrigation needed based on factors like soil moisture, predicted rainfall, and overall crop conditions.

Drone Technology

An unmanned aerial vehicle (UAV), also referred to as a drone, is a type of aircraft that may be remotely controlled or flown without the need for a human pilot. According to Hassanalian and Abdelkefi (2017), the words Unmanned Aircraft Systems (UAS) and Remotely-Piloted Aircraft Systems (RPAS) are increasingly frequently used. Drones would be used in the farming community for soil analysis in agricultural fields, crop health surveillance and monitoring, input spraying, irrigation and monitoring, crop damage assessment, and livestock tracking. Effective application of plant protection chemicals using drones (UAVs) depends mainly on several factors that interfere with quality and type of application.

e-NAM

The e-National Agriculture Market (e-NAM) is a national electronic trading platform that facilitates transparent online trading, improves market accessibility and offers real-time price discovery for better and more stable price realization for producers, which in turn lowers transaction costs for buyers. platform. The emergence of digital marketing systems such as electronic unified agricultural markets (e-NAM), negotiable warehousing and commodity futures are positive steps, but they are not without implementation gaps that must be remedied with timely incentives, investments and monitoring.

The Internet of Things (IoT)

The Internet of Things (IoT) is a network of interconnected physical devices, vehicles, buildings, and other items that are implanted with sensors, software, and connections to collate and exchange data. In 2019, the global market for AI in agriculture was valued at USD 852 million). The expanding usage of IoT in agriculture—where sensors and aerial photos of crops are being used to create data—is fueling this market's rise. This allows deep learning technology to be employed to increase crop productivity.

Agricultural robotics

The design, building, use, and control of robots as well as computer systems for information processing, sensory feedback, and control are all covered in the multidisciplinary field of robotics.Among the novel uses of robots or drones in agriculture are weed control, environmental monitoring, soil analysis, cloud seeding, seed planting, harvesting, and environmental monitoring. (Anderson, 2017). For locating and keeping track of plants, it is typical to use satellite, aerial (including unmanned aerial vehicles, or UAVs), and ground-based (using unmanned ground vehicles, or UGVs, like field robots or commercially available off-highway vehicles) vehicle platforms.

Genomic technologies/Nutrigenomics

Genome editing tool is a genetic scissor that create desired mutation on the desired native gene and in the native location in a predictable manner, and hence it is a safe, site-directed and precision mutagenesis tool. Genomic technologies are probably best defined as technologies used to manipulate and analyse genomic information. Crop breeding has been transformed by genomic advances such as marker-assisted selection and CRISPR-Cas9 gene editing methods. These methods enable the creation of crop varieties with increased nutritional value, disease resistance and yield.

Blockchain in agriculture

All participants write and store a ledger of accounts and transactions that makes up the block chain. It offers a trustworthy source of information regarding contracts, inventories, and farm conditions in agriculture, an industry where gathering this data is frequently quite expensive. (Xiong et al., 2020). Farmers are able to monitor critical information about their products, such as their provenance, manufacturing processes, and quality, thanks to the agricultural supply chain. This transparency promotes fair trade, builds consumer confidence, and improves the efficiency of the supply chain management procedure.

Artificial intelligence (AI) and machine learning (ML)

Artificial intelligence (AI) refers to computer programs that emulate human cognitive functions to carry out sophisticated activities like data analysis, language translation, and decision-making that were previously limited to human performance. On the other hand, machine learning (ML) is a branch of artificial intelligence that focuses on using data sets to train machine learning algorithms in order to create machine learning models that can do sophisticated tasks like sorting photos, predicting sales, or analyzing large amounts of data. Many agricultural tasks, including planting, harvesting, and sorting, are being automated with the help of AI and machine learning technologies. For these technologies to operate precisely and effectively, they need data from sensors, cameras, and machine vision systems.

Bioinformatics

Bioinformatics, the application of computational methods to biological data, plays a crucial role in agricultural research. It enables scientists to analyse and interpret large-scale genomic and biological datasets, leading to advancements in crop improvement, livestock breeding, disease management, and sustainable agriculture. Through transcriptomics and proteomics, researchers can investigate gene expression patterns, protein interactions, and metabolic pathways. This knowledge enhances our understanding of plant growth, development, and responses to environmental stimuli, enabling the development of innovative strategies for crop improvement and management.

Crop simulation modelling

Crop simulation models use quantitative descriptions of eco-physiological processes to predict plant growth and development as influenced by environmental conditions and crop management, which are specified for the model as input data (Hodson and White, 2010). These models recreate the intricate relationships between crops, soils, climate and management techniques using mathematical equations and algorithms. List of some crop simulation modelling tools is as detailed.

a.**DSSAT (Decision Support System for Agro Technology Transfer)**

DSSAT has been developed by IBSNAT (International Benchmark Sites Network for Agro technology Transfer) to simplify the use of crop models in the agricultural sector (Jones et al., 2003). DSSAT primarily supports several crop simulation models in decision-making procedures. DSSAT integrates several crop simulation models, such as DSSAT-CSM, APSIM, and CERES. In response to various management techniques and climatic circumstances, it enables researchers to simulate crop growth, yield and nutrient dynamics.

b. Crop Environment Resource Synthesis (CERES)

It is a commonly used agricultural modelling system that aids in understanding and simulating crop growth and are able to determine the effects of various management techniques and environmental factors on crop output, enabling them to make educated decisions to increase yield, alleviate resource use and lessen environmental effects. CERES WHEAT, CERES RICE, CERES MAIZE are some of the widely used models.

c. Agricultural Production Systems Simulator (APSIM)

APSIM is a modelling framework that can combine models created as a result of dispersed research initiatives. The complex model was developed to simulate biophysical processes in agricultural systems, particularly those related to the ecological and economic consequences of management decisions made in the face of climate change.

d. CROPGRO Model

For simulating the development and yield of numerous crops, including maize, wheat, rice, soybean and cotton, the CROPGRO model is frequently used. To forecast crop performance, it takes into account variables including temperature, rainfall, solar radiation, soil characteristics and management techniques. The model has received significant validation and is currently being used to investigate agricultural responses to climate change and to manage irrigation and fertilizer more effectively.

e. Global Gridded Crop Model Intercomparison (GGCMI)

GGCMI is an international cooperative project with the goal of evaluating and contrasting the effectiveness of several crop simulation models on a global level. Through GGCMI, researchers examine future estimates under various climatic scenarios as well as the capacity of models to replicate historical crop yields.

f. Crop yield forecasting

In order to evaluate production levels and foresee future crop failures, crop simulation models are employed in crop yield forecasting. These forecasts aid in making decisions about resource allocation, trade and food security for governments, farmers and other stakeholders.

g. Climate change impact assessment

Assessing the possible effects of climate change on agricultural output requires the use of crop simulation models. Researchers may assess how changes in temperature, precipitation and CO2 concentrations may affect agricultural yields and identify locations at risk from climate-related concerns by simulating how crops respond to various climate scenarios. These evaluations offer insightful data that can be used to create policies and strategies for adaptation.

3. Constraints in the Use of New Technologies in Agricultural Research

a) Technical limitations

In areas with lack of internet connectivity and reliable power supply poses obstacles to adopt technologies that require online access and electricity. For instance, precision agriculture techniques relying on sensing technologies may entail internet connections and dependable power sources.

b) Skill gap

It can be challenging to train researchers and farmers on the use of technologies. For example, implementing data analytics or AI driven solutions demands a workforce in these domains.

c) Economic challenges

Emerging technologies often come with costs, which can be unaffordable, for small scale farmers or research institutions with limited resources. Precision farming tools like GPS guided machinery fall into this category.

d) Limited access to financing

Limited access to credit or financing options can hinder the adoption of technologies. Farmers may face difficulties in obtaining loans to purchase equipment or implement practices.

e) Social factors

Socio-cultural aspects heavily influence the acceptance of technologies. For instance, traditional farming communities might exhibit hesitancy towards adopting modified crops due, to concerns regarding religious practices.

f) Gender gap

Some technologies may provide advantages to one gender compared to the other. The level of access and control that female farmers have over resources can affect their ability to embrace methods and techniques.

\4. Conclusion and Way forward

The development and adoption of emerging technologies is at infancy stage in India. Pilot testing and scientific validation of these technologies need to be done by scientific institutions to work out scope and opportunities of their adoption for achieving food and nutritional security. However, it should be accomplished keeping in view the sustainable development goals (SDGs) and without damaging the environment. Further, the farmers need to be trained fully to adopt and reap higher profits with least damage to natural resources and ecosystem.

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