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Applications of Emerging Smart Technologies in Farming Systems: A Review

By Vipin Kumar Choudhary

Abstract- The future of farming systems depends mainly on adopting innovative, intelligent, and smart technologies. The agricultural sector's growth and progress are more critical to human survival than any other industry. Extensive multidisciplinary research is happening worldwide for adopting intelligent technologies in farming systems. Nevertheless, when it comes to handling realistic challenges in making autonomous decisions and predictive solutions in farming, applications of Information & Communications Technologies (ICT) need to be utilized more. Information derived from data worked best on year-to-year outcomes, disease risk, market patterns, prices, or customer needs and ultimately facilitated farmers in decision-making to increase crop and livestock production. Innovative technologies allow the analysis and correlation of information on seed quality, soil types, infestation agents, weather conditions, etc. This review analysis highlights the concept, methods, and applications of various futuristic cognitive innovative technologies along with their critical roles played in different aspects of farming systems like Artificial Intelligence (AI), IoT, Neural Networks, utilization of unmanned vehicles (UAV), Big data analytics, Blok chain technology etc.

Keywords: *agriculture, artificial intelligence, farming systems, neural networks, smart technologies.*

GJCST-G Classification: *DDC: 630*

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I. Introduction

Crop cultivation is really a challenging task since ancient time. However, some aspects of it require more attention than others. Therefore, farmers have urged intervention of smart technologies since long back to help them address their numerous challenges, such as a lack of quality seeds, affordable fertilizers, manure, a lack of modern Agri-based equipment/machinery, fragmented small land holdings, insufficient irrigation sources, and dominating regional traders.

However, with emerging Information and Communication Technology (ICT) seamlessly integrating advanced technologies into the traditional farming ecosystem, most of these issues can now be resolved efficiently.

ICT (Information and Communication Technology) is a collective term that incorporates many communications equipment or applications, cell phone, drone, sensors, cloud services, IoT, radio broadcasting, television, desktop, internet backbone hardware and software, communications satellites, and so on (Fig.1). Innovative, intelligent technologies and practices are transforming agriculture a profitable industry.

Digitization in the 21st century implies that every contemporary field or industry becomes more dependent on hardware equipment linked through certain media and guided by programming software. Some analysts also call this development "*Agriculture 4.0-The Future of Farming Technology"* a term the World Government Summit used (Dubai United Arab Emirates, 2018). Innovative, intelligent technologies and practices are transforming these industries from the inside out. The farming business has undergone a substantial technological change. These intelligent technologies have pushed the entire agricultural business into the digital age. Agriculture involves big spatial data, sensors, drones, environmental controls, farm management software, micro-farms, intelligent packaging technology, gene manipulation and e-grocer businesses. In addition, artificial intelligence (AI) provides decision support through machine and advanced digital learning processes (*Choudhary VK et al. 2019*).

A farmer needs the intervention of Smart Technology to provide timely Information on various stages of farming. A farmer needs innovative technology to assess the appropriate input requirement, such as seeds, fertilizers, pesticides, timely favorable weather conditions, credit availability, soil testing mechanism, etc. before planting. Innovative technology may assist in adopting good agricultural practices, Pest control, appropriate harvesting technique, and safe, adequate packaging of goods before the harvesting stage. The farmer needs technology help in intelligent storage, grading, and maintenance of international standards, providing supply chain logistic facility and proper post-harvest management. A farmer desperately needs reliable Information on commodity prices in mandis /market, alternative market channels, and consumer behavior.

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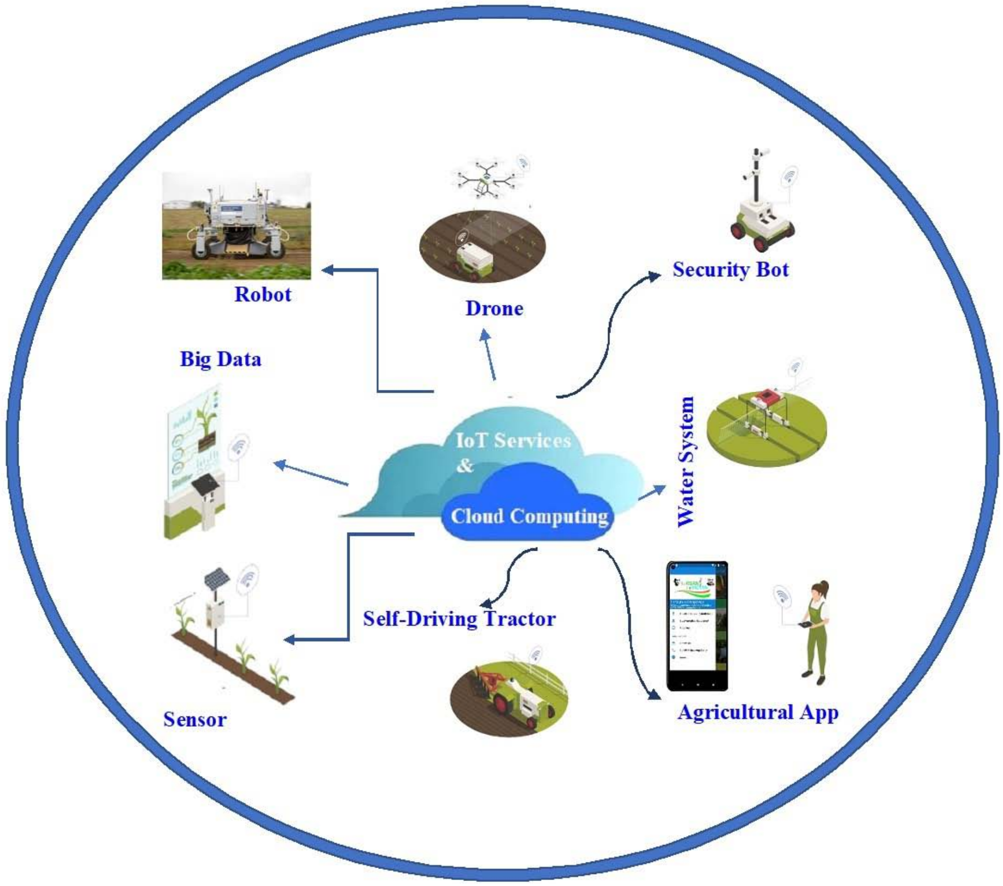

Fig. 1: ICT applications in Farming Systems

Nowadays, the application of Artificial Intelligence (AI), such as Artificial Neural Networks (ANNs), Fuzzy Systems and Genetic Algorithms, Block Chain technology, IoT, etc., has shown greater efficiency in problem-solving like Prediction of crops *(Barriosetal. 2020).* These application areas are essential for economic planning, dry farming growth, crop genetics, pest and pathology effects, weed influence, Quality control, and management during the growing period. These innovative practices and technologies are likely not only limited to the future of agriculture (*Patel and Patel 2013*) but may be the key to human race survival.

II. Technologies

a) *The Drones*

Applications of Drone in agriculture are a big boon to farmers. Drones are made with sensors and software capable of capturing high-resolution photos of fields to analyze crop health and help provide accurate farming decisions (*Abderahman Rejeb et al. 2022)*. Typically, drones consist of high-quality cameras, GPS, navigation systems, multiple sensors, programmable controllers, and tools for autonomous drones. Unmanned aerial vehicles (UAVs) can get more precise data than satellites. Agri-tech software processes and transforms Data captured by drones into valuable information. In agriculture, drones equipped with sensors and cameras are used to image, map, and survey farms. Drones operate in combination with sensors and GPS. (Fig. 2*)* they can be remotely or automatically controlled using agriculture software-controlled flight plans in their embedded systems.

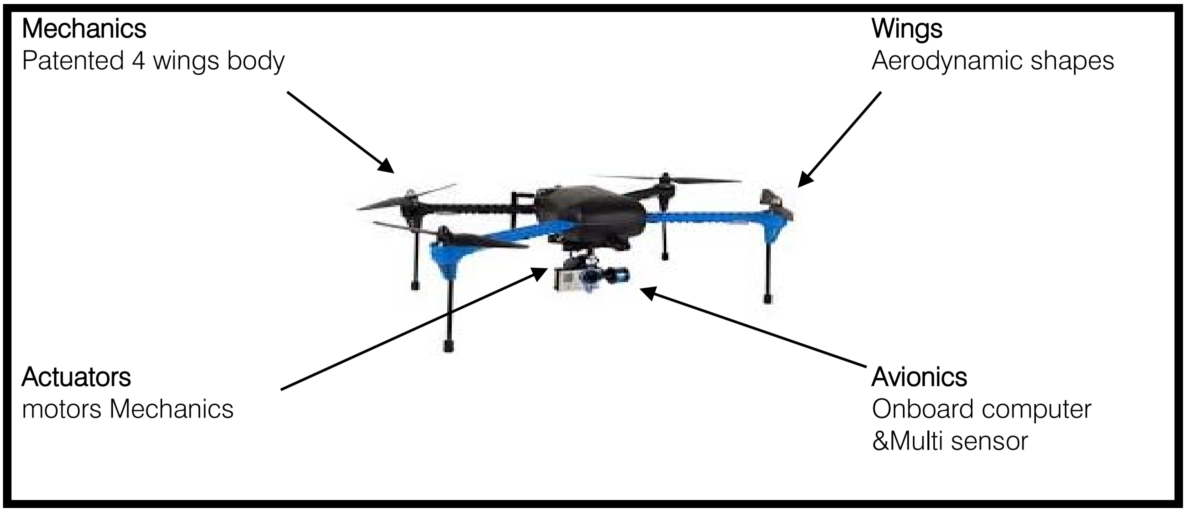

Fig. 2: The Drone

Drones can operate in both satellite and non-satellite modes. The drone works on the propulsion system technology (motors, electronic speed controllers, and propellers), which propels the UAV into the air and allows it to fly in any direction or hover. The motors and propellers on a quadcopter work in pairs, with two motors propellers rotating clockwise. Almost all drones include a Ground Station Controller (GSC) or a smartphone app allowing you to fly the drone and monitor its current telemetry. Telemetry data on the remote controller may include UAV range, height, speed, GNSS strength, battery power remaining, and warnings (*Fintan Corrigan, 2020*). In addition, many UAV drone ground controllers use FPV (First Person View), which transmits the video from the drone to the controller or mobile device.

UAV drones come in a wide variety of sizes-

1. Predator Drone

These are largest in size being mostly used for military combat purposes, having dual Global Navigational Satellite Systems (GNSS) such as GPS and GLONASS.

2. Medium Size Drone

These have fixed wings and require short runways, generally used to cover large sections of land, working in areas such as geographical surveying or to counter wildlife poaching.

3. VTOL Drones (Vertical TakeOff and Landing)

VTOL drones are light sized, generally quadcopters. VTOL drones can take off, fly, hover and land vertically.

An agricultural drone is used to help farmers in increase crop production, optimize agriculture operations and monitor crop growth (Fig. 3). These are high-tech systems equipped with Advance Sensors and digital imaging capabilities that can perform various difficult tasks: monitoring crop health, applying fertilizers and watering the fields, soil health scans, even tracking weather and estimating yields, and then collecting the data and analyzing it.

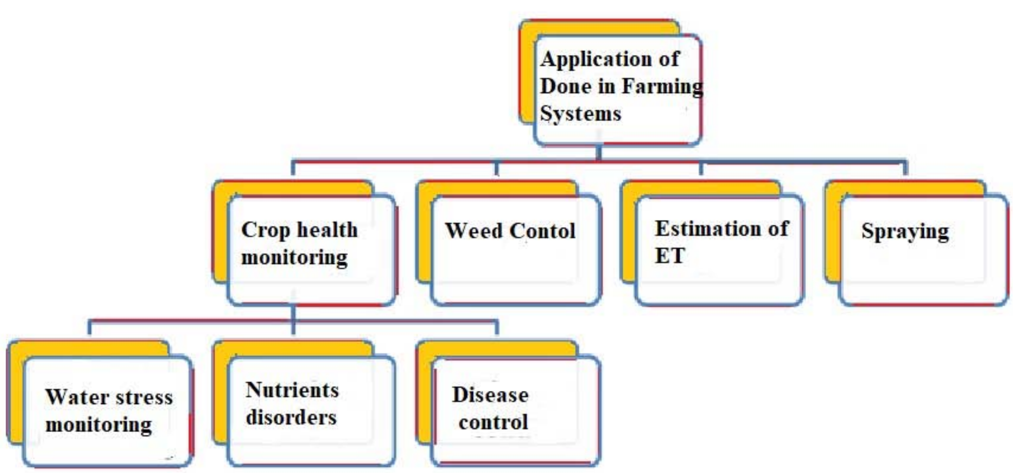

Fig. 3: Major Applications of Drone in Farming Systems

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In addition, drones are now being used in projects supplementing the work on pollination that bees have generally perform. Environmental change is a significant issue for humankind. If climate change continues to exacerbate, a crisis of food shortages could occur, resulting in price rise exuberantly even in more developed countries (*Andy Heikkila 2018)* and a public health crisis in the form of global food shortages and hunger. As such, Govt. policymakers should pay attention to the problem. Time magazine reports that more than seven hundred bee species are going extinct. This bee extinction could be catastrophic because bees play an important economic role as pollinators that help to sustain agricultural production.

Having the real time monitoring capabilities, drone can play a vital role in future farming. Drones can mechanize every step of farming, eliminating the costs of human errors and enabling farmers to quick reliable solution. *(Abderahman Rejeb et al. 2022)*

b) Urban/Vertical Smart Farms

The most significant advantage of urban agriculture is the innovative use of space. As a result, urban farms may be as productive as our typical outdoor garden. Nevertheless, on the other hand, they could be as sophisticated, well-regulated, and futuristic as a stack of environmentally controlled pods. We have begun to experience that yields in urban or vertical farming ventures are higher than in traditional Farming. (*Andy Heikkila 2018).* However, "Vertical farming does not promise to change how we farm fundamentally, just make it more effective, competitive and take up less space."

Conventional farmers should come forward to learn vertical farming principles and follow smart design principles in their buildings and construction design to reduce waste and increase production output. Ample space means more energy required for heat and light, resulting in higher costs and more waste of resources. As we keep on overpopulating, we need more space and will need to rely on the effective use of space and growth to continue to feed ourselves.

c) Down on the Robotic-Farm

New generation intelligent innovating machines will radically transform crop cultivation in the future by using expertly selected inputs. Eventually, agricultural robots can work in all farming operations, from weed management driving tractors (automatic weeding), fruit picking, and disease control. The 'adaptable multi-purpose robotic platform' of Bosch's BoniRob (*Fig 4. Trevor Daugherty 2015*) build on an artificial intelligence platform. This agricultural robot uses camera and image recognition technology to detect and remove weeds by driving a bolt into the ground. It learns to discriminate between weeds and crops through picture training on leaf size, shape, and color. BoniRob can roll through a field, removing unwanted plants without destroying anything valuable. *(Trevor Daugherty 2015*). This robot is to cut down the considerable amount of time spent on labor-intensive tasks associated with farming, like planting and picking the seeds. The operating brain of this system can view and distinguish between different plant types based on form, shape, color, and other characteristics. It uses this astute knowledge to correctly classify good and poor plants when working in the field. *(Trevor Daugherty 2015*)

The standout feature of BoniRob is its weed management system. According to Bosch, it can remove weeds by striking them with a metal rod with enough force that the intruder cannot survive. This is a better alternative to chemicals for both humans and the environment. In addition, the system will decide on any item on the ground based on what its trainer has taught.

Source: Trevor Daugherty, 2015

Fig. 4: Bosch-Bonirob

d) Smartphone

With the advent of mobile phone technology, everyone has more access to information. Introducing low-cost mobile phones and data has resulted in the development of new affordable agricultural services and applications. For example, farmers can quickly and timely access weather information, plant health monitoring, market information, education, and other agricultural services on his/her smartphones. In addition, Smartphone holder farmer can manage yield management systems to monitor and make insight-driven decisions about fertilizer, crop yields, weather patterns, water requirements, growing conditions, understanding of Pest Population Dynamics, and disease detection. Voluminous data generated world-wide is used to provide online advisory services for arable farms and other agribusiness organizations. A mobile phone-based remote-control Smart water system helps alleviate leaks and equipment breakdowns by informing farmers timely and allowing them to control water pumps remotely. As a result, farmers can slash travel and water costs/waste by irrigating crops remotely. It is auto-smart, robust & simple, controlled by a mobile phone for soil/tank sensors. In India, farmers already use a device named Nano Ganesh. (*Ostwal Santosh 2015*).

Mobile Technology using Artificial Intelligence, can help an average Indian farmer to get information regarding forecasting and to predict the weather, crop production, etc., in a timely and precise manner. Scientists at Indian Institute of Farming Systems Research are working on developing an Artificial Neural Network (ANN) -based mobile application (Fig. 5) to help farmers and researchers in the selection of crop variety, planting schedule, disease, pest, weed, weather information, yield forecast, Soil testing labs, and prevailing Govt schemes related to farming, Contact to Kisan Helpline, etc. The application is being developed using the Android Studio platform, Java language, XML, and SQLite database. The neural network *(Back-propagation algorithm)* is being used to create a feature of yield prediction network that can contain three layers of neurons: an input layer, a hidden layer (which is optional), and an output layer. So far, two hidden layers are employed with four neurons in each hidden layer. The final number of hidden layers and number of neurons will be determined by conducting fair numbers of training schedules on data sets

Therefore, resource-poor farmers can be benefitted more from the help of ICT (Information & Communication Technology)/Artificial intelligence.

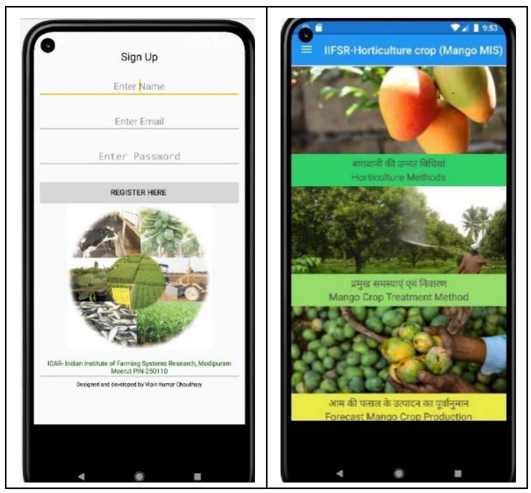

Fig. 5: Smart Phone Application in Mango Crop Management

e) Artificial Intelligence, Internet of Things, and Automation

In AI and IoT-based smart farming, a system is built for monitoring the crop field with the help of sensors like light, humidity, temperature, soil moisture, etc. The agriculture farmers can monitor the field conditions from anywhere. IoT-based farming is highly efficient when compared with the conventional approach.

Most promising AI technologies that transform the agriculture sector, as discussed below.

f) Crop and Soil Monitoring

AI can analyze and interpret data on image perception to track crop health (Fig. 6) and predict production. crop malnutrition may be detected considerably quicker than in humans. In addition, AI models can advise farmers about specific problem regions, allowing them to take prompt action. *(Pradeep N. et al. 2020).* Crop health assessment and early detection of crop infestations are critical in ensuring good agricultural productivity. Climate change, nutrient deficiencies, weed, insect, fungal infestations, and other challenges must be detected early enough to enable farmers to mitigate their effects.

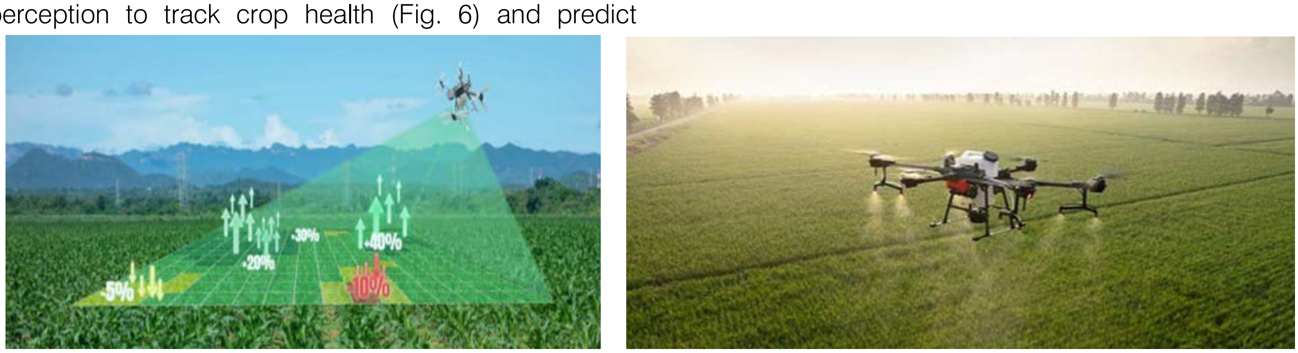

Fig. 6: Crop assessment & Field Spray by Drone

In collaboration with the International Crops Research Institute for Semi-Arid Tropical regions (*ICRISAT*), Microsoft India has developed a sowing application for farmers and a personalized village advisory dashboard for Andhra Pradesh Govt. The sowing app is designed to provide powerful cloud-based predictive analytics to farmers with critical information and insights that will help reduce crop failure and increase yield, reducing stress and generating more income.

Plantixapp a Berlin-based AI agricultural startup (*PEAT GmbH.*) has developed a deep learning application called plantix that identifies potential defects and nutrient deficiencies in soil. The analysis is conducted by software algorithms which correlate foliage patterns with certain soil defects, plant pest and disease. The app uses images to detect plant diseases and other possible defects through images captured by the user's smart phone camera.

Soilsens, a low-cost smart soil monitoring system, has emerged as a potential support to farmers who experience difficult farming decisions. Proximal Soilsens Technologies Pvt. Ltd. developed this technology with the Ministry of Science and Technology (DST) and the Ministry of Electronics and Information Technology. The system includes soil moisture sensors, soil temperature sensors, ambient humidity sensors, and ambient temperature sensors. A mobile app advises farmers on optimal irrigation. The technology has the potential to improve the efficiency of agricultural water use (*Diksha Manaware. 2020*). Furthermore, the intelligent irrigation system based on the Internet of Things (IoT) automate the irrigation process by analyzing soil moisture and weather.

g) Livestock Health Monitoring

Connected wearables make livestock and fisheries management easier, from tracking location to monitoring health conditions. Farmers use these devices also to track pregnant calves, milking frequencies, abnormal behavior, and disease symptoms. There are several M2M livestock solutions, such as the satellite collar-based management system, e.g., FindMySheep (Fig 7. *Source: Globalstar Europe Satellite Services*). This application system makes it possible to find the animal and view a video of its whereabouts around the globe. (*Globalstar Europe Satellite Services, Dublin, Ireland 2014*)). Another system from General Alert adds an extensive list of health and management monitoring for use in pig farms.

Fig. 7: FindMySheep (Source: Globalstar Europe Satellite Services)

Animals are essential to our agricultural systems, requiring slightly more monitoring than plants. CattleEye is an excellent example of an AI application in farming system. Overhead cameras and computer vision algorithms are used to monitor the health and activity of cattle. *(CattleEye.com)*Cattle can be followed and monitored remotely and in real time, allowing farmers to be informed as soon as a problem is detected (*Alberto Rizzoli2022)*. This is not limited to cattle. Computer vision can also count animals, detect disease, identify unusual behavior, and track life-changing events such as pregnancy and birth. Data from cameras and drones (UAVs) are combined with other technologies to inform farmers about animal health and food and water availability. A few countries have recently begun testing a new AI system that screens animal location, health, and well-being using a combination of computer vision, voice recognition, and temperature sensors. (*Gill Sukpal Singh et al. 2017*).

h) Driverless Tractor

Typically, when we imagine the future of driving, we imagine vehicles on the road and passengers not required to keep their hands on the steering wheel because Artificial Intelligence (AI) is handling the driving. Nevertheless, we rarely consider driverless cars on farms. Smart-Ag has announced the working driverless tractor technology as an "AutoCart" (*Smart-Ag.com)* application using Artificial Intelligence. This software program completely automates a grain cart tractor, giving farmers much-needed support during harvest. This cutting-edge technology will enable farmers to automate and maximize the efficiency and capacity of their existing equipment regardless of manufacturer. The AutoCart software is a cloud-based platform, meaning these automated farming vehicles will join the internet of things (IoT) worldwide. (*Smart-Ag.com)*

i) Electrofishing

Electrofishing is a popular scientific survey method for sampling fish populations to determine abundance, density, and species type. Fishery Management & Surveys of Colorado's Waters stated in their study that correct electrofishing method does not cause permanent harm to fish, which return to their natural state. in just two minutes after being captured. Marine Harvest employs secure video surveillance to track fishery production and assist in fishing management. Fish breeding may be relatively low-tech on the surface, but becoming a world leader requires ongoing data monitoring at each stage of the value chain for seafood.

j) Blockchain Technology

Blockchain technology is mainly known for its application in cryptocurrency finance (BitCoin). However, the agricultural world is beginning to recognize this innovative new technology from a different perspective. Blockchain technology could include producers, retailers, logistics providers, and regulators in any supply chain. Blockchain technology based trading platforms reform agricultural trade by transparently connecting each transacting client to the same dataset (*intellias.com*).Block Chain technology aims to reduce transaction costs and establish financial security. Blockchain technology simplifies and reduces the cost of validation and monitoring in the supply chain, (Fig. 8) which in turn, encourages smaller suppliers in the global food economy. Blockchain technology can transform the supply chain mechanism in the agricultural industry *(intellias.com).*

Blockchain technology in the agricultural supply chain can:

1. Simplifying all phases
2. Track down a product along its entire path from farmland to store shelf
3. Work to improve food safety and removing counterfeit goods
4. Significantly reduce financial risks and encouraging inclusive trade
5. Facilitate toaccess agricultural finance services for farmers and enterprises.
6. Apply data science concepts to generate more intelligent market data for better decision-making.
7. Provide legally valid certifications to relevant authorities.

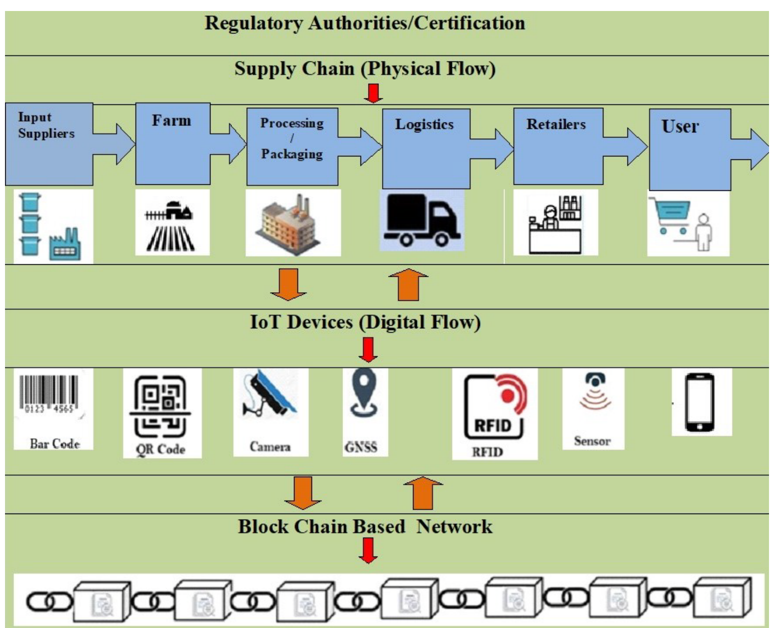

Fig. 8: A simplified Agriculture Supply Chain System.

Commodity traders Louis Dreyfus Co. (LDC), a leading merchant and processor of agricultural goods, completed selling and delivering thousands of tons of soybeans to China in December 2017. This is considered to be the first blockchain-powered agriculture trade. *(ldc.com)*. Many of the initial blockchain applications in agriculture focused on traceability and supply chains, blockchain ledger can record and refresh crop status from planting to harvesting, storage, and delivery. A robust, secure, irreversible ledger that never loses a load is an advantage for large operations. All crops' statuses can be viewed in real-time. Blockchain technology can also be used to manage resources, such as machinery tracking, record-keeping, or monitoring other sensors and equipment.

Jivabhumi is an agri- tech platform connecting farmers directly with Institutional buyers and consumers.

Jivabhumi partners (*https://jivabhumi.com/*) with farmers, and farmers groups, aggregates farm produce and makes it traceable by leveraging a BLOCKCHAIN-enabled platform called FOOTPRINT. Jivabhum is incubated and accelerated by India's leading start-up accelerators, such as YES Scale Accelerator. Jivabhumi enables consumers (B2C) and institutional buyers (B2B) to buy chemical, pesticide-free, and traceable farms directly produced by the producers. It aims to digitalize agriculture to solve supply chain inefficiencies.

k) CRISPR and Genetic Editing

Scientists have recently started using CRISPR/Cas9 (Fig. 9 *Clustered Regularly Interspaced Short Palindromic Repeats, Plec Corrie 2020)*. To achieve precise genetic surgery that allows them to concentrate and modify an organism's genome by ablating or replacing specific parts of the genetic sequence of a DNA strand. Medical News Today states that findings of recent case study of biotechnology company Verve Therapeutics, New Zealand, genetic engineering has been shown to reduce cholesterol through this avenue. (*Plec Corrie2020*).

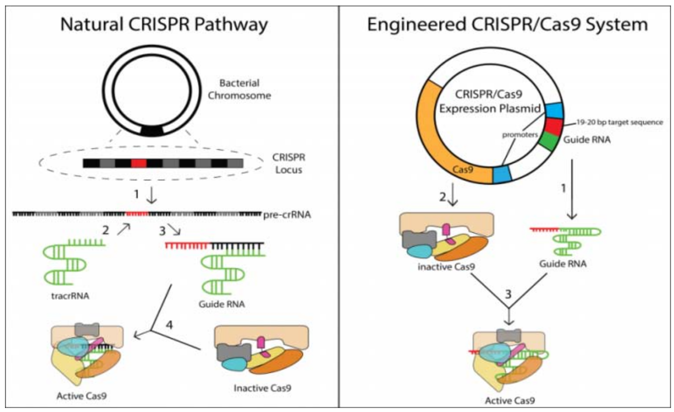

Fig. 9: Natural Vs Engineered CRISPR systems (*Plec, Corrie, 2020*)

CRISPR is now being used to adjust cow's gut microbes in order to reduce the amount of methane produced. Adapting cow microbiomes to produce more meat from fewer foods could boost the meat industry's competitiveness and profitability. Furthermore, methane has approximately twenty-five times more heat-trapping capacity than carbon dioxide. Hence reducing cow methane production could have a significant impact on the environment. Scientists have also begun to develop engineered crops that require less water and produce more food. However, tampering with genetics in any ecosystem or environment may result in unanticipated consequences. So, we must avoid generating more problems to fix a few.

l) Data, the Life of New Agriculture

Agricultural activity does not only generate crops with M2M (Machine to Machine). It also grows another valuable crop, "data." The scientific community is uncovering evidence to support sustainable soil health intensification and soil health maintenance at the field, farm, and enterprise levels. The researchers at IBM anticipate more significant use of extensive data analysis in the agricultural sector *(business.weather.com)*

Farmers and farming companies are trying to discover the advantage of precision farming. "Smart Farming" integrates remote sensing, IoT tools, robotics, extensive data processing, artificial intelligence, and other emerging technologies into an integrated high-crop production system. (*Choudhary VKetal.2016*). *Precision technology* is a farm management concept that uses satellites and GPS tracking systems to measure and respond to crop field variability. Precision farming can double the farming output to feed the 9 billion people predicted to populate the planet by 2050 and shift societal perceptions of the agriculture industry. Precision farming was also the subject of a Goldman Sachs 2016 report, subtitled Cheating Malthus with Digital. According to agricultural researchers, crop yield can be increased by 70% by 2050 through precision planting, fertilizer application, irrigation spraying, and autonomous driving applications, with adoption commencing in existing marine applications. *(Lyndsey Gilpin 2014)*

m) Bio Informatics in Agriculture

Bioinformatics is a multidisciplinary scientific field that uses information technology to process and manage biological data using cutting-edge computer tools. Bioinformatics is a branch of computer science that studies and predicts the structure and function of genomic data, biological sequence data, and macromolecules. Agriculture genomics is a classic example of a bioinformatics application in agriculture in which genomic data is collected, stored, and interpreted.

Bioinformatics tools and methods are used in agriculture in many ways, including increasing plant resistance to biotic and abiotic stressors and improving nutritional quality in depleted soils. (*CuffariBenedette 2021*) Aside from these priorities, gene discovery using computer software has enabled researchers to develop targeted strategies for improving seed quality, introduce extra micronutrients into plants for improved human health, and engineer plants with phytoremediation capabilities. Some of the most widely used plant/crop bioinformatics online databases include BGI Rice Information System, Gateway of Brassica Genome, Chloroplast DB, The Crop Expressed Sequence Tag (CR-EST_ database, CyanBase, the European Molecular Biology Laboratory (EMBL) nucleotide sequence database, and many more *(biotechgo.org,Bulgaria)*.

Bioinformatics tools play a vital role in providing information about the genes found in the genomes of species. These technologies have also allowed researchers to predict the function of specific genes and the factors that influence them. For example, the information the tools provide about the genes enables scientists to develop drought, herbicide, and pesticide-resistant plant varieties. Similarly, specific genes can be altered to increase meat and milk production. Furthermore, their genes can be altered to make them disease resistant.

Plants' genomes stayed conserved and did not supply much information when evolutionary changes occurred. It is now feasible to extract the needed information from the genome of certain plants thanks to bioinformatics techniques. There are two species of food plants, the genome of which has been entirely mapped, for example, Arabidopsis thaliana and Oryza sativa *(CuffariBenedette 2021)*. These two species of plants have their names in English as watercress and rice, respectively.

Watercress is a tiny plant that grows on rocks. Because of its smaller genomic size, researchers took an interest in its genome and studied plant developmental processes. Its genome consists of 5 chromosomes on which 100 Mbp DNA is distributed. It reproduces in 5 weeks and makes a new generation. Therefore, knowledge of its genes and how they are expressed reveals information about the proteins and expressions of other plants.

By adding the desired genes, many plants have become insect-resistant. For example, Bacillus thuringiensis is a bacterial species that improve soil fertility while protecting plants from pests. When the researchers sequenced its genome, they incorporated its genes into the plant to make it insect-resistant. Corn, cotton, and potatoes, for example, have all been insect-resistant in the past. When insects consume plants with bacterium genes in their genomes, the bacteria enter their circulation and starve them, eventually killing them. Bt corn is a type of food plant that the introduction of bacterial DNA has genetically modified. It works against insects by causing them to acquire resistance. The use of Bt genes in the plant's genome has made agriculturists use insecticides in minimal amounts. As a result, plants' productivity and nutritional value will also increase and benefit human health. When alterations are introduced to a plant's genome, the nutritional value of the plant rises as well. For example, some genes are added to the rice genome to boost the crop's Vitamin A levels.

n) Soft Computing in Agricultural

Soft computing refers to a collection of computational techniques that includes fuzzy logic (FL), artificial neural networks (ANN), and genetic algorithms (GA*). (JacekMZurada et al. 2017*)

Soft computing is advantageous in offering strategies for incorporating human-like ambiguity and real-world uncertainty into traditional computing algorithms. For instance, soft computing-based categ-orization, modelling, prediction, optimization, and control have been used to tackle problems in soil and water, crop management and post-harvesting, precision agriculture, food processing, food quality and safety, and agricultural vehicle and robotics. (*Lotfi A. Zadeh*).

Agricultural production management is a challenge that includes determining the best sowing season, crop variety selection, land preparation, sowing method, fertilizer, and pest selection based on variety. There is a need for a more versatile fuzzy logic based expert system approach that provides the end user with a diverse range of farming approaches. *(Expert-system-questions, 2018).* Agricultural pest management used the color co-occurrence approach for textural analysis to see if classification algorithms could distinguish between sick and normal citrus leaves.

i. *Fuzzy Logic*

Fuzzy logic is very well-known for its application in developing an image capture/processing system for weed detection (*Dubey Sonal et al. 2013*) and a fuzzy logic decision-making system for deciding where and how much herbicide to spray in a crop field. However, information on the economic thresholds of weed influence on crop productivity is difficult to adapt to a specific region or farm. *(Ogunleye G O et.al 2018)* Therefore, a fuzzy logic approach was used to convert image data into sprayer commands, allowing farmers to use their experience to classify weed status at a given location in the field this research indicated that a fuzzy logic system could understand and facilitates the representation and processing of human knowledge in a computer.

A functional approach to soil characterization is used in the precision agricultural decision support system, which includes water stress, nitrate stress, nitrate leaching, and residual nitrogen content at harvest. First, a fuzzy c-means classifier was used to classify the soil profiles into functional groups. Next, the researcher investigated ways to use the nitrification inhibitor for management zone designation based on slope and surface texture for a site-specific application. Rather than using expensive grid sampling of soil chemical and physical attributes, fuzzy cluster analysis highlighted the possibility of readily available spatial yield or soil to establish management zones for applying nitrification inhibitors. Finally, in precision agriculture, (*Ortiz et al. 2011*) used fuzzy clustering of elevation and slope of the terrain to delineate root-knot nematode (RKN) risk zones for a comparison test of two nematicide application rates on nematode population density and cotton lint yield.

ii. *Artificial Neural Networks in Agriculture*

Artificial neural network (ANN) has emerged as a new technology that offers a variety of solutions to complicated challenges in agricultural research. Since it can address a wide range of issues that a linear system cannot. Modern agriculture requires a high level of production efficiency as well as a high level of product quality in agricultural and livestock production. (*Russian Federation: Gazprom Neft 2020, Sustainable Development Report*).ANN tools are extensively employed in a variety of classification and prediction tasks. Their applications vary from crop quality classification to disease and pest verification, predicting the impacts on production based on multiple independent parameters and intelligent weed management. ANN techniques improve agricultural decision-making processes, assist in optimizing storage and transportation procedures, and enable the forecasting of expenses. Machine learning methods in the "life cycle of a farm" requires handling large amounts of data collected during the growing season and having the appropriate software to analyze it. The evident growth of digital agriculture and precision farming leads many farms to switch to ANN intelligence-based products. (*AbderahmanRejeb et al. 2022*)

iii. *Genetic Algorithm Applications*

Genetic algorithms are similar to natural systems, created through gene reproduction, cross-over, and mutation to provide better environmental adaptation. It works on the principle of pheromones that are substances which are secreted to the outside by an individual and received by a second individual of the same species. A complex structure could be built using its more fundamental constituents. *(LiuLingxiao 2022*). Genetic algorithms determine the best cropping pattern while considering various constraints and complexities using search and optimization technique. Genetic algorithms have also been used to assist with modelling and Prediction. Genetic algorithm approach can address the issues in Crop management, water management, food quality and safety, food processing, precision agriculture, agricultural biology, agricultural machinery, agricultural facilities, animal behavior, and forecasting agricultural commodity prices.

The standard genetic algorithm's steps can be summarised as follows.

1. The population of individuals is initialized. This can be done by randomly generating a definite number of people represented by fixed-length character strings. The following stages (2–4) are repeated until the halting requirement is reached.
2. Every individual in the population has a chance of experiencing a mutation. In other words, the given individual can be randomly modified
3. In some unexpected way, the (possibly modified) individuals split and interchange these splits in pairs, creating new individuals (cross-over). As a result of Steps 2 and 3, the population modifies.
4. The fitness of each individual in the newly obtained population is assessed. As a result, only a subset of all individuals is advanced to the next stage. (i.e., Step 2) or, if some individuals obtain satisfactory fitness. The procedure is stopped.

In this way, a solution—or an approximate solution—to the problem can be found, *Table-1:* Summary of Soft Computing Techniques in Smart Farming

Sl. No.	Soft Computing	Application thrust Area	Technique
1.	Fuzzy Logic	Pest Management	Colour co-occurrence Classification
		Soil Analysis (Mapping & Caracterization)	Fuzzy set grid spacing
		Irrigation and ET calculation (evapotranspiration)	Estimation of daily reference evapotranspiration using FL crop water stress index (CWSI)
		Prediction of sediment and phosphorous movement Yield Prediction based on different energy Inputs	Fuzzy c-means clustering for RBF training Adaptive neuro-fuzzy inference system)ANFIS
2.	Artificial Neural Network (ANN)	Weed Management	classification of images based on color. estimation by multi-linear regression and discriminant analysis for classification of images
		Irrigation, demand and water supply	Feedforward ANN model trained with Back Propagation algorithm
		Soil Analysis	Fuzzy neural network classifier and multilayer ANN trained with GA.
		Prediction of rainfall and crop production	Fuzzy logic k-mean Neuro fuzzy with genetic algorithm
3.		Weed management, vegetation cover	GA based image segmentation algorithm, component analysis technique based on GA uses GPS data and hyperspectral remote sensing data
		Soil Analysis, water	stochastic imaging

	Genetic Algorithm (GA)	capacity (AWC), uncertainty and variability	
		Irrigation , optimal crop water allocations	GA models
4.	Decision Tree (DT)	Weed and Nitrogen Management	Classification of multispectral images
		Precision Agriculture (Distinguishing between chemical fertilizer and manure treatments)	spatial decision support system (SDSS)

o) Data Mining Techniques a Boon for Modern Agriculture Research

Data mining is a highly interdisciplinary field that includes statistics, machine learning, databases, pattern recognition, and other disciplines (*Choudhary V K et al. 2013).* Data mining is the time-consuming process of discovering authentic, relevant, potentially useful, and eventually visual patterns in data. The pattern should be novel and potentially beneficial, resulting in some benefit to the user or activity *(Choudhary VK et al. 2011).* Furthermore, if not instantly, then after some post-processing, the pattern should be understandable.

Data mining is the process of extracting hidden predictive information from large databases. *(Robert P. Schumaker et al. 2010).* Data mining techniques forecast future trends and behaviours, allowing enterprises to make more informed decisions. The automated, prospective analysis provided by data mining goes beyond the retrospective analysis provided by decision support system tools. Agriculture data mining is a relatively new field of research. It entails the application of data mining techniques to agroeco systems. For example, the Naive Bayes data mining technique was developed to categorize soils using massive experimental soil profile datasets. Data miners use the decision tree method and clustering approaches (based on partitioning algorithms and hierarchical algorithms for forecasting soil fertility) to find information on productive agricultural land. (*Hassina AitIssad et al. 2019*)

p) Application of Data Mining in Smart Farming

i. *Grading Segregation of Fruits and Vegetables*

Fruits and vegetables are frequently classified into different price ranges based on size, color, and water content. These external variables, however, cannot be used to assess the quality of fruits and vegetables properly. Data mining can help us solve this problem by capturing images of fruits and vegetables at the packaging line. These images are then further analyzed to estimate the product's quality accurately. Furthermore, data from various specimens help to develop a more precise prediction of the quality of fruits and vegetables. These images can be fed into a deep layered Convolutional neural network for large-scale image recognition. (*Bagal Yash V et al. 2020)*

ii. *Maximizing Yield Depending on the Quality of the Soil*

Assessing soil quality is necessary to hike the agricultural income from farmers' land. Assessing soil quality analyzes the amounts of minerals and nutrients in the soil, the alkalinity, salinity, moisture content, and other variables that also affect the soil quality. Data mining is utilized to explore different soil types. (*Bagal Yash V et al. 2020*) Analysts of soil data propose the crop to be planted and harvested based on the soil's fertility to provide the optimum yield. Data mining can also be used to study cross-cultivation (*Bagal Yash V et al. 2020*). Different crops can be grown simultaneously, bringing in more revenue than single-crop cultivation and utilizing resources to the best possible extent without affecting soil fertility. The scope of data mining is enormous, and its scope can be seen in the soil analysis as follows (*Bagal Yash V et al. 2020*).

1. Crops can be grown by sensing and detecting soil capabilities.
2. Previously unknown soil patterns can be discovered.
3. Soil traits and behavior can be predicted based on climate conditions and ingredients.
4. d) Soil fertility testing can be done using statistical methods.

iii. *Optimizing the use of Pesticides*

Agricultural researchers revealed in a recent study that pesticides are overused, which is highly hazardous for the environment. Additionally, overuse of pesticides can result in pest immunity, which makes them less vulnerable to control and ultimately more harmful to crops. Clustering is one of the data mining methods that can cluster the features by providing interesting patterns of farmer practices and thus provide meaningful information highlighting the negative effect of excessive pesticide use. (*Bagal Yash V et al. 2020*). The system employs an image processing mechanism based on aspect ratios, shapes, and surface area. Later, images of the cultivation area are processed to detect weed patches using specific algorithms. Color density in the images is used to represent the density of crop growth in a specific area, whereas a different color represents irregular crop growth. (*Bagal Yash V et al. 2020*).

iv. *D. Prediction of wine Fermentation*

This Prediction can be made using the k-means Data Mining technique (*Han and Kamber, 2006*). This Prediction can warn the chemist to fix any stuck or slow fermentation processes and ensure a good fermentation process.

v. *Weather Forecasts*

A k-nearest neighbor approach can be used to improve weather forecasting, where it is assumed that the climate during a specific year is similar to the one recorded in the past. The same data mining technique can also be used to estimate soil water parameters. Before marketing, apples, and other fruits are thoroughly examined in agriculture. Humans can inspect apples on conveyor belts, and bad apples (those with defects) can be removed. The data mining tasks can perform the same task efficiently. The apple water core is examined using X-ray images in this task. It is based on an artificial neural network that learns how to classify X-ray images from a training set. *(Winter School Notes of ICAR-IASRI2011).*

III. Issues & Challenges

Smart technologies are a boon for the farming community in many ways, but they pose challenges. The main challenges are privacy, reliability, data confidentiality, and security. The Weather Company, an IBM business, held a first-of-its-kind event titled The AgriTech Challenge 2018 in Mumbai on 13 June 2018 to find solutions to transform the lives of over three million Indian farmers. The event was held in association with the Agripreneurs Group, SMART AGRIPOST and Graype.in and discussed the top challenges faced by the whole ecosystem in adopting smart technologies.

a) *Cost of Technology*

Smart technologies such as machine learning, robotics, IoT, big data analytics, bioinformatics etc., necessitate expensive equipment. However, while sensors are the least expensive, outfitting at farmers' fields would cost more. Moreover, automated machinery is far more expensive than manually operated machinery since it covers the cost of agricultural management solutions software and cloud access to record data. However, Farmers are eager to invest in these techniques to enhance their earnings, but they might need help to raise the initial investment to set up a smart farm.

b) *Poor Bandwidth and Internet Connectivity*

Adopting digital technologies in rural farmer's fields will be improved by providing better network connectivity and adequate bandwidth speeds. Smart farming agriculture technologies, including satellite mapping systems, soil sensors, and many monitoring tools, rely on cloud services/cloud-based computing for data storage and retrieval. These services might be compromised by inadequate bandwidth. Furthermore, farms with large, dense trees and hilly terrain must receive GPS signals seamlessly, making it much more challenging to use smart farming techniques there. Implementing smart technologies in remote rural areas may be difficult due to limited electricity and network coverage.

c) *Lack of Technical Know-how in Farming and Allied Workforce*

In general, farmers are typically ignorant and unskilled, and many of them would not prefer to learn about new technologies. On the other hand, policymakers have yet to make enough efforts to create online /offline capacity-building programs for farmers in locally relevant content. Lack of technical expertise in handling smart farming setup and bad implementation, such as installing a sensor in the wrong place or forgetting to switch off the irrigation tank, might harm farm productivity and efficiency. Farmers need to be adequately familiar with the concept and operation of the tools/devices featured in the system of smart farming technologies. It would ensure the desired outcomes of higher profitability, decreased environmental risk, and better crop output. Lack of knowledge will cost them a waste of time and effort, making it harder to adopt smart farming systems smoothly.

d) Monitor and Manage BIG Data in Agriculture

For many farmers and agribusinesses, data management is a significant concern. Even a tiny farm collects and maintains a plethora of data to guide marketing and associated operations. Monitoring or analyzing these millions of data points daily or weekly throughout the growing season is practically impossible. This problem grows bigger in large farms and multi-crop fields. A novel data processing and management approach is required to overcome this obstacle *(Kumar Prakash et. al 2018)*. In order to accomplish this, farmers need to decide which data points they must track frequently and which ones can be left to be analyzed only during different seasons. *(Andrew Meola 2021).* Farmers must know when and how to use the information recorded in their agriculture databases. Tech giant IBM estimates that the average farm can generate half a million data points daily, helping farmers improve yields and increase profits. Even though the typical Indian farm is tiny and may generate substantially lesser data points. (*Abhishek Beriya2020*).

e) Privacy and Security Issues

Since the need for explicit norms and regulations around smart technologies, ICT-based innovative technologies pose several legal issues that usually need to be solved. Unfortunately, many farmers are exposed to privacy and security risks like cyber attacks and data leaks. However, the following important factors must be appropriately addressed to adopt these technologies successfully.

1. To make efforts to develop affordable technology,
2. Ease of access and operations,
3. Easy maintenance of systems,
4. Timely grievance redressal
5. Appropriate policy support,
6. To develop good ICT infrastructure,
7. Provide adequate ICT skills,
8. To facilitate excellent and affordable internet connectivity,
9. To provide adequate bandwidth for internet service from a reliable ISP.
10. Availability of ICT Literature in Local Languages

IV. Conclusion

The use of smart technologies like robots, automated devices, and the application of artificial intelligence in farming is still in the infancy stage. Still, developing countries are finding the relevance of these technologies in farming systems activity. Smart technologies have just been in a prototype phase in underdeveloped countries and their visibility and outcome in global agriculture are almost negligible.

Smart technologies can revolutionize the agriculture system, making crop and livestock production more efficient and environmentally friendly and contributing to higher productivity. All farmer outreach programs must overcome three significant challenges: ensuring cost-effective awareness, designing solutions that meet specific needs, and ensuring sustainability. Large segments of the farming community, particularly rural folk, need access to the vast knowledge base amassed by agricultural researchers and extension people. Even though ICTs have the potential to make a difference and accelerate information access for the farming community, most ICT applications are implemented in smaller geographical areas and cover only a few hundred farmers. The outreach sphere of these technologies should be broader.

This review article has discussed the concept, methods, and use of major state-of-the-art smart technologies applications in farming systems with examples. These technologies can potentially increase the sustainable management of natural resources (soil and water) and reduce the use of agricultural inputs, making agricultural areas more productive and reducing their environmental impact. We have also highlighted some issues and challenges facing in adopting smart farming technologies.

The rate of the adoption trend and its amplitude are challenging to anticipate. The full adoption of smart technologies in global agriculture could take a few more decades. Nevertheless, these findings have their origins in the framework of existing agricultural systems and human nature without considering significant transformations of factors such as human metabolism, biology, or energy absorption, scientific achievable, which may provide exciting answers to the challenge.

These are just a few examples of how innovative, intelligent farming practices transform our future and make the planet more livable. Without these breakthroughs, the threat of overpopulation could devastate humanity. So agricultural creativity is not just fascinating — essential to survival.

V. The Future Road Map: The Way Forward

Adopting intelligent digital technology, particularly by small and marginal farmers, can play a transformative role in significantly improving Indian as well as global agriculture scenario. Digitization makes data management faster and simplifies the communication process to obtain loans, assess the status of their crops, and determine which crops are best suitable for their particular parcel of land. The potential advantages and challenges have been thoroughly explained in this paper. Overall, India's current smart technology application scenario is promising.

To empower farming community meaningfully, further robust research, development, and policy decisions are desperately needed to address the issues preventing the seamless adoption of smart ICT applications in farming systems.

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