Digital Technology: A Game Changer in Vegetable Cultivation

ABSTRACT

Vegetables are important constituents of Indian agriculture and nutritional security due to their short duration, high yielding capacity, nutritional richness, economic viability and ability to generate on farm and off farm employment .increasing per capita income, health consciousness, urbanisation, increasing working women, shifting of farmers to high value vegetables are also important ingredients for fuelling vegetable growth in India. But we are still not getting the required /capita vegetables/day.so the answer to increasing the production of various vegetables employing various digital technologies is required. Growing high yielding varieties/hybrids and applying new production methods can significantly increase yield in most vegetables. The application of digital technologies to integrate agricultural output from the paddock to the customer is known as digital agriculture. These technologies can give the agricultural business the tools and data it needs to make better decisions and increase productivity). Information and communication technology (ICTs) and Artificial intelligence (AI) are the two key technologies used in digital agriculture. Information and communication technology (ICT) can be defined as a collection of technologies that aid or support the storage, processing, or distribution of data/information.Despite a big, well-educated, well-trained, and well-organized agricultural extension workforce, over 60% of farmers in the country remain unreached, with no extension organisation serving them. Radio and television are the primary sources of information. e- Extension, Agrisnet, Digital green, e- Sagu, Agmarknet, iKisan, Village Knowledge Centers, Kisan Call Centers, SMS Portal/mKisan portal are some of the e-Agriculture efforts in India. Furthermore, information and communication technology (ICT) aid in the timely completion of decisions, as well as the discovery of the best solutions and efficient systems for water management and irrigation in order to maximise production Artificial intelligence is assisting several agricultural sectors in increasing output and efficiency. In every industry, AI technologies are help in overcoming traditional hurdles. AI intervention in agriculture is assisting farmers in increasing their farming efficiency while reducing harmful environmental impacts. The agriculture business has embraced AI with open arms in order to improve overall results.AI is changing the way food is produced, resulting in a 20% reduction in agriculture sector emissions. Incorporating AI technology into agriculture, aids in the control and management of any unwelcome natural occurrence. It consists of robotic process automation, a machine learning platform, and sensors, among other things. Harvesting, weed management, pest and disease monitoring, irrigation control, and predictive agricultural analytics are all possible with these. Artificial intelligence and information and communication technologies (ICT) have the potential to be a technological revolution and a boom in agriculture, helping to feed the world's growing population.

Keywords: ICT; AI; Digital technology; agriculture.

1. INTRODUCTION

India's economy is based on agriculture. Over 58 percent of rural households rely on it as their primary source of income [1]. From seed until harvest, however, it encounters tremendous hurdles. As a result, agricultural modernization is critical to addressing these issues. Vegetables are an important part of a well-balanced diet since they provide not only energy but also crucial protective nutrients such as minerals and vitamins. They also produce 4-5 times more food per unit area than cereals and yield higher yields per unit area than other crops. India produces 12% of the world's vegetables, with a productivity of 15.49 MT/ha, which is poor when compared to many other countries [2].According to estimates, we will require 151-193 million tonnes of veggies by the end of 2030 to suit our needs [3]. As a result, increasing the production of various vegetables employing various digital technologies is required. Growing high yielding varieties/hybrids and applying new production methods can significantly increase yield in most vegetables. In the future, there is more possibility to use new technologies to make our farms more productive, profitable, and sustainable. So, in order to close the gap in productivity, we must turn to digital agriculture.

“The application of digital technologies to integrate agricultural output from the paddock to the customer is known as digital agriculture. These technologies can give the agricultural business the tools and data it needs to make better decisions and increase productivity. Precision farming and smart farming are combined in digital farming, which is accomplished via the use of intelligent software and hardware. It includes technologies for collecting, storing, analysing, and sharing electronic data and information across the agricultural value chain in a digital format. Information Communication Technology (ICTs) and Artificial Intelligence (AI) are two important technologies used in digital agriculture In simple terms, ICT, or Information and Communications Technology, can be defined as a collection of technologies that aid or support the storage, processing, or dissemination/communication of data/information, or both. ICT thus encompasses technologies such as desktop and laptop computers, software, peripherals, and Internet connectivity that are designed to support information processing and communication.Information and communication technology (ICT) is becoming increasingly significant in agriculture. E-Agriculture is a new field that aims to boost agricultural and rural development by enhancing information and communication operations. e-Agriculture, in particular, entails the conception, design, development, assessment, and deployment of novel ways to employ information and communication technologies (ICT) in the rural domain, with a primary focus on agriculture” [4].

AI is fast gaining traction due to its broad applicability, particularly in challenges that are difficult for humans to address. Agriculture is one of the most important areas, with over 80 percent of the people working directly on 159.7 million hectares of farmland [5]. “It is impossible for such a venture to succeed. As a result, AI-powered farming solutions enable farmers to do more with less, improve quality, and provide a speedy GTM (go-to-market strategy) approach for crops. A direct application of AI (Artificial Intelligence) or machine intelligence across the farming sector could represent the pinnacle of today's transformation in farming practises.Agriculture powered by AI is analysing its service in interpreting, acquiring, and reacting to various situations in order to improve efficiency. Artificial intelligence is assisting several agricultural sectors in increasing output and efficiency. In every industry, AI technologies are help in overcoming traditional hurdles. AI intervention in agriculture is assisting farmers in increasing their farming efficiency while reducing harmful environmental impacts. The agriculture business has embraced AI with open arms in order to improve overall results. AI is changing the way food is produced, resulting in a 20% reduction in agriculture sector emissions” [6]. Incorporating AI technology into agriculture aids in the control and management of any unwanted natural occurrence.

AI is a branch of computer science that focuses on the development of tangible or intangible systems that not only think and act intelligently, but also demonstrate behaviour on par with (and, in the future, better than) human beings, reaching human-like performance in all cognitive tasks by purely logical reasoning. While the term "artificial" in AI refers to something that is "non-biological," "intelligence" refers to the "ability to complete difficult goals or activities."Speech recognition, natural language interpretation and translation, information management, picture analysis, decision making, learning, and other cognitive processes that are associated with human thinking will make systems powerful and helpful.

Challenges faced by farmers by using traditional methods of farming

- In agriculture, climatic elements such as rainfall, temperature, and humidity have an essential effect in the life cycle of the crop. Climate change is a result of increasing deforestation and pollution, making it difficult for farmers to make judgments about how to prepare the soil, sow seeds, and harvest.

- Each crop need a certain type of soil nutrition. Nutrient insufficiency can cause crops to be of poor quality.
- Weed control is crucial because it can raise production costs and suck nutrients from the soil, resulting in nutrient deficit.

How Digital Technologies Transforms Indian Agriculture

- It has been proven that adopting new technology modernises farmers' production processes, resulting in more consistent annual returns, lower crop failure risk, and higher yields.
- The use of digital technology in agriculture has been crucial in increasing data creation as well as advanced analytics, which allows farmers to make better farming decisions and save money on inputs and labour.
- Digital technologies offer the potential to give farmers with the information and capabilities they need to address issues such as climate change and seize growth opportunities.

Opportunities from Deploying Advanced Technologies

- “According to the FAO, emerging technologies such as the Internet of Things (which includes sensors, drones, robots, and cameras used for field data) have the potential to boost agricultural productivity by 70% by 2050” [7].
- Weather is responsible for 90% of all crop losses. Using predictive weather modelling and precision agriculture techniques, crop loss might be decreased by 25%. (IBM, Researchers, USA New York).70-80% of the new farm equipment sold today has a precision agriculture component as reported by the European association for agricultural machinery (CEMA) [8].
- Improved accuracy was highlighted by 76 percent of UK farmers as a justification for employing precision agriculture technologies (Defra, 2013).
- By 2024, there will be 27 billion linked devices, with 225 million of them being used in agriculture (Machina Research) (Anon 2014).
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Need For ICTs in Agriculture

- To expand knowledge resource
- To facilitate better information access
- To develop efficient feedback mechanism
- To ensure gender equity in technology transfer process
- To empower small and marginal farmers
- To serve the farm stakeholders beyond technology transfer role.
- To accelerate agricultural growth

Potential of ICT’s in Agriculture:

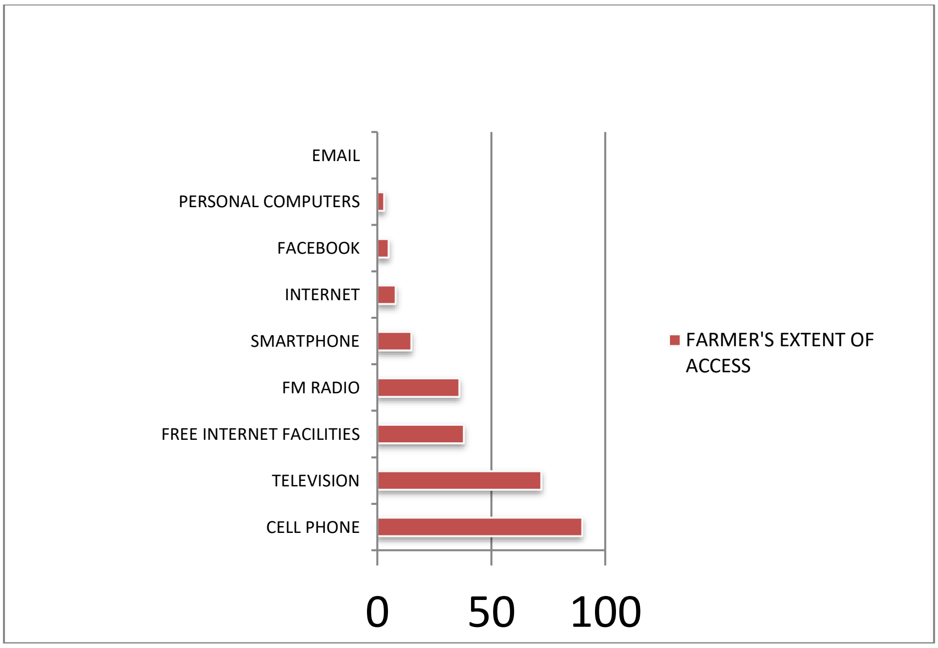
The agricultural sector's ICT potential can be leveraged in two ways:
1. Directly, where ICT is employed as a technology that directly helps to agricultural output productivity.
2. Indirectly, where ICT is utilised as a tool to deliver information to farmers so that they can make better decisions about how to operate their businesses.

Precision farming, which is common in industrialised countries, is based on extensive use of ICT and contributes directly to agricultural productivity. Techniques such as remote sensors with satellite assistance, geographic information systems (GIS), agronomics, and soil science are used to boost agricultural production. Farmers can use ICT to track and react to weather changes on a daily basis. Meteorological stations on solar-powered fields can be connected to farmers' computers to send data on current air and soil temperatures, rainfall, relative humidity of air, moisture of leaves, moisture of soil, length of day, wind speed, and solar radiation. All of these precision farming techniques and technologies necessitate large financial investments, which are only feasible for large farms. They are appropriate for large-scale farming, but they are less appropriate and efficient for small businesses and farms.

“Indirect contribution of ICT to agricultural productivity - Indirect benefits of ICT are evident in farmers' ability to make decisions and should be recognised in agriculture's future development. Farmers require fast and reliable information, as described in the earlier section of this study. Farmers currently rely on incorrect and out-of-date information from traditional sources of information. Farmers need knowledge not simply to stay competitive and survive in a globalised market, but also because of changes in the agricultural environment. Efforts to disseminate information, on the other hand, will be in vain if farmers are unable to use ICT. Elementary computers literacy is essential for farmers to access internet services for searching helpful information and communicating. They can keep track of prices and contact with colleagues all around the world over the internet as often as they wish. They can share ideas, ask questions, and receive answers on a variety of topics. Receiving assistance on crop and animal cultivation from researchers and agronomists is especially important.ICT has an impact on closing the gap between agricultural researchers and farmers, resulting in highly developed agriculture that contributes significantly to the national economy and society" [9].

ICTs and Farmers' Advisory Services: Telephone-based Tele Advisory Services, mobile-based Agri Advisory Services, television and radio-based mass media programmes, web-based online Agri Advisory services, video-conferencing, and online Agri video are the most extensively used and available means for farmers' advisory services.

Aside from traditional media such as written literature, periodicals, and farmer's exhibitions/fairs, the channel most agricultural institutes and organisations have their own telephone-based advisory services for farmers, which provide real-time information and advice via a dedicated phone number. The on-line phone based expert assistance service, Kisan Call Centres (KCC), launched by the Ministry of Agriculture, Government of India is available for everybody within the country since January 2004. The toll-free hotline "1800-180-1551" is available 24 hours a day, 7 days a week, from 6 a.m. to 10 p.m. "Outside of these hours, calls are answered via an Interactive Voice Response System (IVRS). Agri Advisory Services for Mobile Phones provides text, voice, and video content based Agri information services via mobile phones. Mobile phones are becoming an indispensable tool for all types of users, regardless of age. In India, mobile technology has ushered in a fundamental shift in the way people communicate with one another. Community radio is one of the most essential ICT instruments for giving farmers and people a voice and assisting in community development.A community or group of people of a community, own and run community radio" [4].



Graph 1: RANK ORDER OF DIFFERENT ICT MEDIA BASED ON FARMER'S EXTENT OF ACCESS

Fig. 1: **Major Components Used for ICT Initiatives In India**

List 1: Major ICT initiatives for farmers

Name	Sponsoring Agency	Target groups/Area	Year of Starting	Mode of Information	Function
AgricultureTechnologyInformationCentre (ATICS)	ICAR	India	2001	Internet, Mobile/telephone	Support system linking the various units of research institution with intermediary users and end users in decision making and problem solving
AGMARKNET	Directorate of Marketing and Inspection (DMI) - Ministry of Agriculture	India	2000	Internet	Empowering decision making ability of farmers regarding selling of their produce
AGRISNET (Agricultural Informatics and Communications Network)	ICAR	Rural areas of India	2003	Internet	Facilitate farmers and traders to sell and procure agricultural produce.
Digital Mandi	Media Lab Asia & IITKanpur	India	2003	Internet	Facilitate farmers and traders to sell and procure agricultural produce.
e-Sagu	Ministry of Communication andInformation Technology, Govt. OfIndia	Farmers India	2004	India	Provides advice on regular basis from sowing to harvesting
iKisan	NFCL Nagarjuna fertilizer& chemical Ltd,Hydearabad	India	2004	Internet	Transmits information to farmers about crop cultivation, weather forecast, soil quality, marketing updates etc.
eChoupal	ITC's International Business	Farmers ofMadhyaPradesh,Haryana	2000	Internet	Installs computers with internet in rural areas of India to offer farmers up to date marketing and

	Division (IBD	, Uttarakhand,Karnataka,AndhraPradesh, UttarPradesh, Rajasthan, Maharashtra			agricultural information.
Kisan Call Centres	DAC	India farmers	2004	Telephone/mobile	Provide extension services to farming community in local languages
IKSL	IFFICO KISAN SANCHAR LTD	India	2012	Internet/ mobile	Delivers relevant information and solutions to concerned farmers through voice messages on mobile phones
SMS	Short Message Service	India	-	Mobile phones	Provide various services directly to farmers through SMS in local language

[18]

1.1 Major Components used for ICT Initiatives in India

Web portals, mobile applications on Android phones, SMS and voice messaging on basic phones, information kiosks, films, and video conferencing with specialists are all major components employed in our country to provide ICT services to farmers. Agriculture experts are an important part of the information dissemination process for farmers.

“Farmers may receive useful, real-time, personalised information from the ICT components at the proper time. As a result, ICTs provide a platform for reaching out to the public and making global and local information easily accessible to stakeholders. Using ICT to disseminate information in agriculture is cost-effective, time-saving, and quick method ” [10]. “The bulk of urban and rural people have adopted mobile phones as their primary mode of communication” [11] “Farmers discovered that mobile phones were the most extensively used instrument for communication and accessing agriculture-related information, particularly for marketing products” [12]. “Researchers also found that mobile phones were the most commonly used ICT instrument and that farmers had easy access to them” [13]. “In a comparative study, it was discovered that livestock farmers in Uttar Pradesh who used ICT-based information made considerably better decisions on various livestock practises than those who did not” [14]. “In addition, a few studies found that ICT-based efforts aided farmers in India's Madhya Pradesh, Uttar Pradesh, and Tamil Nadu in lowering transaction costs while accessing information and conducting transactions in input and output marketplaces” [15].

1.2 Major ICT Initiatives for Farmers

“Approximately 45 percent of all ICT initiatives in the world have been implemented in India, and rural India has the highest number of information kiosks” [16]. However, it was shown that the majority of ICT projects in agriculture were implemented in socioeconomically developed states in South and North India [17], whereas disadvantaged states were not benefited by ICT initiatives. The following are some of India's e-Agriculture efforts.

Different Farming Apps

I. **MyAgriGuru:** Mahindra Agri Solutions Limited (MASL) introduced this app on February 24, 2017. A leading agricultural app that is tailored to the needs of Indian farmers. This software provides new farming solutions and is available in both Hindi and English. It will also be available in Gujarati and Marathi. The app gives Indian farmers access to the most up-to-date farming technologies and procedures. Farmers may develop healthy crops as well as successful farming with the help of this app. Crop, Agribuzz, Market Price, Weather, Tip of the Day, and other modules are included in the app.

II. **Vari:** Farmer-to-farmer and farmer-to-consumer contacts are made easier with the use of a digital platform. It enables farmers to obtain high-quality agricultural inputs from other farmers who are experts in the field. This tool assists farmers in overcoming obstacles when purchasing inputs for their farms. By promoting creative and smart farming, the app streamlines the Agri-business experience of farmers in rural India.

III. **Hi Tech Kisaan:** This farming app was created specifically for Maharashtra farmers. This app provides information to farmers and businesspeople interested in agriculture-related operations. It contains information on market products, vegetable, fruit, and agricultural production, fertilisers, and insecticides. It also contains information on the trade of modern agricultural equipment and agricultural-related industries.

IV. **KisanSuvidha:**Prime Minister Narendra Modi inaugurated it in 2016. Developed by the Ministry of Agriculture and Farmers Welfare to provide weather, market prices, and other information to farmers. This Agri app contains a wealth of crop data. It's also supposed to be an all-in-one smartphone app designed exclusively for farmers. This software has unique features such as alerts and market prices for commodities in the nearby area. It also shows current weather conditions and can forecast the weather for up to five days. The information is available in English, Hindi, Tamil, Gujarati, Odia, and Marathi at the moment.

Benefits of Farming Aid Apps

- ❖ Provides crop information that helps farmers in contributing to better delivery of nutritious and economical produce.
- ❖ Assists farmers with expert guidance.
- ❖ Real-time updates on weather, local markets, fertilizers, seeds etc.
- ❖ Acts as a direct gateway between farmers and government schemes
- ❖ With Apps, farming becomes socially, economically, and environmentally sustainable.
- ❖ Mobile apps can help farmers step into the digital world, where they can take advantage of technology in farming

2. ICT TECHNOLOGIES

Global Positioning System (GPS): "The GPS constellation comprises of 24 satellites orbiting the earth in six orbital planes, each with four satellites and supporting base stations" [19]. "These satellites are distributed in an unusual way to ensure that the entire planet is covered. Farmers can use GPS to navigate to specified spots in the field, to take soil samples or monitor farm conditions year after year" [20]. "The Department of Defense (DOD) United States Air Force launched and maintains these satellites, known as NAVSTAR (Navigation by Satellite Timing and Ranging), to offer all weather ranging 24 hours a day anywhere on the earth's surface" [21].

"The global positioning system (GPS) has allowed in-field variability to be recorded as regionally encoded data. It's also used to keep track of where you're at all times. This technology concentrates on agricultural fields in great detail, and the user has access to a large database. Only at places where GPS position tracking has occurred can reliable yield data be provided. The geographic coordinates for yield monitor data are provided by GPS receivers in conjunction with yield monitors.This can be turned into field yield maps" [22]. "Information gathered from multiple satellite data sources and geo-referenced using GPS can be used to construct field management strategies for cultivation, chemical application, and harvesting activities" [23]. Precision agriculture was developed and implemented using a combination of the Global Positioning System (GPS) and geographic information systems (GIS). These technologies allow real-time data collection to be combined with precise position data, allowing for fast processing and analysis of massive amounts of geographical data. GPS-based applications are used in precision farming for farm planning, crop scouting, soil sampling, field mapping, tractor steering, application rates, and yield mapping. Farmers can also use GPS to work in low-visibility fields such as rain, dust, fog, and darkness.

GIS in agriculture: GIS is a set of strong tools for gathering, storing, and retrieving data on demand, as well as modifying and displaying geographic data for specific purposes [24]. GIS's capacity to evaluate and display agricultural settings and work flows has proven to be quite useful to individuals in the farming business. On a farm, balancing inputs and outputs is critical to its success and profitability. Models that replicate the dynamics of complex natural systems are increasingly using GIS technology to combine diverse map and satellite information sources.GIS can be used to create pictures, such as drawings, animations, and other cartographic products, in addition to maps. GIS is playing an increasingly important role in agriculture production around the world, assisting farmers in boosting production, lowering expenses, and better managing their property. While natural inputs in farming cannot be controlled, GIS applications such as crop yield estimations, soil amendment assessments, and erosion identification and remediation can help farmers better understand and manage them.

3. AGRICULTURAL DRONES

In recent years, the use of drones in vegetables and agriculture in general has grown. Drone technology has been marketed and used ahead of research and development. Drones (also known as Unmanned Aerial Vehicles (UAVs) or Remote Piloted Aircraft (RPAs)) are essentially aerial platforms that can be used to perform various jobs or collect data, depending on the payload and/or sensors they carry. Drone technology is increasingly becoming indispensable for farmers, providing new ways to increase crop yields through in-depth field analysis, long-distance crop spraying, and high-efficiency crop monitoring. Drones have a number of advantages over traditional crop sensing systems, including their ease of deployment, ability to cover huge areas quickly, and ability to collect ultra-high resolution images. To collect still or video imagery, most drones are equipped with digital cameras. Depending on the drone's purpose, additional sensors or payloads can be added. The sensor is the most important component for data or information collection, and it defines which drone may be utilised. Photogrammetry is the most popular and accessible use of drones in agriculture. Photogrammetry is the process of capturing a series of photographs that may later be analysed to disclose information about the topic.

Common applications of drones in agriculture include:

- Digital RGB images or video capture of crop condition,
- Multi-spectral sensor for crop sensing,
- Thermal cameras (crop and pest),
- Beneficial insect dispersal,
- Spot spraying of agricultural chemicals.

4. DIGITAL RGB IMAGERY

Most drones use digital RGB cameras (visible spectrum) as their standard sensor. Hundreds of individual photographs are shot as the drone flies (usually overlapping by 70–80%). These are then ‘stitched' together during processing to create an orthomosaic, which is a single image (Fig. 2). In vegetables, high resolution RGB digital imaging (e.g., a 20 mega pixel camera) can be utilised for a variety of reasons. It can be equally as effective as multispectral images in most instances. Recent advances in software that specialises in RGB image editing have made RGB the industry standard in agricultural evaluations. Crop variability, such as obvious differences in plant and canopy size and irrigation patterns, can be assessed using several vegetation indices.

This photography can also be used to create three-dimensional point clouds, from which 3D products such as crop digital surface models contour lines, above-ground biomass, volume, and surface water drainage maps can be created.

Automated plant counts: Plant counts and weed recognition are now automated due to Artificial Intelligence (AI) and Machine Learning (ML) .These analyses rely on custom-made algorithms to count the plants visible in the orthomosaic. Commercially available algorithms include Agremo and Precision Hawk, which are cloud-based solutions. Some weeds and the crop can be difficult to distinguish using automated counts. Weeds should be kept to a minimum in order to get more accurate counts. For crops with a single unit of produce, such as lettuce and Brassicas, automated plant counts can be used to assess production potential and field losses. They can also be used to estimate plant density, which is useful when deciding whether or not to replant. Damping Augmentation Function (DAF's) validation of the count algorithms revealed accuracy of more than 99 percent.

Fig. 2: Drone Capturing Imagery in Commercial Vegetable Crops

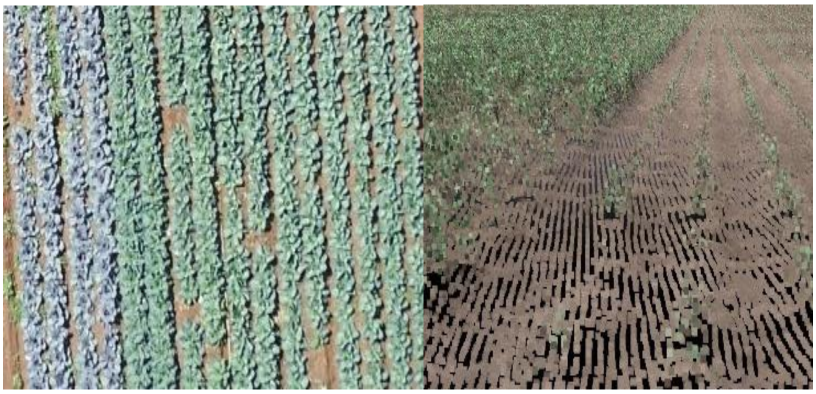


Fig. 3: RGB orthomoasaic of Brassicas; 3D model of sweet corn from RGB imagery.

Fig. 4: Automated Plant Counts in Sweet Corn. Red circles indicate counted plants

5. MULTISPECTRAL IMAGERY FOR CROP SENSING

Drones can be equipped with a variety of commercially available multispectral sensors. Image data is captured by multispectral sensors at precise frequencies across the electromagnetic spectrum. For example Near infrared wavelengths, , are good for detecting photosynthesis in plants. When the sensor is triggered, four or five distinct images are shot in different areas of the spectrum at the same moment. Additional regions of the spectrum allow for the assessment of extremely minor variations in plant health/vigour that are typically invisible to human sight or a standard RGB camera.

5.1 Vegetation Index

Various cloud-based services, such as Drone mapper, Dronedeploy, and Precision Mapper (Precision Hawk) (accessible by subscription), provide a variety of vegetation indices derived from multispectral sensor reflectance data. Table 1 lists the most often used indexes.

Multispectral photography can be used to measure geographic variation in crop vigour/growth and to identify locations for crop scouting in vegetables. While this imagery can show areas that are underperforming or strained, it can't tell you what's causing the stress or growth restriction. This necessitates field verification; the imagery just points growers or agronomists in the right direction

Thermal imagery: The transfer of invisible radiation patterns resulting from plants into a visible thermal (heat) map is referred to as thermal imaging. The primary use of thermal photography is to monitor crop moisture stress and water use. The resolution of thermal cameras is far lower than that of multispectral or RGB cameras. Thermal data will also require temperature calibration, which is currently difficult to accomplish.

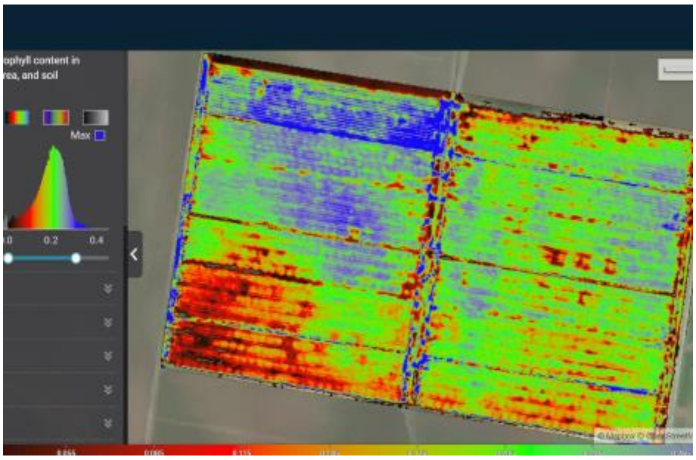


Fig. 5: Multispectral Drone Imagery of green beans showing Normalised Difference Red Edge (NDRE) Vegetation Index

Table 1: Common Vegetable Indices derived by Cloud Based Software/processing platforms

Vegetation index	Measure of Crop Vigour
NDVI Normalised Difference Vegetation Index	Differentiates crop vigour based on amount of near infrared light reflected compared to red
OSAVI	Differentiates crop vigour but is adjusted for high soil backgrounds
NDRE Normalised Difference Red Edge	Uses NIR and the red edge band (the band between visible red and NIR) Capture further down crop canopy than NDVI. Can be used in mature crops when NDVI is saturated.
Chlorophyll index	Provides an indication of total chlorophyll content based on reflectance data

These indices are all essentially an indication of crop vigour

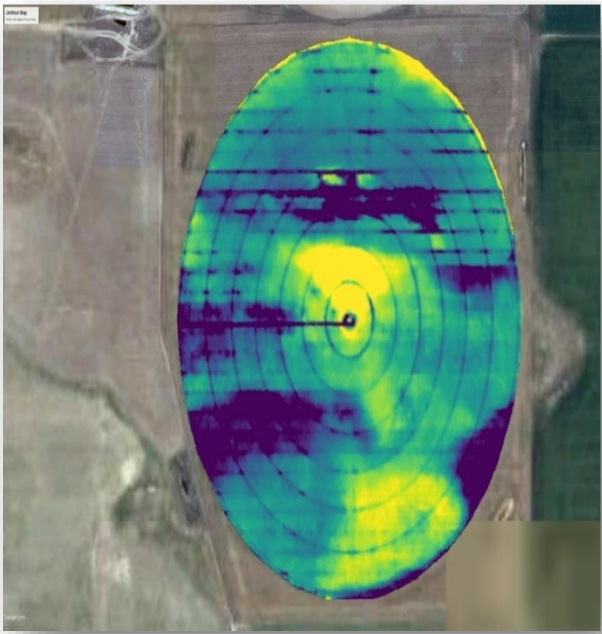


Fig.6: Drone Captured Thermal Imagery of Potatoes. (Source: Melissa Fraser, PIRSA)

6. BENEFICIAL INSECT DISPERSAL AND SPOT SPRAYING OPERATIONS

Commercial operators typically carry out these applications, but these services are still not extensively available across vegetable-growing regions. Beneficial insect dissemination by drone is a more cost-effective and wider-coverage solution than hand distribution. Weed spot spraying often involves two operations: one to detect the weeds and another to spray them.

Problems Associated with ICT: Farmers are highly driven and put in long hours to create a wide range of tricks; nonetheless, they confront numerous challenges in using ICT in agriculture and managing their agricultural tricks [25]. Farmers are confronted with the following issues:

- Inadequate access to ICT services for rural farmers
- Lack of operational knowledge of modern gadgets
- Low level of education
- Lack of awareness of appropriate agricultural methods
- Lack of training facilities
- Lack of farmers' knowledge of ICT applications for agriculture
- Lack of access to markets and prices
- Need for government machinery to increase ICT application in rural areas.

6.1 What is AI (Artificial Intelligence)?

"It is the simulation of human intelligence in computers that have been trained to think and act like humans. The phrase can also refer to any machine that demonstrates human-like characteristics like learning and problem-solving. Or It's the intelligence displayed by machines or software, as well as the discipline of computer science that creates intelligent machines and software" [26]. ANI, AGI, and ASI are the three forms of AI. The first type, ANI (Artificial Narrow Intelligence), is everywhere. It's great for discovering efficient routes to places when driving, or it can be compared to a chess playing programme. The second option is AGI (Artificial General Intelligence), which is a computer that is as smart as a human in every way. So, anything we can do with our brain, including learning, is possible. AI is becoming more powerful by the day, with applications leading to machines and systems leading to more advanced AI, such as ASI (Artificial Super Intelligence) – when a computer or a system is smarter than a human being – wiser, more creative, and socially adept, and this ranges from a little bit smarter to smarter than the sum of all humanity combined.

Scope: Agriculture has adapted quickly to AI in its varied farming strategies. The term "cognitive computing" refers to a computer model that mimics human thought processes. This results in turbulence in AI-powered agriculture, with the technology interpreting, acquiring and reacting to various scenarios (depending on the gained learning) to improve efficiency. Farmers can be offered solutions via platforms like chat bot to reap benefits in the field by keeping up with latest innovations in the farming business. In India, Microsoft Corporation is currently working with 175 farmers in the state of Andhra Pradesh, providing services and solutions for field preparation, sowing, fertiliser addition, and other crop nutrition supplements. In comparison to prior harvests, a 30 percent increase in crop output per ha has already been observed. Farming includes a considerable lot of uncertainty and decision-making. The weather fluctuates from season to season, as do the prices of farming materials, soil degradation, crop failure, weed suffocation, pest damage, and climate change. Farmers must cope with these uncertainties. Although agricultural practice is vast, soil, crop, disease, and weeds are all key contributions to agricultural production in this study. Reviewing the application of AI to agriculture in terms of soil, crop, disease, and pest management is critical.

- Soil is an important component of successful agriculture since it is the source of the nutrients needed to develop crops. Soil is the foundation of all agricultural, forestry, and fishing production systems. Water, minerals, and proteins are stored in the soil until they are needed for crop growth and development.
- Crop cultivation is extremely important to Nigeria's economy [27]. It does, however, provide food, raw materials, and jobs. Marketing, processing, distribution, and after-sales support are now considered part of agricultural production in modern times. Crop cultivation and other primary industries are being emphasized in locations where real income per capita is low. Increased crop production output and productivity are thought to contribute significantly to a country's overall economic development. As a result, a higher emphasis on crop production development will be warranted.
- Plant diseases affect agricultural production quantity and quality as agriculture tries to support the constantly rising population. Post-harvest disease losses in agriculture can be devastating.
- Weeds are a significant danger to all agricultural activity. Weeds diminish farm and forest productivity, invading crops, suffocating pastures, and even harming cattle in some circumstances. They fiercely compete for water, nutrients, and sunlight with the crops, resulting in lower agricultural output and poor crop quality.

Artificial Intelligence (AI) is increasingly gaining traction as it makes its way into a variety of businesses. From industrial to automotive, AI is expected to be employed for a variety of applications, and as time goes on, it will only become more prevalent. Agriculture is one of the more intriguing fields where AI is making inroads. Agriculture is a large business and an important element of our economy's basis. The agricultural industry generates over $330 billion in annual revenue, according to the Environmental Protection Agency (EPA).AI is becoming a technical innovation that is boosting and safeguarding food productivity as climates change and populations grow. Here are some of the most significant ways that AI is helping the agricultural industry.

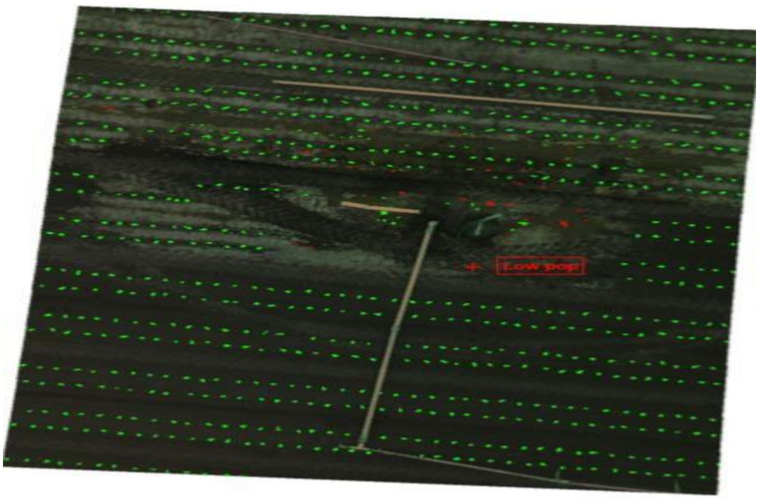


Fig. 7: Weed Detection Analysis from Drone Imagery in Sweet Corn. Weeds appear as red and the sweet corn plants green. (Source: Airborn Insight)

Table 2: AI in Soil Management

S. No.	Technique	Strength	Limitation
1	MOM	Minimizes nitrate leaching, maximizes production.	Takes time. Limited only to nitrogen.
2	Fuzzy Logic: SRC-DSS	Can classify soil according to associated risks.	Needs big data. Only a few cases were studied.
3	DSS	Reduces erosion and sedimentary yield.	Requires big data for training.
4	ANN	Can predict soil enzyme activity. Accurately predicts and classifies soil structure.	Only measures a few soil enzymes. It considers more classification than improving the performance of the soil.
5	ANN	Can predict monthly mean soil temperature	Considers only temperature as a factor for soil performance.
6	ANN	It predicts soil texture	Requires big data for training. Has restriction in areas of implementation.
7	ANN	Able to predict soil moisture.	The prediction will fail with time as weather conditions are hardly Predictable.
8	ANN	Successfully reports soil texture.	It does not improve soil texture or proffers solution to bad soil texture.
9	ANN	Cost-effective, saves time, has 92% accuracy	Requires big data.
10	ANN	Can estimate soil nutrients after erosion.	Its estimate is restricted to only NH 4

Use of AI and related technologies has the potential to impact productivity and efficiency:

- ❖ Soil health monitoring and restoration.
- ❖ Weather Prediction.
- ❖ Crop health monitoring and providing real time action advisories to farmers.
- ❖ Increasing efficiency of farm mechanization.
- ❖ Increasing the share of price realization to producers.

6.2 Applications of AI in Agriculture

Soil Management: Soil management is a crucial aspect of agricultural operations. Crop production will be improved and soil resources will be conserved with a thorough understanding of diverse soil types and conditions. It is the application of operations, techniques, and treatments to improve the performance of soils. Pollutants may be present in urban soils, which can be studied using a typical soil survey method [28]. Compost and manure help to promote soil porosity and aggregation. Better aggregation implies the inclusion of organic elements, which are vital in preventing the formation of soil crusts. Alternative tillage strategies can be used to prevent soil physical degradation. Organic materials must be used in order to increase soil quality. Several soil-borne diseases that must be controlled through soil management have a substantial impact on the production of vegetables and other consumable crops. With acknowledgement of the reality that soils differ in their ability to resist change and recover, sensitivity to soil degradation is implicit in the assessment of the sustainability of land management techniques.

Table 2 provides an overview of AI soil management strategies. Because it consists of a set of created plausible management options, a simulator that assesses each alternative, and an evaluator that determines which alternative matches the user-weighted multiple criteria, management-oriented modelling (MOM) decreases nitrate leaching. MOM employs a strategic search strategy called "hillclimbing" and a tactical search method called "best-first" to identify the shortest path from start nodes to goals. The Soil Risk Characterization Decision Support System (SRCDSS) requires engineering skills in three stages: knowledge acquisition, conceptual design and system implementation. Based on features gathered from current coarse resolution soil maps paired with hydrographic characteristics produced from a digital elevation model, an artificial neural network (ANN) model predicts soil texture (sand, clay, and silt concentrations) (DEM). A remote sensing device incorporated in a higher-order neural network is used to describe and estimate the dynamics of soil moisture (HONN).

“With the use of sensors, cameras, and infrared rays that scan the soil for nutritional qualities, AI can be used to monitor soil health” (Sennaar, 2019) [29]. “This also aids in determining how individual seeds react to different soils, effects of weather changes on the soil, and the likelihood of disease and insect dissemination” [30]. “With this information, farmers may improve the efficiency of their agricultural inputs, resulting in cost savings and increased output. Haryana currently uses an average of 207.56 kg of chemical fertilisers per acre per year (one of the highest among Indian states).Fertilisers, in addition to being expensive for farmers, also introduce dangerous compounds into the food chain via crops and the water table” [31].

Case Study: “The application of AI-backed soil health monitoring in Raleigh, North Carolina, USA, resulted in enormous efficiency benefits in the usage of agro-inputs, with chemical fertiliser consumption reduced by about 40%”. (Sennaar, 2019). “Furthermore, geographic information system (GIS) technology's spatial analytic capabilities aids in efficient water management during irrigation. GIS irrigation methods, for example, helped enhance per acre crop output by up to 37.5 percent while reducing water usage by 20 percent in Alfalfa in Riverdale, California” [32].

Crop Management: Table 3 summarises the crop management approaches. Crop management begins with the sowing of seeds and continues with growth monitoring, harvesting, and crop storage and distribution. It can be characterised as practises that promote agricultural product growth and yield. Crop production will undoubtedly grow as a result of a thorough understanding of the many crop classes and their timing in relation to the thriving soil type. Precision crop management (PCM) is an agricultural management technique that optimises profitability and protects the environment by targeting crop and soil inputs according to field requirements. The lack of timely, widely disseminated information on crop and soil conditions has impeded PCM. To deal with water deficits caused by soil, weather, or inadequate irrigation, farmers must combine diverse crop management practises. Crop management systems that are flexible and based on decision rules should be favoured. Drought timing, intensity, and predictability are all essential factors to consider when deciding between cropping options.

Soil type, pH, nitrogen, phosphate, potassium, organic carbon, calcium, magnesium, sulphur, manganese, copper, iron, depth, temperature, rainfall, and humidity are just some of the variables to consider. Demeter is a computer-controlled speed-rowing machine featuring two video cameras and a navigational global positioning sensor. It can plan harvesting activities for a full field and then carry them out by cutting crop rows, rotating to cut subsequent rows, repositioning itself in the field, and recognising unforeseen obstructions. Soil type, pH, nitrogen, phosphate, potassium, organic carbon, calcium, magnesium, sulphur, manganese, copper, iron, depth, temperature, rainfall, and humidity are just some of the variables to consider. Demeter is a computer-controlled speed-rowing machine featuring two video cameras and a navigational global positioning sensor. It can plan harvesting activities for a full field and then carry them out by cutting crop rows, rotating to cut subsequent rows, repositioning itself in the field, and recognising unforeseen obstructions.

Case Study: “Microsoft launched a pilot project in Devanakonda Mandal in the Kurnool district of Andhra Pradesh in 2016, in collaboration with ICRISAT (International Crop Research Institute for the Semi-Arid Tropics). A total of 175 farmers were enrolled in the trial, and they were notified through text message about appropriate cropping dates, site preparation, and soil test-based fertiliser application. This resulted in a 30 percent increase in crop output. During the Kharif cycle in 2017, this programme was expanded to serve around 3,000 farmers in Karnataka and Andhra Pradesh for a variety of crops including groundnut, ragi, maize, rice, and cotton, among others.The increase in crop yield following the AI intervention ranged from 10-30% across all crops” [33].

Disease Management: “Disease control is required for an optimal yield in agricultural harvest. Plant and animal illnesses are a key stumbling block to increasing productivity. Genetics, soil type, rain, dry weather, wind, temperature, and other elements all have a role in the incubation of these illnesses that target plants and animals. Managing the consequences of these factors, as well as the unpredictability of some illnesses' causal influences, is a major issue, especially in large-scale farming. Table 4 summarises the AI applications in disease management that have been published. A farmer should use an integrated disease control and management approach that incorporates physical, chemical, and biological measures to successfully control illnesses and minimise losses" [34] To attain these goals, it takes a long time and is not very cost effective, necessitating the use of an AI strategy for disease control and management. The explanation block (EB) provides a clear picture of the reasoning followed by the expert system's kernel. In order to draw intelligent inferences for agricultural disease control, the system employs a novel methodology of rule promotion based on fuzzy logic. For the text-to-speech (TTS) user interface, a text-to-speech (TTS) converter is employed. It offers a highly effective interactive user interface for live interactions on the web.

Weed Management: Weed regularly lowers predicted profit and yield for farmers. If weed infestations are not controlled, a survey confirms a 50% drop in output for dry beans and corn crops. Weed competition has resulted in a 48 percent reduction in wheat yield. These losses might sometimes reach 60 percent. A research on the influence of weed on soybean yields found that yields were reduced from 8% to 55%. According to a study on sesame crop production losses, range from 50 to 75 percent. The length of exposure of the crops to the weeds and the geographical heterogeneity of the weeds can be blamed for the volatility in yield losses. Weed has both beneficial and harmful effects on the ecology in addition to these. Weed effects include flooding during hurricanes, some species of weeds can pave their way during wildfires, some cause irreversible liver damage if consumed, and they muscle out plants or crops by competing for water, nutrients, and sunlight, according to the Weed Science Society of America (WSSA) report. Some weeds are harmful, causing allergic reactions or possibly posing a health risk. Table 5 summarises the applications of AI in weed management.

Over the last few decades, rigorous herbicide control has been used to decrease the impact on crops. Even with this management pattern, crop losses due to weed in western Canada field crops are expected to surpass $500 million per year, necessitating the development of a more sophisticated weed control approach to compensate for this loss [35]. A system can divide an image, compute and convert to binary the vegetation indexes, recognize crop rows, tune parameters, and develop a classification model using unmanned aerial vehicle (UAV) imagery. Because crops are frequently arranged in rows, using a crop row identification technique can help distinguish between weed and crop pixels, which is a common problem due to their spectral similarity. Online weed detection employing digital image analysis acquired by a UAV (drone), computer-based decision making, and GPS-controlled patch spraying can be used to control weeds in sugar beet, maize, winter wheat, and winter barley [36]. The drone flew at a pace of 1.2 km per hour, taking 58.10 milliseconds and 37.44 milliseconds to find the tomato and weed locations to the spray controller, respectively.

Table 3: AI in Crop Management [41]

S.No.	Technique	Strength	Limitation
1	CALEX	Can formulate scheduling guidelines for crop management activities.	Takes time.
2	PROLOG	Removes less used farm tools from the farm.	Location-specific.
3	ANN	Predicts crop yield.	Only captures weather as a factor for crop yield.
4	ROBOTICS-Demeter	Can harvest up to 40 hectares of crop	Expensive: Uses a lot of fuel.
5	ROBOTICS	Has 80% success rate in harvesting crops	Slow picking speed and accuracy.
6	ANN	Above 90% success rate in detecting crop nutrition disorder.	A little number of symptoms were considered.
7	FUZZY Cognitive Map	Predict cotton yield and improve crop for decision management.	It is relatively slow.
8	ANN	Can predict the response of crops to soil moisture and salinity.	Considers only soil temperature and texture as factors.
9	ANN and Fuzzy Logic	Reduces insects that attack crops.	Shows inability to differentiate between crop and weed.
10	ANN	Can accurately predict rice yield.	Time-consuming, limited to a particular climate.

Table 4: AI in Disease Management

Technique	Strength	Limitation
Computer vision system (CVS),genetic algorithm (GA), ANN	Works at a high speed. Can multi- task.	Dimension-based detection which may affect good species.
Rule-Based Expert, Data Base (DB)	Accurate results in the tested environment.	Inefficacy of DB when implementing in large scale.
Fuzzy Logic (FL), Web GIS	Cost effective, eco friendly.	Inefficiency due to scattered distribution. Takes time to locate and disperse data. The location of the data is determined by a mobile browser.
FL Web-Based, Web-Based Intelligent Disease Diagnosis System (WIDDS)	Good accuracy. Responds swiftly to the nature of crop diseases.	Limited usage as it requires internet service. Its potency cannot be ascertained as only 4 seed crops were considered.
FL & TTSconverter	Resolves plant pathological problems quickly.	Requires high speed internet. Uses a voice service as its multimedia interface.
Expert system using rule-base in disease detection	Faster treatment as diseases are diagnosed faster. Cost effective based on its preventive approach.	Time consuming. Needs constant monitoring to check if pest has built immunity to the preventive measure.
ANN, GIS	95% accuracy	Internet-based. Some rural farmers will not have access.
FuzzyXpest provides pest information for farmers. It is also supported by internet services.	High precision in forecast.	Internet dependent.
Web-Based Expert System	High performance.	Internet and web based.
ANN	Has above than 90% prediction rate.	The ANN does not kill infections or reduces its effect.

Weed infestations have been observed to cause losses of up to 90 percent of overall crop productivity [37]. As of now, there are 250 species of weeds that have developed total herbicide resistance [38], posing a serious danger to agricultural production sustainability**.**

Case Study: "AI can aid with weed and pest management by lowering the amount of weedicides and pesticides needed by up to 80%" [38-41]. According to a Bloomberg storey from (2018), Blue River Technology (now owned by John Deere & Co.) undertook a project to assess the efficacy of AI-assisted weed control technologies. The 'See & Spray' technology utilised in this project in Marianna, Arkansas, USA, cut weedicide costs by 90%, cutting the amount of weedicide required per acre from 20 to just 2 gallons" (Little, 2018).

Agricultural Robotics: Many AI companies are concentrating their efforts on producing autonomous robots capable of performing a variety of agricultural jobs. These robots can pick crops at a considerably faster rate and in a lot larger volume than humans. The robots are intended to assist in the picking and packing of crops, as well as to address other issues facing the agricultural workforce. Furthermore, agricultural robots have the potential to defend crops against weeds that are resistant to pesticide chemicals used to eradicate them.

Blue River Technology – Weed Control: Farmers' capacity to control weeds is a critical priority, and it's becoming more difficult as herbicide resistance spreads. Herbicide resistance has now developed in an estimated 250 kinds of weeds. The impact of uncontrolled weeds on maize and soybean harvests is predicted to cost farmers $43 billion annually, according to a study done by the Weed Science Society of America.

Automation and robots are being used by businesses to assist farmers in finding more effective ways to safeguard their crops from weeds. See & Spray, a robot developed by Blue River Technology, is said to use computer vision to monitor and accurately spray weeds on cotton plants. Herbicide resistance can be avoided by precision spraying. According to the company's website, their precision technology may reduce herbicide expenses by 90% and eliminates 80% of the volume of chemicals routinely sprayed on crops.

Harvest CROO Robotics – Crop Harvesting: Automation is increasingly gaining traction as a means of addressing worker shortages. Between 2014 and 2024, the number of agricultural employees is expected to decrease by 6%.

Strawberry producers can now use a robot made by Harvest CROO Robotics to help them pick and pack their crops. Millions of dollars in revenue have reportedly been lost due to a manpower shortage in important farming regions such as California and Arizona. Between 10,000 and 11,000 acres of strawberries are regularly picked in a season in Hillsborough County, Florida, which has been dubbed the "nation's winter strawberry capital."

Harvest CROO Robotics claims that its robot can harvest 8 acres in a single day and replace 30 human labourers.

6.3 Crop and Soil Health Monitoring

PEAT – Machine Vision for Diagnosing Pests / Soil Defects: Deforestation and soil degradation continue to pose serious concerns to food security and have a severe economic impact. The USDA estimates that the annual cost of soil erosion in the United States is at $44 billion dollars.

PEAT, a Berlin-based agricultural tech business, claims to have developed Plantix, a deep learning application that detects probable flaws and nutrient deficits in soil. Software algorithms are used to associate specific foliage patterns with specific soil deficiencies, plant pests, and illnesses.The image recognition app uses photos collected by the user's smartphone camera to identify potential flaws. Following that, users are given soil restoration strategies, tips, and other potential solutions.

The company claims that its software can recognise patterns quickly and accurately, with an estimated accuracy of up to 95%. PEAT recently announced that its international clientele had surpassed 500,000 people. On its website, the company mentions its partners and client testimonials, but no concrete case studies appear to be available.

Trace Genomics – Machine Learning for Diagnosing Soil Defects: Trace Genomics, situated in California, provides soil analysis services to farmers, similar to the Plantix app. The system, which employs machine learning to provide clients with a sense of their soil's strengths and limitations, was developed with the support of lead investor Illumina. Preventing faulty crops and maximising the potential for healthy agricultural production are the main goals. Users supposedly obtain an in-depth breakdown of their soil's composition after sending a sample of their soil to Trace Genomics, according to the company's website. A pathogen screening focused on bacteria and fungus, as well as a full microbial evaluation, is included in the packages.

Table 5: AI in Weed Management [41]

Technique	Strength	Limitation
ANN, GA	High performance. Reduces trial and error.	Requires big data.
Optimization using invasive weed optimization (IVO), ANN	Cost effective, enhanced performance.	Adaptation challenge with new data.
Mechanical Control of Weeds. ROBOTICS. Sensor machine learning	Saves time and removes resistant weeds.	Expensive. Constant use of heavy machine will reduce soil productivity.
UAV, GA	Can quickly and efficiently monitor weeds.	Has little or no control on weeds. Expensive.
Saloma expert system for evaluation, prediction & weed management.	High adaptation rate and prediction level.	Requires big data and usage expertise.
Support Vector Machine (SVM), ANN	Quickly detects stress in crop that will prompt timely site–specific remedies.	Only detects low levels of nitrogen.
Digital Image Analysis (DIA), GPS	Has above 60% accuracy and success rate.	Its success was achieved after 4 years and as such, it is really time consuming.
UAV	High rate of weed detection within a short period of time.	It is really expensive and requires vast human expertise.
Learning Vector Quantization (LVQ), ANN	High weed recognition rate with short processing time.	The method of data input used affected the AI's performance.

Table 6:Estimated yield of a vertical farm compared to traditional agriculture

Crops	Yield in vertical farm (tons/ha)	Field yield (tons/ha)	Factor increase due to technology
Carrot	58	30	1.9
Radish	23	15	1.5
Potatoes	150	28	2.4
Tomatoes	155	45	3.4
Pepper	133	30	4.4
Strawberry	69	30	2.3
Peas	9	6	1.5
Cabbage	67	50	1.3
Lettuce	37	25	1.5
Spinach	22	15	1.8
Total (Average)	71	28	2.5

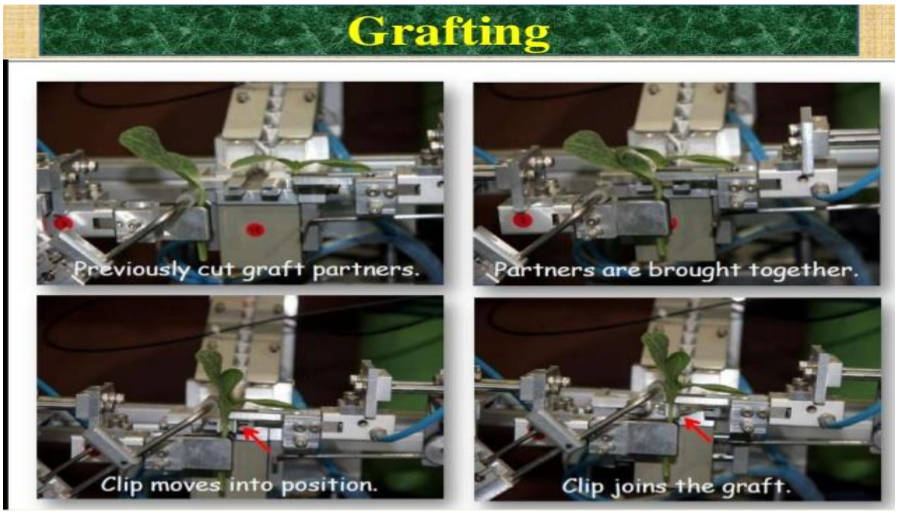


Fig. 8:Robotic grafting

Table 7:List of Robotic grafting [41]

Grafting robot	Company (country)	Crops	Efficiency
CCG	IAM BRAIN (Japan)	Cucumber	500/hr
G-892	IAM BRAIN(Japan)	Cucumber	1200/hr
G-710	Nasmix Co. (Japan)	Cucurbits	600-800/hr
G-720	Nasmix Co. (Japan)	Solanaceous	600-800/hr
AG-1000	Yanma (Japan)	Solanaceous	1000/hr
TGR grafting robot	TGR-Insititute (Japan)	Solanaceous and cucurbits	800/hr
Grafting robot	Kyungpuk university (Japan)	Solanaceous and cucurbits	900/hr
Pin grafting robot	RDA (Korea)	Solanaceous	1200/hr

6.4 Vertical Farming

Estimated yield of a vertical farm compared to traditional agriculture: Vertical farming uses indoor farming techniques and controlled-environment agricultural technologies to grow crops in vertically stacked layers. The Wangree Health Factory combines a vertical agricultural system with IoT technologies. Watering, lighting, nutrition addition, and temperature control are all entirely automated during the growth phase.

Robotic grafting: In 1993, the first semi-automated cucumber grafting method was released. With two operators, a simple grafting machine can create 350-600 grafts per hour, whereas manual grafting techniques produce roughly 1000 grafts per person per day (Gu, 2006). A completely automated grafting robot is capable of conducting 750 grafts per hour with a success rate of 90-93 percent.

6.5 Predictive Analytics

aWhere – Satellites for Weather Prediction and Crop Sustainability: aWhere, a Colorado-based firm, combines satellites and machine learning algorithms to forecast weather, analyse crop sustainability, and assess farms for diseases and pests. Daily weather forecasts, for example, are tailored to the specific needs of each client and span from hyperlocal to worldwide.

On a daily basis, the company claims to provide its users with access to over a billion points of agronomic data. Temperature, precipitation, wind speed, and solar radiation are among the data sources, as are "comparisons to past values for anywhere on the agricultural earth."

FarmShots – Satellites for Monitoring Crop Health and Sustainability: FarmShots, based near Raleigh, North Carolina, is another firm that analyses agricultural data generated from satellite and drone photos. The startup wants to "detect illnesses, pests, and inadequate plant nutrition on farms," in particular.

The company says, for example, that its software can tell users exactly where fertiliser is needed and thereby save fertiliser usage by over 40%. The software is designed to work on a variety of mobile devices.

7. AUTOMATED IRRIGATION SYSTEM

It is aimed at minimising manual intervention by the farmers and to prevent excessive wastage of water and electricity. The system takes care of the moisture content of the soil and waters it accordingly.

- ➢ Main Components
- • ARDUINO UNO
- • MOISTURE SENSOR
- • WATER PUMP

Working:

- ✓ To operate the motor, use the Arduino Uno. The Arduino IDE software is used to programme the Arduino Board.
- ✓ If watering is required, the moisture sensor monitors the level of moisture in the soil and sends a signal to the Arduino.
- ✓ The plants are watered by the motar/water pump till the necessary moisture level is reached.

Automated Irrigation systems:

8. EFFECT OF USAGE

- ✓ Increasing the competitiveness and sustainability of the vegetable business by lowering production costs.
- ✓ Average vegetable yields must be maintained (or increased).
- ✓ Excess applied water and consequent agrichemical leaching have a negative influence on the ecosystem.
- ✓ Maintaining an optimal soil water range for plant growth in the root zone.
- ✓ Maintenance of the irrigation system requires little labour.
- ✓ Significant water savings when compared to irrigation management based on average weather conditions in the past.

9. IMPACT OF AUTOMATIC IRRIGATION SYSTEM ON VEGETABLES (AIS)

- ✓ Al Ghobari *et al*., 2017 looked at how AIS affected water use efficiency (WUE) and agricultural water usage efficiency (IWUE). The WUE and IWUE values for tomato crops under the AIS treatment were 7.50 and 6.50 kgm-3, respectively; the values under the CIS treatment were 5.72 and 4.70 kgm-3, respectively.
- ✓ The results showed that the AIS had higher water use efficiency (WUE) and irrigation water use efficiency (IWUE) than the traditional irrigation control system (CIS).
- ✓ By using up to 26% less water than the CIS and producing greater total yields, the automated irrigation system (AIS) brought considerable benefits in both water savings and crop yields.

Challenges in AI Adoption in Agriculture

Despite the fact that AI offers enormous prospects in agriculture, there is currently a lack of expertise with advanced high-tech machine learning solutions in farms around the world. Farming is highly exposed to environmental elements such as weather, soil conditions, and insect attack vulnerability. Because it is influenced by external circumstances, a crop raising plan planned at the start of the season may not appear to be good at the start of harvesting.

AI systems, too, require a large amount of data in order to train machines and make exact forecasts or predictions. In the case of a very big tract of agricultural land, geographic data is relatively easy to obtain, however temporal data is more difficult. The numerous crop-specific data could only be acquired once a year, during the growing season. Because the database takes time to grow, it takes a long time to build a reliable AI machine learning model. This is one of the main reasons why AI is used in agronomic items such as seeds, fertiliser, and insecticides rather than on-field precision solutions.

To summarise, the future of farming will be heavily relied on adopting cognitive solutions. Despite the fact that extensive research is still ongoing and numerous applications are currently accessible, the farming business continues to be neglected. Farming with AI is still in its infancy when it comes to dealing with real-world difficulties and demands, and applying AI decision-making systems and predictive solutions to solve them.

Applications should be more robust in order to take use of AI's enormous potential in agriculture. It will thereafter be capable of handling frequent shifts and changes in external conditions on its own. This would allow for real-time decision-making and the sequential application of the right model/program for efficiently acquiring contextual data. Another important consideration is the exorbitant expense of the numerous cognitive farming technologies currently available on the market. To ensure that this technology reaches the farming community, AI solutions must become more viable. If AI cognitive solutions are made available on an open source platform, they will be more economical, which would lead to faster adoption and higher insight among farmers.

Advantage of Implementing AI in Agriculture:

- AI implementation emphasis on checking defective crops and improving the potential for healthy crop production.
- The growth in Artificial Intelligence technology has strengthened agro-based businesses to run more efficiently.
- It can improve crop management practices thus, helping many tech businesses invest in algorithms that are becoming useful in agriculture.
- AI solutions have the potential to solve the challenges farmers face such as climate variation, an infestation of pests and weeds that reduces yields.
- It not only helps farmers to automate their farming but also shifts to precise cultivation for higher crop yield and better quality while using fewer resources.
- AI can identify a disease with 98% accuracy. Thus, AI helps farmers monitor the fruit and vegetable by adjusting the light to accelerate production.

9. IMPACT OF AI ON AGRICULTURE:

- The technologies which are AI based help to improve efficiency in all the fields and also manage the challenges faced by various industries including various fields in agricultural sector like crop yield, irrigation, crop monitoring, weed or crop establishment.
- It has the potential to deliver much needed solution to increasing population for the crisis faced by them related agricultural sector.
- Tackle the problems faced by farmers related forecast weather data, labour challenge and use of pesticides etc.
- AI can be appropriate and efficacious in agriculture sector as it optimizes the resource use and efficiency. Artificial Intelligence can offer effective and practical solution for the problem.

10. CONCLUSION

- Technological development and digitalization shape feasible boundaries to increase resource use efficiency.
- It reduces the negative environmental impacts of farming, increases resilience, soil health and decreases costs for farmers.
- Artificial intelligence can be technological revolution and boom in agriculture to feed the increasing human population of world.
- ICT and AI helps in transforming agriculture sector into the modern digital agriculture to further improve social and economical benefits.

- ICT helps in Improving the digital access by farmers with technological advances and skill improvement.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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