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Review article

Disruptive technologies: Shaping the Future of Agriculture

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ABSTRACT

Disruptive technology is an innovation that significantly alters the way that consumers, industries, or businesses operate. Robotics, artificial intelligence (AI), and internet of things (IoT) are all technologies that have the potential to radically transform the way we grow food. These are poised to revolutionize future of agriculture as we know it. Robotics can take over many of the tasks currently performed by human workers, from transplanting and watering to harvesting and packaging. AI can be used to monitor crops and optimize conditions for maximum yield. And IoT devices can provide real-time data on everything from soil moisture levels to pest infestations. Drones or Unmanned Aerial Vehicles (UAV) with sensor and imaging capabilities can play an increasingly role in identifying and reducing crop damage. In India, over 80 per cent farmers are small and marginal (<1 ha), it is difficult to manage invasive pests. If one field is sprayed, the pests shift to the neighbouring fields. These can be employed in several field operations and is an excellent tool for rapid, reliable, and non-destructive detection of field problems. Not only will these make our crop production more efficient and sustainable, but it will also free up farmers. In combination with vertical farming, these technologies could increase the efficiency and quality of horticultural products. The entire growth process could be digitized and made available in the form of algorithms. This would allow tech companies to get into the food-growing business. And they could probably do it much cheaper and faster.

Keywords: Disruptive technology, Robotics, Artificial intelligence, Internet of things, Future of Agriculture

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INTRODUCTION

In order to match the anticipated 2050 world population of 9.7 billion (India 1.67 billion), agriculture production will need to increase 69 per cent between now and 2050, with shrinking agricultural lands, and depletion of finite natural resources, the need to enhance farm yield has become critical. This drastic increase would require more innovative agricultural techniques. Limited availability of natural resources such as fresh water and arable land along with slowing yield trends in several staple crops, have further aggravated the problem. Another impeding concern over the farming industry is the shifting structure of agricultural workforce. To meet these challenges, a concerted efforts are required by the governments, investors, and innovative agricultural technologies. Let us welcome to the fourth agricultural revolution. As it is known that Agriculture 1.0 was concerned with the transition from hunting and gathering to settled agriculture, the second (Agriculture 2.0) saw a commercialization of farming, and the third agricultural revolution (Agriculture 3.0- Green Revolution-), involved a surge in genetic engineering and the use of chemical pesticides. This fourth agricultural revolution (Agriculture 4.0) tends to be driven by the integration of technology, data collection and analytics with agriculture. Agriculture 4.0 will no longer depend on applying water, fertilizers, and pesticides uniformly across entire fields. Instead, farmers will use the minimum quantities required and target very specific areas. The farms and agricultural operations will have to be run very differently, primarily due to advancements in technology such as sensors, devices, machines, and information technology. Future agriculture will use sophisticated technologies such as robots, temperature and moisture sensors, aerial images, and GPS technology. These advanced devices and precision agriculture and robotic systems will allow farms to be more profitable, efficient, safe, and environmentally friendly (IOTSWC2, 2022).

What is Disruptive Technology?

Disruptive technology is an innovation that significantly alters the way that consumers, industries, or businesses operate. A disruptive technology sweeps away the systems or habits it replaces because it has attributes that are recognizably superior. Examples include e-commerce, on-line news sites, ride-sharing apps, and GPS systems, electricity service, and television etc. A disruptive technology supersedes an older process, product, or habit. It usually has superior attributes that are immediately obvious, at least to early adopters. Blockchain is another example of Disruptive Technology. Blockchain, the technology behind Bitcoin, is a decentralized distributed ledger that records transactions between two parties. It moves transactions from a centralized server-based system to a transparent cryptographic network. The technology uses peer-to-peer consensus to record and verify transactions, removing the need for manual verification.

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Components of Disruptive Technology

Robotics, artificial intelligence (AI), and internet of things (IoT) are all technologies that have the potential to radically transform the way we grow food. These are poised to revolutionize future of agriculture as we know it.

Robotics: Those associated with farming might not realize that the new generation of farm workers doesn't aspire to pick fruit, pick up animals or do many of the common back-breaking tasks associated with farming. Robots now milk cows, pick coconut/ areca nut, strawberries; and help in chopping of animals, birds, fishes for processing etc. Robotics use in farming is getting momentum recently and likely to increase in the next 4-5 years.

Artificial Intelligence (AI): AI stands for artificial intelligence which refers to systems or machines that mimic human intelligence to perform tasks and can iteratively improve themselves based on the information they collect. AI manifests in a number of forms. Many careers in food and farming rely upon learning by doing, rather than explicit knowledge transfer. This creates real challenges, such as how to avoid human error, misunderstandings and cognitive bias. AI may sound farming experts, consultants, extension agents, and professional expertise, but more likely, it will alter how these professional's function. More accurate data will be available faster but will still need interpretation.

Internet of Things (IoT): The internet of things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. A 'thing' in the IoT can be a farm animal with a biochip transponder, an automobile that has built-in sensors to alert the driver when tire pressure is low, a person with a heart monitor implant, or any other natural or man-made object that can be assigned an Internet Protocol (IP) address and is able to transfer data over a network. Internet of things (IoT) technology used in farming allows for sustainability. The monitoring sensors and software applications made available to farmers can optimise expenses on resources which saves money and allows farmers to farm in sustainable way. IoT smart farming solutions is a system that is built for monitoring the crop field with the help of sensors (light, humidity, temperature, soil moisture, crop health, etc.) and automating the irrigation system. The farmers can monitor the field conditions from anywhere. **IoT solutions are focused on helping farmers close the supply demand gap**, by ensuring high yields, profitability, and protection of the environment. The approach of using IoT technology to ensure optimum application of resources to achieve high crop yields and reduce operational costs is called precision agriculture. IoT in agriculture technologies comprise specialized equipment, wireless connectivity, software and IT services. Smart farming based on **IoT technologies enables growers and farmers to reduce waste and enhance productivity** ranging from the quantity of fertilizer utilized to the number of journeys the farm vehicles have made, and enabling efficient utilization of resources such as water, electricity, etc. IoT smart farming solutions is a system that is built for monitoring the crop field with the help of sensors (light, humidity, temperature, soil moisture, crop health, etc.) and automating the irrigation system. **The farmers can monitor the field conditions from anywhere.** They can also select between manual and automated options for taking necessary actions based on this data. For example, if the soil moisture level decreases, the farmer can deploy sensors to start the irrigation. Smart farming is highly efficient when compared with the conventional approach (https://www.mindbowser.com/iot-in-agriculture-why-it-is-future-of-connected-farming-world/**).**

Drones: As precision agriculture demands complex mapping, surveying, and monitoring, equipped with cutting-edge technology- the drones or unmanned aerial vehicles (UAV) is the leading aerial solution for farm owners and operators looking to level up their operations and produce high-quality results. Some of the more common agricultural applications for UAVs include pest control, plant health monitoring, livestock management, soil analysis, and aerial survey. Crops are susceptible to pathogens, fungus and insects. Improper level of carbon and nitrates in the soil also impact crop productivity. Even lack of proper water can affect production. Traditionally, farmers monitor all these conditions through visual observations which is time consuming, and soil analysis. Soil analysis can take more time than visual inspections. Drones can perform all these tasks in real-time, and provide accurate data that farmers can act on immediately. The ability of drones to go where humans can't and see things not readily observed from the ground creates real insights into pest protection, fertilizer and herbicide application, irrigation and harvest timing. This disruptive technology is revolutionizing precision agriculture.

Extended Reality and the Metaverse: The potential for extended reality (XR), as human vision, is limited to visible light, and XR can let us see a broader spectrum. This can be valuable in managing crops, animals and food production and has the potential for improving health and food safety practices.

Virtual Reality (VR): The ability of VR to know as to how plants grow, or simply to be able to visit farms, is an extraordinary opportunity for us and consumers alike to engage with farming.

Blockchain: Both the most exciting and the most misunderstood technology (using the same technology as Bitcoin), blockchain can create transparency in a sector that is often failed to capture consumer confidence. For example, US Walmart's global food-chain see blockchain as a tool to address consumer concerns about provenance and food safety.

Business Intelligence (BI): Raw data is collected, processed and then stored in data warehouses, the cloud, applications, and files. Once it's stored, users can access the data, starting the analysis process to answer business questions. BI platforms also offer data visualization tools, which convert data into charts or graphs, as well as presenting to any key stakeholders or decision-makers.

Data Analytics: It is estimated that the world will store 175 zettabytes of data by 2025.. It is assumed that the future capturing, controlling, protecting, and processing of data will justify the high valuations of disruptive technology start-ups. The power of data analytics can unleash meaningful new insights for farmers and food producers.

Cloud Connectivity: Cloud computing is used to collect, analyse and store agriculture data from tools like soil sensors, satellite images, and weather stations to help farmers make better decisions about managing their crops. Cloud-connected wireless sensors capture data from the field and

machine learning algorithms analyse that real-time information, giving farmers a better understanding of crops conditions. The cloud's analytical capabilities also aid farmers in understanding their production environment. Cloud-based computing services use real-time connections to the internet to offer more flexible resources and economies of scale than available with conventional server-based or even edge options. The requirement for connectivity—especially 5G—represents a genuine challenge when many farms aren't connected at all yet. Governments understand that if farming is to be revolutionized, addressing connectivity is essential. Without it, the rural-urban divide will be exacerbated. Cloud computing is named as such because the information being accessed is found remotely in the cloud or a virtual space. Cloud services providers enable users to store files and applications on remote servers and then access all the data via the Internet.

The consequences of leaving agriculture undigitized are stark. If the world is to realistically face up to a transformed food-chain, delivering what consumers say they want (sustainability and welfare-friendly, abundant, affordable food), it can't be achieved without digital disruption. **As a result of the currently declining agricultural workforce, adoption of internet connectivity solutions in farming practices has been triggered, to reduce the need for manual labour.** Applying the internet of things (IoT) in farming would provide insight on crops and livestock that keeps crops growing efficiently, and prevent illness among animals. The IoT solutions are not possible without reliable connectivity. The ability to track weather among all crops in real-time, wearable IoT devices (chips) that track animal locations and vitals, and sensors that report on how well pest control is working are just a few examples of IoT in agriculture. Digitization will pave the way for profitability, efficiency and sustainability in the farming sector. The global agriculture internet of thongs (IoT) market is estimated to grow from $11.4 billion in 2021 to $18.1 billion by 2026 and advances in IoT have the potential to produce a 70 per cent increase in agricultural productivity by 2025. Precision agriculture can substantially improve environmental outcomes. It is found out that innovation in technology and agricultural practices could reduce GHG emissions from grain production by up to 70 per cent within the next 15-20 years. Cutting edge agricultural technologies will bring about a new standard for farming that will meet our present and future needs. Labour shortages, water and sustainability are concerns for many growers. Disruptive technologies are creating new products that leverage advances in robotics, machine learning, computer vision and computational analysis to solve the big challenges we face today in agriculture. From soil-sensing technologies to collaborative robots, many new solutions are emerging to help growers optimize their operations for both greater profitability and better social and environmental outcomes.

Drivers of Growth

Advancements in technology and its availability is a major driver of adoption. The efficacy of edge computing and IoT performance have improved markedly and the cost of sensors has now reduced while their capabilities have improved by orders of magnitude. The proliferation of broadband connectivity and data storage is enabling a much higher volume of data capture as well as the improvement and increased adoption of digital decision-making tools. Demand for this disruptive technology is also consumer-driven with health and environmental concerns spurring interest in increased safety, transparency, and sustainability. Consumer packaged goods (CPGs) looking to meet consumer demands for low carbon products need the technology to quantify upstream activity. Additionally, the growing market demand for carbon credits requires underlying digital agriculture technology to measure and track carbon levels and quantify carbon sequestration.

Agriculture, a sector which has traditionally been relatively data poor is now seeing dramatic improvements in the availability, timeliness and quality of data. Consequently, data has become a key input to help producers with critical decision making. The need to monitor agricultural inputs such as fertilizer, chemicals and water both for market purposes as well as to ensure compliance with new regulations is becoming increasingly urgent. Interest in monitoring capabilities to control pests, manage weather changes and improve crop growth are also amplifying demand for decision agriculture capabilities. Technologies that capitalize on the increasingly robust availability of data captured from sensors and other hardware by applying advancements in machine learning and artificial intelligence (AI) can deliver an incredibly detailed level of visibility into farm operations and actionable insights to growers. These types of technologies that utilize advanced data collection and analysis can generate measurable value for farmers and environmental outcomes.

A section of consumers today is used to have unprecedented amounts of information at their fingertips and are steadily becoming more health and environmentally conscious. Technologies that enable consumers/farmers and technology-developing companies along the supply-chain give consumers a kind of visibility of their food. These companies give farmers a comprehensive view of their soils, genomics and machine learning. The company measures both harmful and beneficial bacteria and fungi in the soil and combines these measurements with soil chemical characteristics to provide farmers with a window into the health and productivity of their soils. With the ability to effectively gauge soil health, carbon sequestration and sustainable agricultural production, the companies can revolutionize how we measure sustainable and regenerative farming practices, transforming what are currently fairly vague terms and labels and backing them up with measurements, data and standards that customers can access and compare. They can help the meet the climate goals by providing a way to quantify these efforts. The soil microbiome also plays an important role in transferring nutrients to plants which influences the nutritional content of the food that we eat. Understanding and quantifying this process will enable customers to access much more precise nutrition information. While the opportunities for disruptive technology to impact the farming sector are many and diverse, any technology will need to scale to truly make inroads. There are a few common strategies or characteristics that will enable these technologies to become widespread.

Unlocking the Power of Data

Over the last half century or so, food systems have become

lengthy and complex with numerous actors involved from production to consumption. But the food and ag sector still represents the lowest penetration of digitization relative to every other sector of the economy. Many Consumer-Packaged Goods (CPGs) have almost no visibility between warehouse and point of sale and even further upstream, most producers have very little insight into when, where, and by whom their raw materials are purchased and how they are marketed and sold. Digitization can improve food production, logistics planning, supply chain transparency, and the consumer experience and will enable us to address critical issues such as sustainability, food security, and food safety. Digital platforms that synthesize data streams and deliver actionable insights to food system players will make the entire supply-chain less vulnerable to future disruptions. With the intensifying pressures of population growth and climate change on today's food systems, data may well become the most critical agricultural input.

Technologies that enable better farm data collection and analysis will be essential for increasing output to sustain our growing and evolving supply-chains while minimizing environmental impacts. Sensors on fields and crops can provide granular data points on soil conditions as well as detailed information on wind, fertilizer requirements, water availability and pest infestations. GPS units on farming equipment can determine optimal use, and drones can patrol fields and alert farmers to crop stage and pest issues. Synthesizing this data to produce holistic actionable insights will be the key to ensuring a sustainable and sufficient food production.

What are the opportunities of IoT in agriculture?

The increasingly negative effects of climate change that we are witnessing in the recent period are disrupting agricultural production, bringing up the need for taking well-informed and adequate decisions in a very short period of time. In addition to this, but totally another perspective, is the following of the strict legal framework and correct record-keeping process, where the producers are losing too much of their precious time. In the context above, the implementation of IoTs across the farm and agricultural operation can help solve one of the main issues of the modern farmer. The IoTs can help the farmers in getting insights about the conditions in the agricultural productions in real-time. They also can help feed the decision-support software for generating proper advice in the decision-making processes. Additionally, all of the recorded data can be later used as proof for every operation that is made and all of the inputs that are applied, allowing the farmers to not spend additional time in crunching numbers which extensively alleviates the record-keeping process. Specifically, the implementation of IoT in agriculture can shorten the time in checking the farm routine activities, monitoring specific operations and statuses and allowing the farmers to focus on important activities such as strategic management and positioning of the products on the market. The end result of IoTs is the potential increase in productivity, cost reduction in input application, traceability, and less labour.

What IoT in Agriculture has to offer?

IoT applications help farmers to collect data regarding the location, well-being, and health of their cattle. This information helps them in identifying the condition of their livestock. The rise of blockchain technology is making its way to the IoT, and could be important in the farming sector due to its ability to provide important data on crops. Farmers can use sensors to gather data about crops, which is written onto blockchain, and includes identifying factors as well as salt and sugar content and pH levels.

Precision Agriculture : Precision agriculture is a farming management approach that uses digital technologies to enable farmers to **make better decisions** about where, when, and how much to fertilize, irrigate, and spray pesticides. Advance resources help us track and analyse data. Agricultural sensors and paired technology can produce detailed maps of the topography. It can also give climate forecasts. By using sensors to collect data on weather, soil moisture, crop health, and real-time locational asset tracking, we can make more informed decisions about how to care for their crops, for example where to place crops, what type of crops to plant, and how to adjust their crop care (https://www.parsintl.com/publication/business-insider/**).**

Crop Management/Monitoring: **Internet of Things (IoT)** leverages crop management devices such as soil monitors. These devices are typically placed throughout fields to collect data specific to crop farming. The temperature, moisture, presence of pests, and more is detected by these devices and delivered for us to analyse. Crop monitoring involves the use of sensors, drones, and satellites to **monitor crop health and identify locations requiring attention**. Crop monitoring systems also include all data such as crop health, humidity, rainfall, temperature, and more. Sensors help farmers determine the best time to sow crops and harvest them, and can also detect problems early.

Livestock Monitoring: Livestock can be given wearable IoT that monitor the animal's vitals, location, and even reproductive patterns. Sensors and RFID tags are used to **track health of livestock**. This information aids ranchers in determining the condition of their livestock. For example, finding sick animals so that they can be isolated from the herd to avoid spreading disease to the rest of the cattle. The ability for ranchers to use IoT-based sensors to locate their livestock minimizes labour costs by a significant extent.

Irrigation Management: Irrigation management uses sensors to detect **when and how much water is needed by individual plants**. This saves water and also reduces weeds and runoff.

Smart Pest Control: Sensors **detect the presence of pests** and then dispense pesticides as required to protect crops. This helps reduce pesticide usage and can be used with smart irrigation management for targeted spraying only where it is needed.

Fertilizer Management: When fertilizer gets too low, sensors notify farmers so they can use a crop-yield map to **determine which areas need more fertilizer**. They can also track how much fertilizer has been used by each plot or farm throughout the season. This reduces costs and keeps runoff to a minimum, reducing environmental damage.

Weather Forecasting: Farmers employ satellite weather forecasts to decide **when it is appropriate to plant or harvest** in the course of the season. Weather stations with smart sensors can collect data and send valuable information to a farmer.

Crop Storage Optimization: Once crops are harvested, IoT devices can help the crops last longer when they are stored.

Sensors can help monitor and adjust temperature and humidity levels.

Furthermore, complex software analyses the data, providing ready-made analysis that helps farmers gain an accurate forecast helping avoid crop failure.

How does IoT work in agriculture?

The IoT implementation on-farm can help the farmers to cut their costs by applying inputs that are more accurate in quantity, just from the interpretation of the information generated on the fields. With the IoTs data, the farmers can run different models for detecting disease and pest occurrence, directly influencing the number of applied pesticides and the number of executed operations that will ultimately lead to saving time, cutting costs, and putting less impact on the environment. Additionally, by calculating the evapotranspiration with the help of the generated IoT data, the farmers will have an opportunity to timely schedule their irrigation patterns allowing them to minimize the applied water. Saving irrigation water is extremely important in places where there is water scarcity. In addition, the data needed for executing such an operation can be managed with the implementation of several IoT sensors mentioned above.

Apart from crop production, the IoT technology is also very useful in livestock management, where the costs for raising livestock are rising from moment to moment. Lately, in livestock management, a great accent is put on how the farmers are treating the animals and different concerns sides are pushing the farmers in to threaten the animals in a more humane way. The implementation of IoT allows farmers to attach different sensors to the animals without making any kind of discomfort, thus giving them away to constantly monitor their health and activity status. There are a lot of types of data that are measured through the IoTs, such as animal heart rate, blood pressure, ruminating time, body temperature, etc. Additionally, there are sensors that can be found on the market that are transmitting GPS data. Location monitoring is very useful to farmers who have open-range pastures. Utilizing all of the above-mentioned types of data is giving the farmers enough time to be proactive about their operations resulting in increased productivity, lowering the negative impact on the environment, and mitigating the negative effects of climate change.

How to use IoT in agriculture?

The advantages of IoT in agriculture can be many, mainly because of their wide-ranging applications. In order to gain a more complete picture of the importance of IoT in agriculture, we are going to mention several types of IoT applications in different types and phases of agricultural production:

Weather stations: Sensors combined within weather stations collect data providing measurements that map climate conditions, inform crop decision making, and potentially help to improve crop capacity, delivering maximum possible yields. By measuring these environmental factors, and generating data from them, the IoTs can build up a precise history that can help farmers with their decision-making processes, or make probabilistic-based plans, thus lowering the risk of unexpected costs and operations.

Greenhouse automation: Weather stations are not only used for collecting necessary environmental data but can also be used to automatically adjust conditions in controlled microclimate conditions, such as greenhouses, to match specific growing parameters. Whether the use is for hydroponics or substrate-grown plants, the benefits of automated greenhouses can be significant. Instantaneous data obtained by the sensors can be combined to give a broad picture of the conditions in the greenhouse. If the optimal parameters for optimal growing conditions are known and set, automatic adjustment of the environment is readily achieved.

Crop management devices: There is a large range of sensors that can be placed in the field to collect decision-making information such as temperature, precipitation, crop health, crop nutritional state, and many others. These devices are core elements in precision farming. From the sensor measurements, many forms of valuable data can be obtained. When that data is stored, it creates a temporal history that feeds into the decision-making software that helps the farmers in their decision-making processes.

Livestock management devices: Sensors can be applied, or even attached, to animals to provide information on the temperature, health and nutritious insight of each individual animal, as well as overall information about the herd. With this kind of sensor, the farmer knows exactly where specific animals with unique identifiers are. The sensors can also provide information such as when a specific animal last ate, slept, walked, etc.

***Farm productivity management systems*:** There are many potential systems that monitor and control all sensors installed in the field, combining them to provide a powerful analytical dashboard for logistics, accounting and reporting functions. By knowing the exact inputs and outputs used across the farm, farmers can obtain a clear of potential risks that they might face but have information to hand to help with formulating optimal solutions.

What are the challenges of IoT in agriculture?

The biggest challenges faced by IoT in the agricultural sector are lack of information, high adoption costs, and security concerns, etc. Most of the farmers are not aware of the implementation of IoT in agriculture. By adopting IoT in the agricultural sector we get numerous benefits, but still, there are challenges faced by IoT in agricultural sectors. The biggest challenges faced by IoT in the agricultural sector are lack of information, high adoption costs, and security concerns, etc. Most of the farmers are not aware of the implementation of IoT in agriculture. Major problem is that some of them are opposed to new ideas and they do not want to adopt even if it provides numerous benefits. The best thing that can be done to raise awareness of IoT's impact is to demonstrate farmers the use of IoT devices like drones, sensors and other technologies and they could provide them ease at work and accompanied by real-world examples.

1. ***Lack of Infrastructure:*** Even if the farmers adopt IoT technology they won't be able to take benefit of this technology due to poor communication infrastructure. Farms are located in remote areas and are far from access to the internet. A farmer needs to have access to crop data reliably at any time from any location, so connection issues would cause an advanced monitoring system to be useless.
2. ***High Cost:*** Equipment needed to implement IoT in

agriculture is expensive. However, sensors are the least expensive component, yet outfitting all of the farmers' fields to be with them would cost more than a thousand dollars. Automated machinery cost more than manually operated machinery as they include cost for farm management software and cloud access to record data. To earn higher profits, it is significant for farmers to invest in these technologies however it would be difficult for them to make the initial investment to set up IoT technology at their farms.

3. ***Lack of Security:*** Since IoT devices interact with older equipment they have access to the internet connection, there is no guarantee that they would be able to access drone mapping data or sensor readouts by taking benefit of public connection. An enormous amount of data is collected by IoT agricultural systems which is difficult to protect. Someone can have unauthorized access IoT providers database and could steal and manipulate the data.

IoT solutions are focused on helping farmers close the supply demand gap, by ensuring high yields, profitability, and protection of the environment. The approach of using IoT technology to ensure optimum application of resources to achieve high crop yields and reduce operational costs is called precision agriculture. IoT in agriculture technologies comprise specialized equipment, wireless connectivity, software and IT services. Business Intelligence (BI) survey expects that the adoption of **IoT devices in the agriculture industry will reach 75 million in 2020,** growing 20 per cent annually. At the same time, **the global smart agriculture market size is expected to triple by 2025,** reaching $15.3 billion (compared to being slightly over $5 billion back in 2016).

Smart farming based on **IoT technologies enables growers and farmers to reduce waste and enhance productivity** ranging from the quantity of fertilizer utilized to the number of journeys the farm vehicles have made, and enabling efficient utilization of resources such as water, electricity, etc. IoT smart farming solutions is a system that is built for monitoring the crop field with the help of sensors (light, humidity, temperature, soil moisture, crop health, etc.) and automating the irrigation system. **The farmers can monitor the field conditions from anywhere.** They can also select between manual and automated options for taking necessary actions based on this data. For example, if the soil moisture level decreases, the farmer can deploy sensors to start the irrigation. Smart farming is highly efficient when compared with the conventional approach.

Farmers have started to realize that the IoT is a driving force for increasing agricultural production in a cost-effective way. IoT have the potential to transform agriculture in many aspects and these are the main ones.

- ***Data collected by smart agriculture sensors*:** In this approach of farm management, a key component are sensors, control systems, robotics, autonomous vehicles, automated hardware, variable rate technology, motion detectors, button camera, and wearable devices. This data can be used to track the state of the business in general as well as staff performance, equipment efficiency. The ability to foresee the output of production allows to plan for better product distribution.
- ***Agricultural Drones:*** Ground-based and aerial-based drones are being used in agriculture in order to enhance various agricultural practices: crop health assessment, irrigation, crop monitoring, crop spraying, planting, and soil and field analysis.
- ***Livestock tracking and geofencing*:** Farm owners can utilize wireless IoT applications to collect data regarding the location, well-being, and health of their cattle. This information helps to prevent the spread of disease and also lowers labour costs.
- ***Smart Greenhouses:*** A smart greenhouse designed with the help of IoT intelligently monitors as well as controls the climate, eliminating the need for manual intervention.
- ***Predictive analytics for smart farming*:** Crop predication play a key role, it helps the farmer to decide future plan regarding the production of the crop, its storage, marketing techniques and risk management. To predict production rate of the crop artificial network use information collected by sensors from the farm. This information includes parameters such as soil, temperature, pressure, rainfall, and humidity. The farmers can get an accurate soil data either by the dashboard or a customized mobile application.

How does IoT impact farming?

Conventional farming methods are now unsuitable for meeting this demand. It has become imperative to innovate in order to develop solutions that can address these urgent concerns. Fortunately, the Internet of Things (IoT) offers a number of smart solutions that can help address these challenges. Smart agriculture is already making a big difference in the sector with its ability to optimize resources, reduce wastage, and increase farm productivity. With IoT, companies can enjoy benefits like better crop productivity and improved worker safety. They can use less fertilizer, water and pesticides. Because farmers can decrease the fertilizers and pesticides they use, there is less runoff into groundwater and rivers. This results in a lower impact on the ecosystem. What makes agricultural technologies so interesting right now is that the innovations of the Agriculture 4.0 converge and coincide with what is also termed the "Second Green Revolution." Agribusiness, agriculture, and producers around the world face disruption on a scale that baffles imagination. Smart farming, or Agricultural IoT, is often overlooked business-case for the Internet of Things (IoT) because it doesn't fit into the well-known categories such as health, mobility, or industrial IoT. The IoT will revolutionize every aspect of agribusiness, from the way farmers work to yields per acre, and will soon become the most important application of IoT.

How IoT can transform the agriculture farming sector?

With a population of 1.40 billion, India is the world's second

most populous country. It is the seventh largest country in the world with an area of 3.288 million sq. kms. India is the world's largest producer of milk, pulses and jute, and ranks as the second largest producer of rice, wheat, sugarcane, groundnut, vegetables, fruits and cotton. It is also one of the leading producers of spices, fish, poultry, livestock and plantation crops. Worth $ 2.1 trillion, India is the world's third largest economy after the US and China.

A sector that has such a large effect on the economy, simply relying on climatic conditions and manual farming practices, seems to be a little obsolete, and with the growing global population, a change in the system is more important than ever. This is why we believe that, with the advent of the smart Agriculture Sector, the Internet of things (IoT) sensor systems can be used more commonly in agriculture, enhancing its operations in any way. Farming has experienced many technological transformations in the last decade or two, which is why it has become more developed and technology-driven. Farmers have greater leverage over the method of planting seeds and growing crops by using smart farming devices. In the scenario of IoT-based smart farming, a system is built to monitor crop field with use of sensors (soil moisture, temperature, humidity, light, etc.) and to automate irrigation system. IoT technology can be used in a variety of ways, depending on the needs of a specific region. Environment surveillance, greenhouse automation, seed monitoring, drones, and livestock GPS tracking are only a few examples. This way, farmers will be able to monitor field conditions from just anywhere regardless of their current location (IOTSWC2, 2022).

Many aspects of the agriculture sector will benefit from the new technologies and the Internet of Things (IoT). Climate conditions, soil quality, crop growth development, and cattle health are only a few examples. Data analysis will assist in monitoring the condition of farming, as well as employee performance, equipment quality, and other factors. Once you know what your production output is, it helps in scheduling its sale and ensuring crop spoilage or go unsold as the technology understands the crop location. The technology detects seed damage early in the process, lowering the chance of yield failure. Smart devices can automate processes like irrigation, fertilization, and pest control in the development cycle. Automation enables the technology device provider to further track the production process, achieve higher crop quality levels, and expand its profitable capacity. *Implementing IoT in the agriculture sector will have a huge impact.*

Internet of Things (IoT) and Future of agriculture

IoT based Smart Farming improves the entire Agriculture system by monitoring the field in real-time. With the help of sensors and interconnectivity, the Internet of Things in Agriculture has not only saved the time of the farmers but has also reduced the extravagant use of resources such as Water and Electricity. **Research and innovation create pathways for disruptive technology to assist in agriculture. In Japan, scientist created insect size drones capable of pollinating flowers in the same manners as bees.** The drones use GPS to select the optimal flight path for pollinating all plants in a given area. As the world faces a crisis in dwindling bee populations, drones may very well become a replacement pollinator. In Canada, drones used for planting trees using pressurized air cannon for putting seeds into ground effectively. One drone is capable of planting 100,000 seed pods per day. In due course of time, as research continues, a day is not far when we see significant jump in crop production. The time has come when decision makers involved in agriculture to consider the integration of disruptive technology into their operations. With the promise of great efficiencies, it will soon be difficult to imagine successful operations without drones (Angela Scott-Brigg. 2020; IOTSWC2, 2022).

In nutshell, IoT helps biologists study the effects of genomes and micro-climates on crop production to optimize quality and yield. Implementing smart, connected IoT program enables farmers to make use of the massive amounts of data generated on their farms. Using satellite imaging and IoT track-and-trace technology, farming operations can be monitored all the way from harvest to delivery to maximize productivity and ensure the quality of food in the supply-chain. In areas like precision agriculture, real-time data about soil, weather, air quality and hydration levels help farmers make better decisions about the planting and harvesting of crops. Product quality, higher crop productivity, resource conservation and cost control – these are just a few of the ways the agricultural IoT promises to transform farming and food production in the future. The Agricultural IoT, integrated with Web Map Service (WMS) and Sensor Observation Service (SOS) provides a solution to managing water requirements or supply for crop irrigation. It also smartly analyses crop water requirements and uses water supply resources available to reduce waste. In areas of drought, in the crop water management function, IoT can be of great value, as it intelligently manages the limited water supply by calculating the valve operation timing and building optimum irrigation strategy, resulting in better practices to preserve water resources. The technology ensures accurate and efficient communication to farmers of real-time data related to dynamic agricultural processes (like planting, harvesting, etc.), weather forecasts, soil quality, and availability and cost of labour. Farmers who have access to such important real-time information available to them can better plan their course of activities beforehand and take corrective or preventive measures in advance for the future. A farmers' hard work is often destroyed by pests, causing significant monetary losses. To prevent such situations, the Internet of Things has a system to monitor and scan the environmental parameters and plant growth. There is also data available from pest control sensors which are capable of predicting pest behaviour, which can be used by farmers to reduce damage done by pests on a large scale. Along with attaining optimum, quality food production, the Agricultural IoT aims to ensure food safety at different levels, such as storage and transportation. To do so, it has a monitoring system over various factors like shipping time, storage temperature, and cloud-based record keeping. It is useful in livestock management, supporting livestock health with monitoring tools such as ear tags for cattle, capable of detecting respiratory diseases. If a disease is detected, it sends an alert so the animal can be separated from the herd, preventing the disease from spreading. Under precision agriculture, weather forecasting accuracy and other dynamic data inputs affects crop productivity to a great extent. The higher the level of accuracy, the lower the chances of crops being damaged; thus, more accurate weather forecasts can lead to higher profitability and productivity levels. Further, agricultural storage system can establish

baseline performance norms and then set alert and alarm conditions related to temperature, vibration, humidity, and other conditions. When consumers think of IoT applications, connected cows or digitally monitored fields rarely come to mind—but they should with the rise of IoT in agriculture.

Using IoT, the farmer knows when to spray and where. The IoT transforms the farming like never before by empowering farmers and growers to deal with the enormous challenges they face. Till now, agriculture has been a high-risk, labour-intensive, low-reward profession. Farmers are very likely to be impacted by unexpected environmental changes, economic downturns, and many other risk factors. As IoT applications in agriculture continue to develop, farms will become more connected, more streamlined, more efficient and ultimately more productive. It is understood that there are three great general uses of IoT in agriculture- sensing for soil moisture and nutrients, controlling water usage for optimal plant growth, and determining fertilizer profiles. IoT can help farmers in a number of ways. At its most basic level, sensors can be deployed across farm and farming machineries in order to enable farmers to gain an abundance of insightful data, such as the temperature of stored produce, the amount of fertilizer used, the amount of water in the soil, the number of seeds planted, storage conditions, the status of farming equipment and machinery in use, etc. Thus, it can be said that 'smart farming' is a necessary innovation, which if correctly implemented could help farmers to deal with all the challenges they face in farming. Moreover, the insights derived from smart sensors could help farmers to be more precise in their use of pesticides and fertilizers, thus mitigating some environmental impacts also.

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