Artificial Intelligence and IoT-Based Technologies for Sustainable Farming and Smart Agriculture

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soil moisture monitoring, remote water tank level monitoring, temperature, and humidity sensing, the security of farmland, monitoring the environmental conditions, and equipment tracking. This helps farmers protect and monitor their property remotely, etc. Internet of things (IoT)-based smart sensors is the new technique for the smart agriculture system. IoT-based smart agriculture system consists of various sensor nodes placed in different locations, internet service, smart remote devices, or computer systems with the internet that monitor the operation of sensor nodes, WiFi, a camera with a microcontroller, and different interfacing sensing nodes for service. Some of the examples of such sensors are temperature sensors for temperature sensing, soil moisture sensors to check the moisture content in the soil, PIR sensors used in the detection of animals, people and other objects present in the farm field, GPS-based remote control robots that perform spraying, weeding, security, moisture sensing, etc. This chapter will have the following sequence introduction of the agriculture sector with the problems it is facing now and a new technique to overcome the current issues, need of IoT in the agriculture sector, the link of IoT technique with wireless sensor network in full detail study of IoT-based system, IoT-based applications, benefits of IoT technique in the agriculture sector, and future scope.

In India, the agriculture sector has an adverse effect and day by day the crop production is getting reduced. So, it is important to identify and implement a solution for the problem in order to increase the production. Smart technologies are introduced in this domain to improve the agriculture industry. The technologies like IoT, big data, cloud-based services, and GPS are gaining its importance in the field of agriculture. There is a rising need due to the requirement of higher precision in crop analysis, transformation of live data from the field and automated farming techniques for further improvement. The expected result of this is to have smart agriculture industry with the implementation of these smart techniques. In this chapter, the authors have discussed the challenges and benefits of IoT and various types of sensor for data acquisition.

Accurate and timely information is crucial to optimize resources. Sensors determine clay, organic matter, moisture, and nutrients of soil. Sensors at various locations are connected using different technologies. Its data will be automatically reported to cloud without any internet connection. Sensors broadcast data to local base stations (LBS) at different ranges of distances using WiFi, LPWAN, LoRa, Bluetooth, etc., and then to central base station (CBS), which is far away. Modulation, coding techniques, and line of sight keeps signal intact. Data from CBS goes to cloud for analysis, visualization, and trend analysis. This helps farmers to get frequent and real-time data without actual need of physical presence. It reduces manpower, water usage, and other costs of agriculture and has positive environmental impact. Integration with other data like weather forecasts gives more precise information. Convergence of technologies, sensors, cloud, automation, etc. without human interaction contributes to IoT.

In many countries like India, farming is done using indigenous methods. Because of lack of proper knowledge in our farmers, the state of the agricultural sector becomes even more critical. Since the farming methodologies rely mostly on weather forecasts and predictions which might not be foolproof, most often the farmers incur huge losses leading to debts and mass farmer suicides. Adequate soil moisture, soil quality, air quality, and proper irrigation play a major role in the yield of crops, and hence, such factors cannot be overlooked. A major concern now is the exploding population due to which the agricultural supplies are not meeting the ever-increasing demand. The world's population is expected to cross nine billion marks by 2050 due to which the agricultural supply should increase at least by 70% to meet the requirement. To achieve this, it's necessary to monitor the plant growth at all stages starting from sowing until cultivation.

The use of wireless sensor networks, the internet of things, and advanced technologies lead to new direction of research in the agriculture domain called prescriptive agriculture. Prescriptive agriculture is the enforcement of precision agriculture, which is observing, measuring, and responding to inter and intra field variability of farm field. In this chapter, the advent of wireless sensor network, APSim, and communication model spurred a new direction in the farming domain at optimizing irrigation. Sensors are programmed to collect the datasets of climatic parameters such as relative humidity and temperature, where the datasets were forwarded to the server through a GSM module. Datasets collected were analyzed through statistical software for grown crops by considering inter and intra farm field conditions. Finally, information on irrigation is decimated through an algorithm designed by way2SMS and WebHost server.

Smart farming is the one area that has dependably been entrusted with giving nourishment to the world. With the consistently expanding populace, the horticultural segment needs to ensure that it copes with technology in order to build the measure of yield to meet the nourishment prerequisites of the world. To build the produce from farming, every single agrarian partner needs to accordingly get rid of customary rural practices and grasp current horticultural practices that will upset the field of agribusiness. One of these innovations that are intended to alter the field of agribusiness is the fuse of drones into cultivating.

Drones can help famers in a range of tasks from analysis and planning to the real planting of yields and the ensuing observing of fields to find out wellbeing and development. This aim of this chapter is to provide an overview of how drones can help take agriculture to new sustainability heights.

Most countries have an economy that is dependent on agriculture—either in a magnificent or small way, from employment generation to national income contribution—implying that agriculture is inevitable. Polyhouse farming is a new and widely accepted method of farming in the present days. The polyhouse is made in such a way that it can provide water and fertilizers in required amounts in a controlled manner, which can result in high yields. Polyhouse requires severe monitoring of crops as stagnant air, and lack of air circulation will lead to breeding of insects and materialistic loss. Hence, this chapter proposes an IoT-based disease-monitoring prototype for an agricultural/polyhouse application. The prototype is designed and tested to identify the disease onset in cucumbers. This work initially focuses on recognizing the critical cucumber diseases in polyhouse using NodeMCU and Raspberry-Pi-based hardware model. The decisions to be made and the major changes in the sensed parameters if any will be intimated to the farmers using a specifically designed mobile application.

Climate change, the increase in the international exchange of infested materials, and pest control problems cause unpredictable pest outbreaks faced by farmers. To overcome these problems, a sustainable pest control tactic, integrated pest management (IPM), which is providing the effective use of natural resources, is needed. IPM is an ecologically based control management strategy that considers all factors (i.e., natural enemies, economic thresholds, plant susceptibility and breeding factors, pest biology, and climatic conditions). In IPM, expert staff constitutes the essential element. The expert plays a role in system design, monitoring ecological factors, and decision-making mechanisms. For sustainable pest management, it is possible to perform the routine processes such as monitoring biological and environmental components and choosing the appropriate time and method through artificial intelligence. In this chapter, the use of artificial intelligence in IPM and information about algorithms, tools, methods used in artificial intelligence will be explained.

Eighty-five percent of the plants are affected by diseases caused by organisms like fungus, bacteria, and virus, which devastate the natural ecosystem. The most common clues provided by the plants affected

Preface

Agriculture plays an essential role in the growth and development of the world. By the year 2050 world population is expected to hit several 960 crores. It will be required to produce double the quantity of food than now being produced. To fulfil the human requirements, it will be required to revolutionize a new agricultural era by introducing advanced technologies to the field and bringing them on the same platform by using modern digital technologies. Agriculture is the backbone of every country and economy. Smart Farming through IoT technology could empower farmers to upgrade profitability going from the amount of manure to be used to the quantity of water for irrigating their fields and also help them to decrease wastage.

This book aims to explore various applications, techniques and use of future ICT in smart agriculture by exploring the new technical, functional, non-functional future smart technologies for smart agriculture. This book aims to identify and discuss smart agriculture capabilities, demonstrating critical technology solutions to make agriculture smart and efficient. The ultimate objective of this book is to determine whether these management systems are cost-effective in reducing input costs (including labour) and whether they improve water and nutrient application efficiency and minimize the environmental effects of production practices.

The chapters of this book are written by experienced researchers and specialists from all over the world, providing a unique gathering of information relating to the role. The significance and impact of smart agriculture technologies are also discussed very effectively. This book will provide valuable knowledge and insights to a vast spectrum of readers at different hierarchical levels, from graduate to researcher students, and also beneficial to incorporate all the discussed systems into practical use. This book is divided into twenty-one chapters where each chapter has a distinct focus.

Chapter 1. Digitization in Agriculture: Insight Into the Network World

The chapter starts with a focus on the current scenario of the digitalization in agriculture space. It pinpoints the reason behind the need and explains the emergence of new startups that work on new innovative digital technologies. The chapter also tries to discuss the post COVID implications along with the merits of digitalization in the agricultural domain. Apart from this, it also discusses different aspects of the digitalization on the agriculture space in general that includes the concept of telematics, precision farming, blockchain, artificial intelligence, etc. At last, some of the main challenges like the issue of connectivity, interoperability, portability & need for public and private sector cooperation were discussed.

Chapter 2. Artificial Intelligence and Its Applications in Agriculture With Future of Smart Agriculture Techniques

In this chapter, authors discussed how agriculture is now turning to Artificial Intelligence (AI) technology worldwide which help yield healthier crops, track soil, manage pests, growing conditions, coordinate farmers data, help with the workload, and advance a wide range of agricultural tasks across the entire food supply chain.

Chapter 3. Artificial and Natural Intelligence Techniques as an IoP and IoT-Based Technologies for Sustainable Farming and Smart Agriculture

In this chapter, authors describe the new challenges and opportunities of blockchain technology for the Digital Economy in Russia. Their study in Russia showed that the Russian research community has not addressed a majority of these challenges, albeit they note that blockchain developer communities actively discuss some of these challenges and suggest a myriad of potential solutions. Some of them can be addressed by using private or consortium blockchain instead of a fully open network. In general, the technological challenges are limited at this point, in terms of both developer support (lack of adequate tooling) and end-user support (hard to use and understand). Their recent advances in developer support include efforts by the towards model-driven development of blockchain applications sliding mode in intellectual control and communication, help the technological challenges & created tools.

Chapter 4. Digital Technologies for Smart Agriculture

This chapter provides the reader with an introduction to the modern emerging technologies like cloud computing, machine learning, and artificial intelligence used in agriculture. Then a glimpse of the complete crop cycle follows, including seven steps namely: crop selection, soil preparation, seed selection, seed sowing, irrigation, crop growth, fertilizing, harvesting, and how these digital technologies are helpful crop cycle is also explained in this chapter.

Chapter 5. Farming Automation

Farming Automation requires a whole lot of new skills and the use of technology for achieving a substantial increase in the crop yield. Smart farming enables the use of technology in tracking, monitoring, and analysing various farming operations. Internet of Things (IoT) platform is formed with sensors and actuators, cameras and drones, telecommunication technologies, edge devices, cloud servers, and specialized hardware and software. This chapter will discuss the available hardware and software technology elements that can be used in Farm Automation. The chapter is comprised of four sections. The first section provides an overview of Precision Agriculture and Smart Farming. The second section provides the literature review of existing research. The third section describes IoT techniques, sensors, and cloud and edge computing solutions for the implementation of Smart Farming. The fourth section provides a few case studies of the application of IoT in Smart Farming. Specifically, the chapter will describe the IoT platform solution for complete farm automation.

Chapter 6. Food 4.0: An Introduction

The fourth industrial revolution is a prospective innovation path for human life to possibly replace human intelligence and manual labour with artificial intelligence and robotics. The concept of 4IR is being embraced and applied in all sectors of human life. The academics are researching intensely into the revolution, while industry captain braces up for the inevitable and fast implementation in energy, automobile, telecommunication, services, security, medicine, and other industrial sectors. The agriculture and food sector, which is termed food 4.0, being the highest employer of human resources, is a major sector that is expected to benefit tremendously from the concept and application of 4IR in driving the sector into the new era of development.

Chapter 7. Emerging Technological Model to Sustainable Agriculture

Agriculture is undergoing a new technology that revolves around the world. This agricultural industry has witnessed major technological transformations over the last few decades. The state-of-the-art technologies are disrupting agriculture and transforming their traditional models into digital ones. From state-of-the-art technologies, traditional agriculture evolved and shifted towards a smart agriculture system. In a smart agriculture system, farmers can collect and analyse data to fertilize and tend their crops. The smart agriculture system provides cost-effective and highly accurate ways to predict and protect the growth of crops. The incorporation of state-of-the-art technologies essentially digitalizes the agricultural industry improving profits, decreasing waste, improving efficiency, and becoming more sustainable. The objective of this chapter is to study the state-of-the-art technologies used in agriculture and propose a technology model for a smart agriculture system.

Chapter 8. Synergistic Technologies for Precision Agriculture

Precision agriculture (PA) as a concept, allows input optimization by farmers and food producers to improve productivity and enhance quality yields while minimizing costs and environmental impacts. Developed countries typically identify with precision agriculture due to very large sizes of farms and the possibility of mechanized systems of crop production. The method involves the data collection, analysis, and plotting on productivity, soil quality parameters, and environmental levels at different locations within the field, to decide on the amounts of the applicable inputs (such as water, nutrients, and fertilizers) to the field. In most developing countries, precision agriculture technology is still largely missing. The field sizes are smaller, technology access, training, and financial capital are still grossly limited. Nonetheless, the farmers in the developing countries still explore the available resources and means at their disposal to increase their agricultural production and productivity.

Chapter 9. Use of Smart Farming Techniques to Mitigate Water Scarcity

In this chapter, the author discussed the smart farming techniques developed through the use of information technology that can help the farmer in managing the water resources, reducing the wastage of water, and even measure the quality of water. Smart farming techniques can aid in solving the biggest crisis and can help in attaining sustainable development goals.

Chapter 10. Smart Agriculture with Autonomous Unmanned Ground and Air Vehicles: Approaches to Calculating Optimal Number of Stops in Harvest Optimization and a Suggestion

This chapter aims to research smart agriculture and its components, robotic systems and machine learning algorithms, the development of agricultural robots, and their effects on the industry. In application, it is aimed to collect the harvest of autonomous unmanned aerial vehicles and UGVs in communication with each other using time minimization of the target. Deterministic, Binary Mixed (0-1) Integer modelling was used to determine the optimal picking time of the apples allocated to the stalls with the K-Means method. With this modelling, it has been determined which unmanned aerial vehicle will be collected and how it is calculated whether the air vehicle has collected the apple or not using 0-1 Binary modelling. The route of the unmanned UGV was made by using the Nearest Neighbour, Nearest Insertion, and 2-Opt methods.

Chapter 11. Smart Sensors for Smart Agriculture

IoT-based smart agriculture system consists of various sensor nodes placed in different locations, internet service, smart remote devices, or computer systems with the internet that monitor the operation of sensor nodes, WiFi, a camera with a microcontroller, and different interfacing sensing nodes for service. Some of the examples of such sensors are temperature sensors for temperature sensing, soil moisture sensors to check the moisture content in the soil, PIR sensors used in the detection of animals, people, and other objects present in the farm field, GPS based remote control robots that perform spraying, weeding, security, moisture sensing, etc. This chapter will have the following sequence introduction of the agriculture sector with the problems it is facing now and a new technique to overcome the current issues, need of IoT in the agriculture sector, the link of IoT technique with wireless sensor network in full detail study of IoT based system, IoT based applications, benefits of IoT technique in the agriculture sector and future scope.

Chapter 12. Smart Agriculture Using WSN and IoT

In this chapter, the author discussed the challenges and benefits of IoT and various types of sensors for data acquisition. The IoT technologies have led to great benefits to the farmers and also improved the crop production rate and reduction in cost. The different data acquisition sensors and their usage in the field of agriculture is discussed. The integration of these technologies with AI and other data mining methods will lead to the creation, innovation, and implementation of new ideas for efficient production and marketing.

Chapter 13. Smart Soil Monitoring System for Smart Agriculture

Accurate and timely information is crucial to optimize resources. Sensors determine clay, organic matter, moisture, and nutrients of the soil. Sensors at various locations are connected using different technologies.

Its data will be automatically reported to the cloud without any internet connection. Sensors broadcast data to local base stations (LBS) at different ranges of distances using WiFi, LPWAN, LoRa, Bluetooth, etc, and then to the central base station (CBS) which is far away. Modulation, coding techniques, and Line of Sight keeps signal intact. Data from CBS goes to the cloud for analysis, visualization, and trend analysis. This helps farmers to get frequent and real-time data without the actual need for physical presence. It reduces manpower, water usage, and other costs of agriculture and has a positive environmental impact. Integration with other data like weather forecasts gives more precise information. The convergence of technologies, sensors, cloud, automation, etc without human interaction, contributes to IoT.

Chapter 14. Real-Time Crop Monitoring in Agriculture

In this chapter Real-time crop monitoring in agriculture is discussed. Using this technology, one can monitor the various activities in the field like Moisture monitoring, water level monitoring, temperature monitoring, crop state monitoring, weeds monitoring, natural activity monitoring, etc. This innovative idea will be constructive in the agroindustry due to its remote monitoring nature and high dependability. The crop monitoring system can be developed by technologies like IoT, Wireless Communications, ML, and AI

Chapter 15. WSN, APSim, and Communication Model-Based Irrigation Optimization for Horticulture Crops in Real Time

The use of wireless sensor networks, the internet of things, and advanced technologies lead to a new direction of research in the agriculture domain called prescriptive agriculture. Prescriptive agriculture is the enforcement of Precision agriculture, which is observing, measuring, and responding to inter and intra field variability of the farm field. In this paper, the advent of Wireless Sensor Network, APSim, and Communication model spurred a new direction in the farming domain at optimizing irrigation. Sensors are programmed to collect the datasets of climatic parameters such as relative humidity and temperature, where the datasets were forwarded to the server through a GSM module. Datasets collected were analysed through Statistical software for grown crops by considering inter and intra farm field conditions. Finally, information on irrigation is decimated through an algorithm designed by way2SMS and WebHost server.

Chapter 16. Using Drones in Smart Farming

This chapter presents as an eye-opener for industry and farming for advancement and incorporation of more drones for making farming tasks better and thus yielding the best harvest quality in the future. This chapter aims to provide an overview of how drones can help take agriculture to new sustainability heights.

Chapter 17. Disease Monitoring of Cucumber in Polyhouse Through IoT-Based Mobile Application

This chapter describes the Polyhouse technology. This is the technique that provides a favourable environment condition to the plants. It is used to protect plants from adverse climatic conditions such as wind, cold, precipitation, excessive radiation, extreme temperature, insects, and diseases. It allows precision farming and overcomes the limitations of the space and disadvantages of climate change. The choice of crop to be raised in polyhouse is made based on the size of the structure, the economics of the crop production, and income generated (profit). In this work, the sensors are interfaced with NodeMCU and the camera is interfaced with Raspberry Pi.

Chapter 18. Artificial Intelligence in Integrated Pest Management: AI in IPM

In this chapter, the author discussed the importance of artificial intelligence in Integrated Pest Management (IPM) and also discussed various algorithms, tools, methods of artificial intelligence. IPM requires intensive field observation, trained staff, and data mining. In this context, it has emerged that the use of artificial intelligence (AI) algorithms is a necessity for controlling, tracking, and using these agricultural inputs at the optimal times.

Chapter 19. Application of Convoluted Neural Network and Its Architectures for Fungal Plant Disease Detection

Eighty-five percent of the plants are affected by diseases caused by fungal organisms like fungus, bacteria, and viruses which devastate the natural ecosystem. The most common clues provided by the plants affected by fungal diseases are the defaming of the plant colour. In literature, several traditional rule-based algorithms and normal image processing techniques are used to identify the fungal plant diseases. However, the traditional approach suffers from poor disease identification accuracy. Convoluted Neural Network (CNN) is one of the potential deep learning neural networks used for image recognition and classification in plant pathology. In this chapter, some of the potential CNN architectures used for plant disease detection like LeNet, AlexNet, VGGNet, GoogLeNet, ResNet, and ZFnet are discussed with the architecture and advantages. The efficiency achieved by ResNet and ZFNet is found to be good in terms of accuracy and error rate.

Chapter 20. Deep Learning Applications in Agriculture: The Role of Deep Learning in Smart Agriculture

Deep Learning (DL), a part of Machine Learning (ML) comprises a contemporary technique for processing the images and analysing big data with promising outcomes. Deep learning methods are successfully being used in various sectors to gain better results. The agriculture sector is one of the sectors which could be benefitted from the deep learning techniques since the current agriculture techniques cannot keep up with the rapid population growth. In this chapter, the recent trends in the applications of deep learning techniques in the agricultural sector and the survey of the research efforts that employ deep learning techniques are going to be discussed. Also, the models that are implemented are going to be analysed and compared with the other existing models.

Chapter 21. Development of a Solar-Powered Greenhouse Integrated With SMS and Web Notification Systems

Energy for heating and cooling is among the biggest cost in greenhouse crop production. This has led to a rethink on energy-saving strategies, including the demand for solar energy as a viable renewable and sustainable choice for greenhouse farming. This chapter presents the development of a solar-powered system leveraging on the Internet of Things and GSM technologies for sensing, controlling, and maintaining optimal climatic parameters inside a greenhouse. The proposed system is designed to automatically measure and monitor changes in temperature, humidity, soil moisture, and light intensity. The strategy utilized in the design framework provides the user with the information of the measured parameters online and via SMS regardless of their geographical location. This chapter also incorporates a mechanism to self-regulate the climatic condition inside the greenhouse, suitable for plant growth. Such a system can help improve the quantity and quality of crops grown in a greenhouse. Test carried out on the system proves its effectiveness according to the design considerations.

This book will also highlight outputs of research and development (R&D) projects, which include smart farming technologies, products, information systems, methods, and approaches to make farming operations more productive, sustainable, efficient, convenient, and competitive. Scientists, researchers, and experts from related disciplines will be contributing their book chapters related to Technologies for Farm Modernization and Mechanization, Smart Nutrient Management for Corn Production, Food 4.0, Smart Water Management Strategies, Smart Crop, Smart Crop Monitoring System and Sustainable farming, Wireless Sensor Network for Smart Agriculture, etc.

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Chapter 1
Digitization in Agriculture: Insight Into the Networked World

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ABSTRACT

The chapter starts with a focus on the current scenario of the digitalization in agriculture space. It pinpoints the reason behind the need and explains the emergence of new Agtech-based startups that work on new innovative digital technologies. The chapter also tries to discuss the post-COVID implications along with the merits of digitalization in the agricultural domain. Apart from this, it also discusses different aspects of the digitalization on the agriculture space in general that includes the concept of telematics, precision farming, blockchain, artificial intelligence, etc. At last, some of the main challenges like the issue of connectivity, interoperability, portability, and need of public and private sector cooperation were discussed.

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INTRODUCTION

Current Scenario

The great demand for food, limited supply of natural resources, and uncertainties in agriculture productivity are some of the key driving trends impacting the food and the agricultural market of today's world. According to the UN Department of Economic and Social Affairs report (DESA, U., 2017), the world is likely to witness a surge in the overall population from 7.6 billion in 2018 to 9.8 billion by 2050. Such a vast growth in the population is expected to come forward as an influential factor for the food demand around the globe. Another key factor for the upcoming growth in food supply demand is the expected 12 percent increase in the urban population of the world from 2014 to 2050. Predictions reported that the world may face water scarcity of 40% along with the deterioration of more than 20 percent cultivable land by 2030. To fulfill the cereal demand in the world by 2050, its production has to be increased by 3 billion tonnes (Alexandratos et al., 2012). Also by 2030, the livestock demand is likely to be increased by a margin of 80 percent and going up to the level of 200 percent by 2050.

There exist around 570 million smallholder farms around the world and 28 percent of the workforce at a global level which comes from the agriculture and food sector. As evident from all these facts and figures, the agriculture industry is a sector which needs the continuous thrust of technological innovations to feed the growing population for the years to come. Even though it has been shown that conventional tools are sufficient to meet the rising food demand, the actual truth comes from the report that estimates that nearly 821 million people still suffer from hunger due to lack of food supply. This fact itself gives rise to a big question of how to meet the food requirements of 9 billion people by 2050 in a sustainable and inclusive manner.

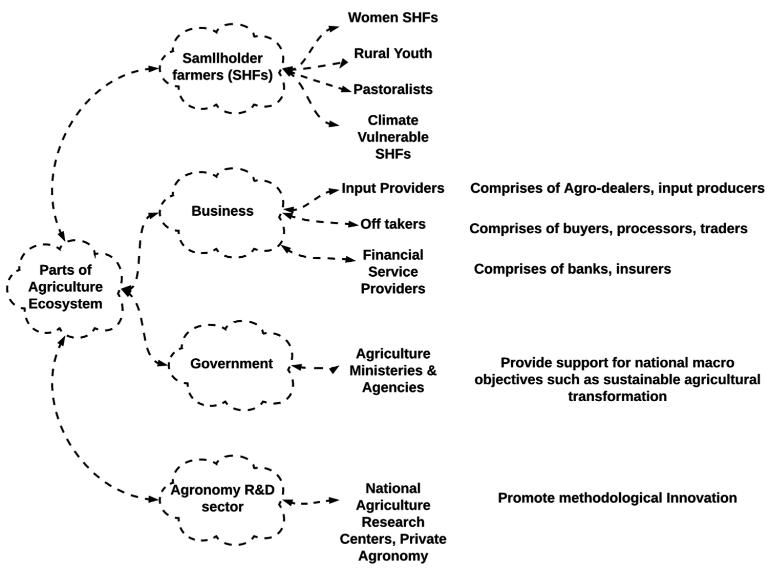
With all these things the world needs introduction of the new scaled-up transformed agricultural ecosystem at a rapid pace as shown in Figure 1. Industry 4.0 (De Clercq,M. et al., 2018) which is also known as the Fourth Industrial Revolution is responsible for transmuting various sectors through bringing in innovations through these disruptive digital technologies. The agricultural industry is also not a special case which is being exempted from this process of digital transformation. This transformation doesn't seem possible in the past only because of the unavailability of the information related to the basic requirements and field challenges that includes inputs like seed, fertilizers, microfinance, or price accessibility from smallholder farmers.

With the technological revolution around the world, the smallholder farmers are getting acquainted with the latest technological advancements in mobile communication through smartphones & other related technologies. All these are contributing to the development of the new digitally driven agrifood systems (UNICEF, A. et al., 2018). All of these implementations being scaled up could bring the revolution in the agriculture sector which is for sure only possible through digitalization.

Rural communities have been the most significant source of the next wave of mobile connections where the majority of the population is occupied in agricultural activities daily (Palmer, T. et al., 2017). Around 70 percent of the poorest 20 percent population of developing countries have access to these mobile technologies (World Bank Group., 2016).

If we see on a global level, 40 percent of the population has access to internet services and there are also ongoing digital initiatives to connect the leftover population especially those from rural areas of developing nations. Over the next 10 years, Industry 4.0 is likely to bring drastic changes in the system of agrifood markets. This is possible only through the revolutionary digital technologies like Artificial

Figure 1. Classification of Agriculture Ecosystem



Intelligence (AI), Blockchain, Internet of Things (IoT). This change is also because of several other factors like the changes in the preferences of consumers and their demands, introduction of e-commerce and its impact on global agri-food trade, changes in the climate, and many more influential factors that may be responsible for the shift in the system. The Food and Agriculture Organization (**FAO**) is bringing in great initiatives to increase food productivity, efficiency, sustainability through the transparent and resilient agri-food systems. The main objective behind these innovations is to match up with the UN Sustainable Development Goals (SGD's) and achieve the dream of making the new world with zero hunger by 2030. These achievements can only be fulfilled by carrying out the transformation through these digital agricultural technologies.

We could possibly work towards the successful implementation of digital agriculture which in turn would help in realizing the potential opportunities and avoiding the possible threats like the "digital divide" to the global system of the agricultural market. This is only possible through the envision of various future use cases and scenarios that mainly focus on highlighting the different challenges to unpredictable degrees (Klerkx, L. et al., 2019). Nowadays the poverty and rural areas don't have these digital divide threats associated with them. Digitization has been widely responsible for widening the gap between different sectors and economies. This gap is related to early adopters and reluctant parties, gender, and urbanization degrees. Africa has been reported with the strongest growth in terms of internet usage where the usage increased to 24.4 percent in 2018 compared to 2.1 percent in 2005.

Despite all this transformation that the world is witnessing, there are some of the critical challenges that are responsible for creating the digital gap. The actual benefit from these technologies is not reflected in the agricultural practices. Some of these key challenges include the lack of strong technological infrastructure, unaware of digital skills and e-literacy, inaccessibility to the internet, and other services along with the priorities of emerging economies. These challenging situations in the agriculture industry however call for the strong implementation of digital technologies into the sector (Rose, D.C. et al., 2018). There is a strong need of figuring out to navigate this new scenario into the agriculture market through some radical thought processes.

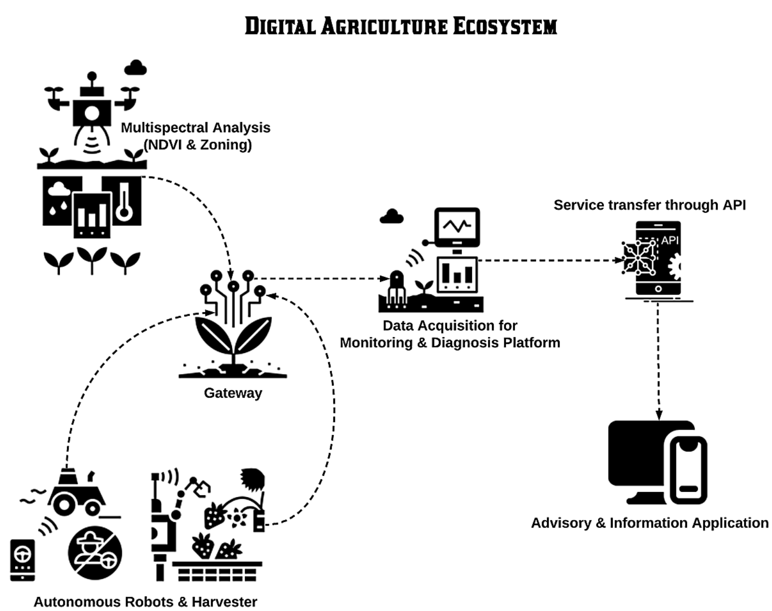
Business leaders, policy-makers, and international organizations need to bring out something innovative rather than the old principle of "business as usual" to devise the solution. The agri-food sector has never been challenged like this when the whole world that is led by the youth population is moving towards globalization and dynamic digitalization to bring up the massive technology and innovations. It's still a challenge to introduce digitalization into the agrifood sector. We need to carry out certain transformations in various fields. Changes in the system of agriculture, rural economies, and communities along with the management of natural resources may prove to be suitable strategies to bring the transformation to achieve its full potential.

Dive Into the Definition

Modern agriculture has recently experienced efficiency, yield, and much more profits through these technological transformations which were not attainable in previous times (Weltzien, C., 2016). The establishment of the very first civilization and societies was made possible through the first revolution in the agricultural sector (ca. 10000 BC) which enabled humanity to settle. The revolutions between 1900 and 1930 introduced mechanization and other changes in the food sector.

Further revolutions like the Green Revolution of the 1960s brought up new varieties of the crop which were more resistant than before along with the encouragement on the use of agrochemicals to increase the farm productivity levels. Between the years 1990 to 2005, there was the introduction of the new technologies to modify the genetics of the farming of the crop. With the help of the digital agricultural revolution, the survival of humanity is possible along with its possibility to continue in the future. Industry 4.0 opens up the availability of computational technologies that are more data-intensive

Figure 2. Digital Agriculture Ecosystem



and highly interconnected, capable of offering new opportunities in the field of digital agriculture, as shown in Figure. 2.

Digitalization in simple terms is the process of leveraging the digital technologies that work on digitized data to automate the various business processes and operations (Shepherd, M. et al., 2018). For example, uploading the digital documents to the cloud for making it accessible to anytime anywhere. Another example is to use Google sheets to work on a collaborative platform which avoids the tedious tasks sharing an excel file to some other person when required. Generating reports in clicks through Business Intelligence tools can be thought of as another example of digitalization.

The last term is Digital Transformation (Boulahya, R. et al., 2020) which is the process of using digital technologies to improve processes, productivity, and customer experiences. It can be thought of developing a mindset to achieve the customer-driven strategic business rather than implementing separately as the projects. It tends to automate the manual business processes and provides agility, customer focus, and data-driven decisions into the sector which it transforms.

Rise of Digital Agriculture

If we compare the digital transformation in different industries then agrifood business is the most transformative and disruptive among all of them. This transformation will not only change the conventional old-age farming methods along with the behaviors of farmers but will also make an impact on every part associated with the sector value chain. We may also see the significant changes in the processing of, marketing, pricing, and selling of the products by input providers along with retail and processing companies. What the digitalization in the agricultural sector brings is the change in the management of resources which would be very much optimized. All this digital infrastructure in real-time would be much more individualized and intelligently made possible through the interconnection of the subcomponents within the sector and the huge dependence on the data available (Tang, S. et al., 2002). Management prescriptions for each of the agrifood fields and crops along with the value chains should be optimized to a good level along and on an individual basis instead of treating them on a uniform ground. Also, it should be taken care that all the animals are monitored and managed individually.

At the lowest level of granularity, we can expect some amount of traceability and coordination in the value chains of the agrifood sector. Systems which are safe and anticipatory along with the good adaptation to the changes in climatic condition have good levels of productivity. These types of systems should ideally be the output of the transformation that the digitalization would bring in the agricultural sector. The increased amount in food security, profit levels, and sustainability can be some of the expectations from these advanced systems. Over the next decade, the agriculture industry and the food sector will definitely transform through the rise of digital technologies according to some market predictions and forecasts. Different technologies will have their role and impact in transforming the different parts involved in the value chain of the agri-food business.

Two key factors generally decide how the integration of these technologies should be managed within the individual part of the agrifood value chain. The first one is the complexity of that individual part and the second one is the stage of the maturity of that particular part of the chain in which the technology will fit into. Digital technologies can be classified as per the below structure which is based on the complexity of that individual technology and the stage of the maturity of that particular part of the agri-food chain in which the technology will fit into. Digitization tools and technologies, according to a research study, can result in much higher levels of yield productivity along with increased revenue generation.

It is predicted that by 2030, these transformations may contribute a total of 14 percent in the growth of the Indian GDP numbers whose value would be equivalent to US dollar 15 trillion at the current rate (Vial, G., 2019). The agriculture industry is a US$ 7.8 trillion industry today and technology has played a vital role in transforming this sector likewise it has impacted other industries. Agrifood business on its own has a 40 percent share in the global level employment responsible for feeding the world .

Therefore, there is a need to address some of the challenges which are being brought up by the process of digital transformation. Some of these are inadequate levels of standardized digital solutions in the aspect of data and the problems surrounding it like incorrect format settings. The properties of the data are unclear along with its usage and access control activities. Digital transformation in agriculture is being used by big international companies in this disparate scenario to carry out the business in agrifood.

Solving the social challenges and issues revolving around transforming rural living, unemployment problems are affecting organizations like government and public sector agencies which are an integral part of this process. These disruptive technologies may have an impact on the environment of the social and economic areas which generates the big challenge of making wise use of these technologies and able to take a good advantage.

Reason Behind the Need of Digital Revolution in Agriculture

We may expect the increase of the world population with a margin of 40 percent by the year 2050 becoming a huge number of 9. 6 billion. With this increasing number in the global population, there will be a need for increased production in food by 70% to fulfill the requirements as predicted by FAO (UN Food and Agriculture Organization).

The requirements of cereals and livestock would increase by 1 billion tons and 200 million tons respectively per year while utilizing the same or just 5 percent more agricultural land (Krishnan, A. et al., 2020). To meet this requirement on a sustainable level, we need to take care of the environmental and regulatory challenges posed by the global agricultural industry. There is a need to achieve these goals by increasing the farm yields as the majority of farmland is already being farmed. The solution to this problem of feeding the world is possible through the support of digital transformational technologies in the field of agriculture.

What one can achieve from this digitalization in the agricultural field is the efficiency, production, and profit levels which were not anyhow possible through the traditional farming systems. All the journey started from mechanization (1900 to 1930), moving to the green revolution (1960) which brought up the development of crop varieties which are more new and resistant along with the usage of agro-chemicals followed by genetic modification (1990 to 2005).

Among all the industries, digitalization has the highest impact in the agrifood business, changing every single part of the agri-food value chain. The correction in the nutrition of the soil along with the management of pests and disease has been on track with the help of technological advancements in the field of agriculture.

Moreover with the genetic development and innovation cycle shortening of the crops made us achieve higher crop yields. There are plenty of climatic changes that the farmers are facing despite the increased demand for food production. Some of these factors are fluctuations in rainfall patterns, extreme weather conditions, water scarcity, and increased temperature levels which are the hindrance to the optimum yields (Wang, H.H. et al., 2014). There is a strong need for innovation and improvements in farm productivity to meet this demand. All these challenges can be overcome by leveraging the digital technologies which will facilitate the farmers with the information and contribute to farm productions.

Along with the farmers, consumers are also very vigilant these days about the products they are consuming and want high-quality products along with every single information associated with products from the farms to their doorsteps. All this level of traceability can be achieved by the digital technologies that can satisfy the consumers and eventually the farm value. Modern agriculture needs innovation more than what was needed in old times. There are a lot of challenges which the agri-food industry is facing right now to ensure the transparency and sustainability in the products which the consumers are consuming.

Some of these challenges are the high cost of supplies, labor shortage, and changes in the buying preferences from the consumers. Agricultural corporations are setting up the demand for the solutions that are required to solve these challenges in the sector. As a result, there has been a massive growth in agricultural technology with an investment of $6.7 billion in the last 5 years and $1.9 billion in the last year; all within 10 years.

Artificial intelligence, indoor vertical farming, modern greenhouse technologies, precision farming, blockchain are some of the key technologies which have been touched to revolutionize the agricultural sector (Llewellyn, D., 2018). With the digital transformation, we can have a world where farming would be considered a high-tech profession and bring a positive impact on the management of natural resources. This can lead to the elimination of food wastage and fulfill the increasing demand for food production. Artificial Intelligence, Blockchain, Internet of Things (IoT) (Kaur, G. et al., 2018), all other digital technologies are changing the way of farming and thus is impacting every part of its value chain.

SURVEY

Digitization and Agtech Transforming Agriculture

With the advent of digital technologies around the globe, the world now has been a lot closer than what it used to look a decade ago. Mobile devices which are the principal component behind the revolution are becoming day by day a lot cheaper, faster, efficient, and smaller than they ever had. With many industries trying to make full use of the emergence of these digital tools, farmers tend to be no exception (Carolan, M., 2020). These next-generation advances in technology are helping farmers by providing better control over the day to day operations, ultimately enabling them to get a better hold of the number of resources they put into use on a daily basis. As a result, the concept of digital technology is currently finding a myriad set of applications in different agriculture practices that includes agriculture processes like livestock handling, to farm machinery.

With the onset of digitalization, the concept of smart farming is expected to rise by double in the coming 5 years. The continuously increasing demand for food for the world has put stress on the widespread adoption of the innovative practices that can leverage the downtrodden old age Agri industry. Some of these systems like the one using the GPS system in seeding alongside harvesting machinery with advanced digital monitoring tools have to broaden the farmer's perspective in terms of the yield. Similarly in horticulture, there has been digital technology that provides an unimaginable level of management precision that includes efficient use of water, effective control of disease, and optimization of the overall yield (Rotz, S. et al., 2019).

The electronic animal identification with remote sensing capability along with automated weighing and drafting is one another example of the use of the digital technologies that exemplify the growth rate, feed conversion ratios altogether with livestock uniformity and quantity. In spite of the development of all such technologies, only a few of them have proved to find their place in the mainstream.

AgTech in India

With the rise in the population around the world, there has been a great surge in the demand for sustainable food, impacting global demand & security. India being an agrarian economy depends mainly on the good rainfall and human labour for its growth. While most of the developed countries around the world developed the modern tech enabling tools & machines, farmers in India still have to plod their farmlands with obsolete farming practices.

Unfortunately, they are neither trained nor equipped with the latest technological advancements to make their demands met in a faster and efficient way (Deichmann, U. et al., 2016). However, with the growth of communication infrastructure in India, the concept of digital farming is entering into the confined space of Indian farmers to assist them better in various activities related to their yield & crop safety. Despite its intervention, this concept still lacks proper penetration into the current market. The main reason behind this is the lack of adoption & proper training to the farmers with the latest cost-effective technologies for different farming practices. This is one of the main reasons why the contribution of the agriculture sector finds it difficult to contribute better to the overall GDP of the nation.

Due to the same reason, the government of India has started to promote new era digital tech-based startups in this domain through various programs. Following up on the digital India programme launched in 2015 by Prime Minister of India Mr. Narendra Modi, there has been a surge in the number of agreements between big software firms & the government to develop various digital technologies for farming. Such an example of such joint collaboration happened in 2019 where the NITI Aayog merged with a big software firm to develop a system for yield predictions using artificial intelligence so that farmers can get to know the real-time advisories. According to a report by Cisco (Liang, Y. et al., 2003), nearly 4.6 billion people will be using the Internet by 2021, which means that the agriculture startups around the world can unleash umpteen opportunities through continuous innovation and can transform the agriculture landscape like never before.

The main challenge that lies in front of India is optimizing growth in agriculture through effective frameworks, policies, and programs that can empower Indian farmers to enable a technology-driven ecosystem for farming. Some other challenges confronting the Indian agriculture ecosystem include declining farm productivity, unsustainable usage of resources, rapidly growing demand for high-quality & safe food, fragmented landholdings, and stagnating farm incomes (Seth, 2017).

The digitalization of agricultural-based business involves leveraging massive amounts of data from agricultural tools, equipment, machines, soil, using modern-day tech to automate agriculture which plays a key role to meet the ever-increasing global demand for food. Apart from this, some of the other useful applications of digital technology in farms includes livestock & farm management, crop & soil health monitoring, geographic information system, remote sensing, etc.

All of these applications supply the ordinary farmer with essential details like crop selection, assistance in obtaining insurance & credit, weather-related advisories etc. Similarly, the application of advanced analytics allows the farmer to make a smart decision about their resources consumptions and other important parameters that ultimately enable them to save a lot of unnecessary investment (Mittal,

S. et al., 2010). With over 500 startups in the agtech space in India, the agribusiness sector is greatly booming only due to the intervention of digital technologies through different stages of farming. With low cost-efficient digital technologies from these startups, India can bring a revolution in its Agri sector across pre, post, processing & logistic stages.

Agri-tech Startup Landscape

For the adoption & development of knowledge-based agriculture education, agricultural digitization projects stood to be of paramount importance. Researchers all over the world are supporting the concepts of smart & precision farming through several innovations & data analytics. Therefore, it seems quite crucial to empower farmers with the latest innovative digital technologies that can ultimately drive further R&D and create a culture to understand and expedite the adoption of advanced technologies in agricultural practices. These latest digital technologies can help farmers to cope better with the calamities and their aftermath in a much better way than what they used to handle with the conventional tools. Despite the recent progress in the agriculture domain due to the involvement of the government there still exists a constant challenge to provide food to its continuously increasing population. With the advent of the Digital India programme in 2015 there has been a surge in the emergence of different types of agtech based startups in the country.

The three main of them can be classified as follows,

Agriculture Market Place

The startups that belong to this kind of category are useful in providing services like the agricultural news, weather forecast, price alerts, and local government vegetable market in their respective language. These startups also help in connecting the farmers to the ultimate seller, ultimately helping in avoiding the unnecessary need of the middle men or broker.

Digital Farm Management

Startups belonging to this category help in providing an overall overview of their whole operation from production to inventory management using state of the art technologies like geospatial analytics, machine learning, and data analytics.

Climate Smart Precision Farming

This category of the startup is responsible to provide better data driven farming decisions using on farm sensing technology that integrate with data science and artificial intelligence to make better useful predictions for growth & optimisation of resources. These resources generally include cost savings in terms of energy, pesticides, water, and fertilizers to product losses prevention, automation and getting real time alerts to make adjustments in their farming practices accordingly. Since the beginning of digital india programme (Lele, U. et al., 2017) there has been a huge adoption of mobile technologies and the internet that open a whole new wave of growth in this sector. As a result there were a number of initiatives that were launched by the indian government of india in the past.

Some of the useful ones in this regard includes the india israel innovation bridge, that developed as a tech platform to facilitate bilateral engagement between the israeli and indian startups, corporations, and tech hubs that aims on fostering growth in different sectors including agriculture. Another useful initiative was the 'Agriculture Grand Challenge' that was developed by the ministry of government under the indian government to look for new innovations and concepts in 12 different areas. It was developed mainly to provide thrust and emerging agri based startups in digital space with the necessary infrastructure for further inclusion into the indian agriculture sector. Some of the main themes for the challenge include things like yield estimation, price forecasting, losses prevention, e-marketplace development, soil testing methods etc. Recently, the department of agriculture and food engineering at IIT kharagpur has launched an online course on "Application of Digital Technologies in Agriculture", that focuses on engaging smart technologies for enhancing productivity with minimal effort and cost.These would include Sensors, Drones, Robots, Artificial Intelligence and Machine Learning, Machine Vision Techniques, Computer Aided Design and Advanced Digital Technologies application in Agriculture. Knowledge about Digital Farming Solutions will help the farming community in Enhancing their productivity by Robots, Drones and AGVs.

Digital Agtech Based Startups

This section will highlight a few notable emerging startups in the agtech space around the world, which are using digital technologies to bring a revolution in the current dormant agriculture sector (Kimle, K. L., 2018).

1. Fasal is an Indian based artificial intelligence powered IoT platform that monitors a number of growing conditions of the farm to provide better decisions for different farming practices. It uses AI & data science to provide an extensive overview and knowledge about the way through which farmers can optimise their yield and get control over the future harvest.
2. The tech giant IBM had partnered with Yara, a global leader in digital farming solutions from norway, to provide smart agricultural solutions for optimization of farming practices to increase yields, crop quality and incomes in a sustainable way. They put their focus on different verticals in farm optimization using machine learning, artificial intelligence and farm related data to unlock new insights for the farmers. Starting from providing hyperlocal weather forecasts alongwith real-time actionable recommendations, tailored to the specific needs of individual fields/crops, they develop blockchain-enabled network of food chain players to allow for greater traceability and supply chain efficiency as well as ways to tackle food fraud, food waste and sustainability.
3. Inability of the farmer to have a formal transaction record of how much they get through the middlemen is one of the problems that hinders their ability to get access to financial services like crop insurance, lending etc. To solve this problem, a startup named BanQu came as a rescue some years ago. It is a blockchain-based software as a service platform that creates a decentralized digital ledger of each transaction, helping farmers build credit and hold processors accountable. Instead of cash, each farmer received a digital payment through BanQu's blockchain platform.

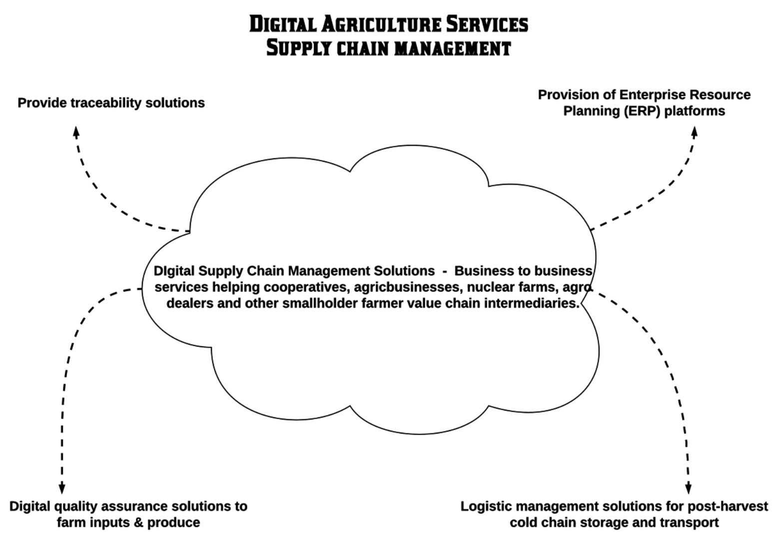
Post COVID Scenario

The consequences of the raging COVID 19 have been felt all around the world. It not only affected businesses but also slowed down the economy of the whole nation tremendously. It could be seen through the percentage declination of the overall GDP of the nation in the first quarter of 2020. Italy being one of the worst-hit countries suffered a GDP downside of 12.4%, while a country like India experienced a GDP drop of 23.9% in the first quarter to the same quarter in 2019 (Timilsina, B. et al., 2020). To get back on track the country must start relying on a technological based agricultural system that can bolster the dormant agriculture sector. In this period of pandemic across the world, the digitalization of agriculture could prove to be the biggest advantage for the Agro based industry. It can help in managing transportation, supply chain, finance in a much better way when there is a need to find an alternative to human-centric tasks.

They cater to various streams in the agricultural supply chain, including cooperatives, farmers, wholesalers, importers, exporters, contract farming companies, retailers, and even consumers. In simple terms, this concept or application of digital technology simplifies the management of farm operation in several ways. Right from the plantation, it takes care of the quality, storage & sales, and everything that comes in between them. That's why enterprise resource planning platform based Agri tech startups could prove to gain much more appreciation than the other ones in this segment. The digitalization is revolutionizing the agricultural landscape in the sense that now farmers are getting much more educated, aware, informed and equipped with the workings & benefits of integrating digital technologies in their agriculture tasks.

With time there has been a demand for the up-gradation of the conventional applications. Thus most of the digital technologies are combining among themselves to offer a hybrid system that provides smarter data insights through farm analytics dashboards along with the power of sensors, unmanned aerial drone, robotics right down to the micro-level.Apart from this, analytics on the nutritional requirement of the land, along with water and crop schedules are provided to the farmer for profitable farm operations (Gregorioa, G. B. et al., 2020) .

Figure 3. Supply Chain Management in Agriculture



Covid-19 Boosts Digitisation of the Agriculture Industry

Despite its catastrophic impact all over the world, COVID 19 has enabled the farmers of today to adopt social and digital media platforms to sell their products directly into the market. It has brought a rapid acceleration in the digitisation of businesses across the agri-sector. The increasing demand for agricultural food products, shift in consumer preferences to higher standards of food safety and quality, and unavailability of laborers during COVID-19 are some of the driving factors for the market. With millions of people relying on online grocery order nowadays, there has been a significant increase in the amount of data giving the demand estimate for each product (Altieri, M. A. et al., 2020). The era of data in food production and consumption has therefore been rapidly accelerated by COVID ultimately demanding the fusion of more digital technologies based applications in real-time.

DIFFERENT ASPECTS OF DIGITAL TECHNOLOGIES IN AGRICULTURE

The global food demand is expected to rise by 50% until 2050 according to a report by the food and agricultural organization (FAO). The future of food production depends upon technological advancement in the agriculture sector. Bringing low-cost Agtech solutions to the farmers could help them to stay competitive enough to preserve in the coming years. With the onset of growing ownership of smartphones across the whole world, a large part of our global food system will likely be digitized (Skvortcov, E. et al., 2018). This will help farmers to get the required assistance to better save the resources in a much more sustainable way.

In the coming years, the market of global digital farming is expected to grow a lot pertaining to factors such as rapidly decreasing arable land, growing population with a growing need for high production of vegetables and grains, etc.In addition to this, the surge in the population of green farming around the world is also giving a thrust to the digital farming market. The increasing demand for quality crops has been a major factor for the adoption of digital farming by a lot of farmers to improve the production ability of their arable lands. As a result, the global farming market is expected to be valued worth 10.23 billion USD by 2025. Other major factors that result in the overall increment in the market share include increasing demand for automation & control systems, sensing devices, antennas, access points & robots.

Telematics in Agriculture

The services of telematics mainly include the usage of tracking devices to locate the position of the tools for management purposes. With the growing number of telematics-based applications in agriculture, there has been a rising demand for digital farming practices. Increasing demand for such management services is one of the main reasons why we see a growth in the digital farming market (Cambra, C. et al., 2017).

Telematics can be defined as a technology that captures useful data from the farm equipment or machine operation in the farm and transfers the user data to the monitoring dashboard in real-time for further actionable decision for farming after proper analysis using the big data tools. In general, it involves Robots and autonomous super-tractors or a fleet of combine harvesters with cameras and sensors that are connected with the digital platform, for bringing optimization in farming practices like sowing, fertilizing, and planting.

Indoor Vertical Farming

The concept of indoor vertical farming can be explained as the process of growing farm produce stacked one over the other in a closed, confined, and controlled environment. From one over the other, it means there are shelves mounted vertically in the same area, where the plants used to grow the same as the farmland (Kozai, T et al., 2019). This method has the potential to increase the yields, cut down distance traveled in the supply chain & overcome the limited availability of land. It is mainly useful in the city and urban setup where there is always a limited space. Some of them are unique in the sense that they don't need soil to grow, meaning most of them are hydroponic, where crops are grown in a nutrient-dense bowl of water. In setups for these vertical farming practices, artificial glow light is used most of the time. Apart from the merits mentioned earlier, another significant advantage of this kind of farming is the less usage of water. It usually accounts for approximately 70% less usage than conventional farms (Benke, K. et al., 2017). Apart from these things, the cost of labour is also reduced due to the employment of robots to handle the process like planting, logistics, harvesting, packing, etc.

Farm Automation

Farm automation in general is a technology that makes farms more efficient and automates the crop or livestock production cycle. With the growing demand for automation, a large number of companies are working on innovation related to robotics to develop drones, robotic harvesters, autonomous tractors, seeding & automatic watering robots (Edan, Y. et al., 2009). The primary goal of farm automation technology is to cover easier, mundane tasks of the farms in much more time & cost-saving ways.

Livestock Farming Technology

Apart from the important technologies that were discussed earlier, one of the underserviced and overlooked sectors of the agriculture domain is the conventional livestock industry. Management of livestock has been known for keeping the business of dairy farms, poultry farms, cattle ranches, and another related agribusiness alive (Banhazi, T. M. et al., 2012). It is required that in such services the manager must keep track of the financial records, ensure proper feeding & care of animals along with the supervision of the related workers. However, with technological advancement, this industry also revolutionized the agriculture sector to serve a number of essential processes and purposes. These technological advancements were discovered as the new developments in the form of nutritional technologies, genetics, digital technology, and more to keep proper track and management of livestock to improve & enhance the production capacity.

One such example of putting into the mainstream can be seen through the putting of individual wearable sensors on cattle that can help to keep a track of their daily activity along with health-related issues. The massive amount of data collected by these sensors are often turned into meaningful, actionable insights, which help the producers to quickly look and make quick effective management decisions.

Precision Agriculture

With a number of emerging technologies in farms, the agriculture sector is reforming itself like never before. Precision agriculture companies are bringing innovations in the market to help farmers maximize yields by taking control of the variable parameters of crop farming (Srinivasan, A., 2006). The parameters often include points like moisture levels, soil & climate conditions, pest stress, etc. Apart from this it also helps farmers by providing accurate techniques for growing & planting crops to manage cost and increase efficiency.

MAIN DIGITAL TECHNOLOGIES IN AGRICULTURAL DOMAIN

In this section, a brief overview of different technologies for precision farming is covered.

Field Monitoring

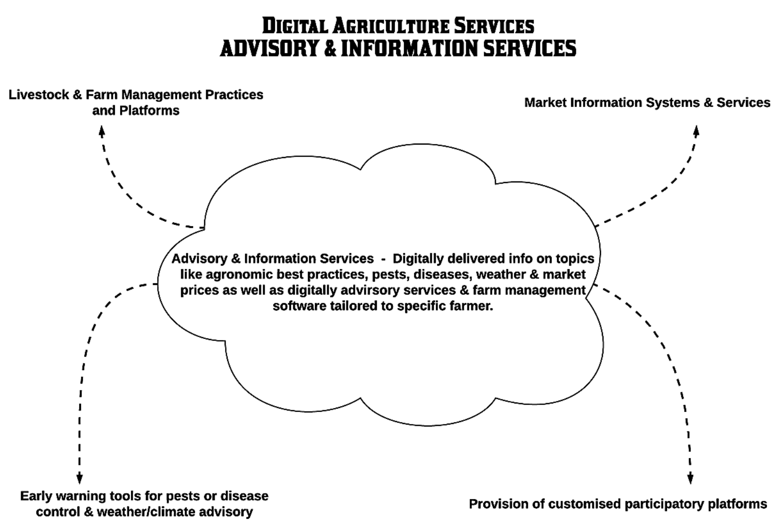
Monitoring Crop Health

One of the popularly known methods used to determine the health of crops through satellite imagery & drones is the Normalized Difference Vegetation Index (NDVI). It takes into consideration different wavelengths of light falling in both visible and nonvisible, to make the required calculations. This technology in simple terms allows the farmer to get an assessment of the general health of their crops along with the detection of crop variability.

Yield Monitoring and Forecasting

With the advancement in precision agriculture technologies, there are different ways to collect information about the yield of the farm. Some of them consist of sensors fitted on the farmer's machinery like tractors or harvesters, drones & satellite imagery. All of them help the farmer in getting important information related to yield of grains, level of moisture, fertilization & allow them to make a better decision about their harvesting plan. The vital points regarding the same can be seen in Figure 4.

Figure 4. Advisory & Information Services in Agriculture



Crop Scouting

This precision agriculture technology is quite similar to the technologies discussed above. The only feature that makes it quite distinct is the usage of mobile phones and tablets to collect & monitor important data about the crops like pest population, growth of unwanted plants, etc.

Detection of Pests, or Weeds and Diseases

From many applications of precision agriculture, we have seen that drones have been making an important role in providing data related to the detection of weeds, pests, and disease. All this has been made possible due to the hyperspectral imaging camera that is fitted in it for scanning. It provides in-depth knowledge of the farm which a typical camera can not capture.

Weather and Soil Quality

To get to know about the quality of the crop, certain plant and ground-based sensors are employed to collect important information about water and soil. Main things that these sensors measure are the salinity levels, pH levels, texture of the soil, nutrient status, and organic matter. Reports about the weather are usually reaching the farmers from the weather stations through their smartphones.

Data Management

Platforms for Farm Management

This kind of software is a platform that usually comes integrated with different hardware devices to help farmers to manage their crop production efficiently. The data collected from these systems are collected & compiled onto a central platform where it is processed and analyzed to help farmers make better decisions on managing & optimizing their overall farm activities & operations, as shown in Figure 6.

Apart from this, it also eases the monitoring and analysis of all related activities & streamlines crop production and harvesting schedules. In short, the software gives the farmer access to environmental conditions and finances as shown in Figure 5., so that they can better manage things like record-keeping, business needs & farm production monitoring functionalities.

With the agglomeration of mobile phones around the world, this kind of software is proving themselves an important & efficient service to help farmers across different locations & conditions, around the world by making them work more efficiently whilst saving money, time, and resources. The extensive set of functionalities that are provided with it also helps specialized companies in the Agri sector to cover the needs of the farmer in a much more integrated manner.

Variable Rate Applications (VRA)

The Variable rate application is a kind of process that mainly focuses on the automated application of things like seeds, herbicides, chemicals based on data collected from sensors, maps, and other monitoring sources. It involves the integration of different forms of technologies related to precision agriculture.

Some of which are like satellite imagery, hyperspectral imaging, machinery on harvesters and tractors, etc. Cut short, it helps in optimizing the usage of fertilizers, seeds, and other relevant chemicals.

Figure 5. Digital Financial Services in Agriculture

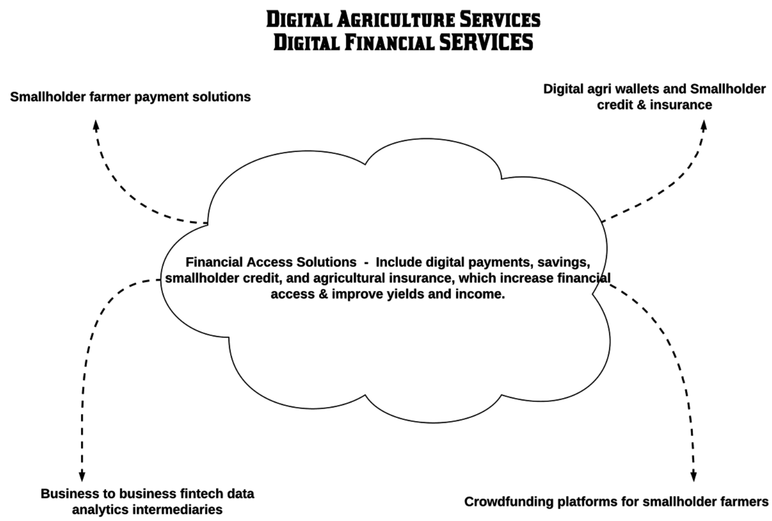
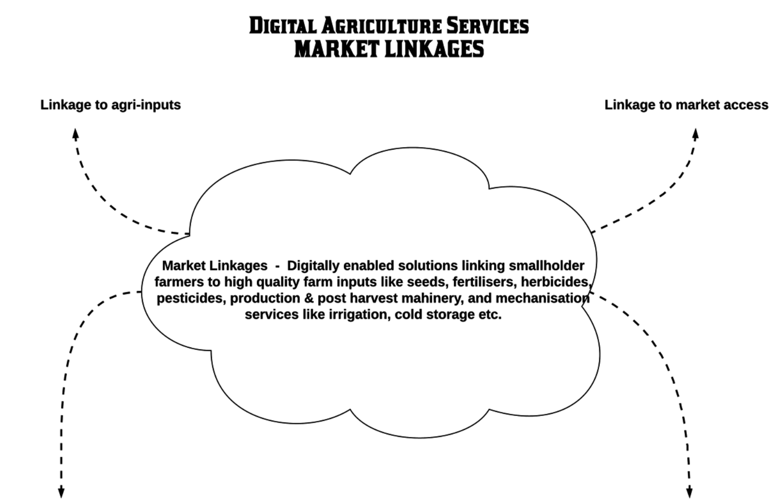


Figure 6. Market Linkages in Agriculture



Agro Machinery Automation

Farm Robots

Over the years, robots have been finding their application in many industries to automate different tasks. However, with the inception of automation in agriculture, robots have been useful in a ton of applications (Yaghoubi, S. et al., 2013). One such big use is the automation of weed management, for which two companies in the united states have developed robots that make use of their cameras to identify weeds in real-time.

Guidance Systems Based on GPS

Global Positioning System also known as the GPS, is a technology that is mainly used in the agriculture sector to guide automated machinery and vehicles like autonomous harvesters, drones, tractors, etc (Parasher, Y. et al., 2019).

Telematics

This technology as described in the previous section is a crucial technology in Agri automation that helps in establishing machine-to-machine communication between the sensors & hardware which are involved in the process of automation (Parasher, Y. et al., 2018). One such example of this could be observed during the process of managing weeds on farms.

So, whenever a camera fitted on a piece of machinery identifies a section of weed, it communicates the information to other related machinery that gets the location of the weed from the former and plucks it wherever it seems necessary.

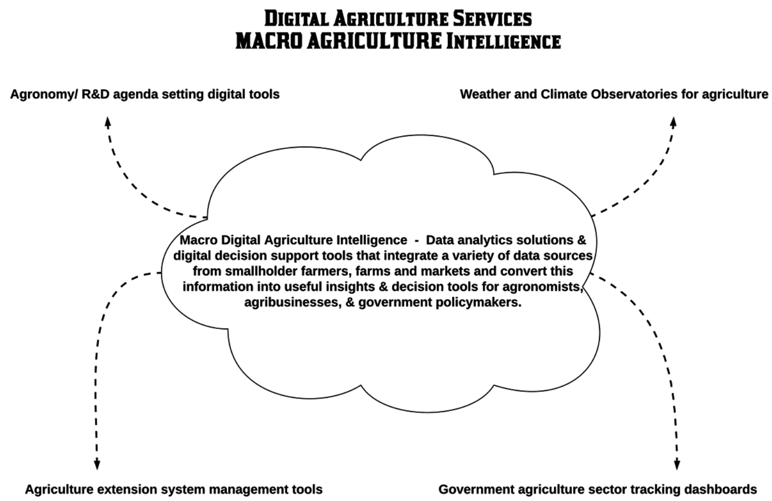
Precision Planting

The concept of precision planting which can be shown in Figure 7. describes an automated process that optimizes the planting of seeds by allowing better depth control, seed spacing, etc (Parasher, Y. et al., 2019). Usually, the optimal condition for planting is provided with other precision agriculture-based technologies on which this concept works.

Blockchain

Blockchain in simple terms is a system where digital information is distributed without getting copied. Meaning to each block of a particular set of data there will be only one owner. Therefore, blockchain holds tremendous capability in tracking down the ownership records to solve issues like supply chain inefficient, food fraud & traceability in the current food market (Kamilaris, A. et al., 2019). Its unique decentralized structure helps in establishing a range of premium products by ensuring the verifications of products & practices with transparency. Among all the tasks where this technology seems useful, it finds its need for food traceability. Due to the presence of artificial and perishable food, the whole food industry resides at a vulnerable end. Whenever a foodborne disease strikes the public health (Singh, P. et al., 2019), it becomes quite necessary to track down the source of the whole crisis.

Figure 7. Macro Agriculture Intelligence



However, huge dependability on paperwork for tracking things is a major time-consuming task. In such a case, blockchain comes as a rescue. Its structure ensures that each party along the supply chain generates and shares securely the information points to form an accountable & traceable system. Such a vast number of points with labels clarifying ownership can be recorded easily with any chance of alteration. As a result, the whole journey of the food item is available to monitor in real-time (Lin, Y. P. et al., 2017).

By helping in the quick food tracking mechanism, the blockchain technology adds value to the current agri market by building a ledger in the network and balancing the pricing of the market. The price for buying & selling the farm produce depends on the judgments of the individual players involved in the market. It also enables verified transactions securely shared with every player in the supply chain of the farm produce, creating an ecosystem with immense transparency.

Artificial Intelligence

With the rise of new digital technologies in the agriculture domain, there has been unprecedented growth in the amount of data that is being collected by remote sensors, satellites, UAVs, etc for different purposes (Patrício, D. I. et al., 2018). These different purposes mainly include processes like monitoring of soil condition, plant health, humidity, temperature, etc. The vast data that is being collected could only serve fruitfully when the farmer is able to gain a better understanding of various things involved with the farm.

Therefore to make sense out of it, this data is operated under various artificial intelligence algorithms (Parasher, Y. et al., 2020) through which farmers can acquire a proper understanding of various processes in general. It is expected that by 2050 the world will need to produce 50% more food than what is producing right now. In such a situation, AI-enabled technologies can help farmers by providing greater yield using the available resource more sustainably.

AI Applications in Agriculture and Farming

Autonomous Tractors

With huge investment in the development of autonomous vehicles in the last few years, the agriculture sector is going to foresee a tremendous surge in the number of driverless tractors, harvesters & other machinery (Eaton, R. et al., 2008). These self-driving or driverless tractors are programmed with different AI algorithms to perform various tasks in general. Some of them include things like detecting ploughing positions into the fields, etc.

Agricultural Robotics

Similarly, AI companies are developing robots that can easily perform multiple tasks in the farming field. Most AI companies in today's world are developing robots that can automate a set of tasks for a number of different farming practices. Some of these tasks mainly include things like crop quality checking, detection of unwanted plants, etc.

Pest Infestations Control

Pests such as grasshoppers, locusts are usually considered as the worst enemies of the farmers. They damage the crops globally before it is harvested and stored for human consumption. To cope with it, few AI companies have developed a system that helps farmers though alert on the smartphones, telling about the likelihood of these pests towards certain farmland or crop fields. These companies are using the satellite images of the present and past few years of the same area as the data for the AI algorithms to provide useful information.

Crops & Soil Health Monitoring

Rapid deforestation & degradation of soil quality has been a problem for several years. To cope with it, a Germany based tech startup had recently developed a deep learning-based image recognition technology application that can help in identifying the nutrient deficiencies and potential defects in soil along with the presence of pests and plant diseases (Jha, K. et al., 2019), if any. Similarly, another machine learning-based company named Trace Genomic provides soil analysis services to farmers so that the farmer can cope with it accordingly.

Advantage of Implementing AI in Agriculture

In the agriculture sector, AI plays a lot of different essential roles in doing the controlled & efficient farming practices through a set of instructions related to water management, timely & optimum harvesting, pest attacks, nutrient management, and crop rotation. They also help in the evaluation of farms for the presence of pests or plant disease along with poor plant nutrition, analysis of crop sustainability, and prediction of weather conditions. Apart from this, AI also helps farmers to bring automation to their farming equipment or machinery to achieve a higher yield of the crop with better quality (Smith, M. J., 2020).

It enables the farmers to understand important data insights for their farms which include parameters like precipitation, temperature, wind speed, & solar radiation. The usage of AI in the agriculture sector helps modern-day farmers in many ways. It helps them to understand the data points like wind speed, precipitation, temperature, and solar radiation. To get a better outcome, the historic value of all these data points are usually considered for the analysis through the AI algorithms. AI altogether provides an efficient way to plant, produce, harvest, and sell the crops into the market.

- Helps in checking the defective crops
- Strengthen agro-based businesses
- Improve crop management activities
- Deal effectively with problems like the infestation of weeds & pests, climatic variations, etc.

CHALLENGES

Over the years cooperatives have always been considering the integration of digital technologies into their working farming model to meet the expectations of the stakeholders. In order to capture this opportunity the technological innovations, business, and regulatory challenges need to be well managed. Despite the growth of technological advancement, the key challenge always lies in the proper physical implementation in the mainstream. Apart from this, another main problem is the need for appropriate working methods to manage different human challenges within the teams and governance (Tzounis, A.et al., 2017). Another factor of concern is data ownership laws & regulations. However, it doesn't prove itself to be a barrier to continued progress. With tons of agtech startups striving hard to combine intelligence with automation to improve agricultural production decisions, there are always a series of main challenges that every single one of them faces on a regular basis. The four key challenges that are faced by each and every startup in this sector are listed as follows,

Connectivity

One of the main challenges affecting the backbone of the digital technologies adoption across the nation is access to the internet to every place in the country. Because without the internet the idea of developing a hybrid Digitech based agricultural system would only be a dream.

The need of the hour is therefore to launch low-cost internet solutions that can help the farmers to feel the impact of digitization on their produce. One such program in this regard was the IIT Bombay's project 'Gram Marg Solution for Rural Broadband' under the leadership of Prof. Abhay Karandikar. The team created an ingenious and "indigenous" technology that utilizes unused white space on the TV spectrum to backhaul data from village wifi clusters to provide broadband access. The main USP of the project was that affordability in setting up the required infrastructure. So far, the solution has been rolled out in 25 villages on a pilot basis.

Interoperability

Another main issue after connectivity is the limited interoperability of various agtech based systems & applications. This challenge mainly calls for the adoption of hybrid systems that can work in sync with each other to provide a multitude of applications instead of the proprietary one which was used to put into use for a long time. These hybrid systems can reduce the risk of inadequate support services and unsupported systems and can help farmers achieve a lot of benefits out of limited investment.

Portability

Working with multiple enterprises often gives rise to the challenge of data portability. To increase farm efficiency, it is important that the data must be transferred from one system to another without degradation. The whole point of this concept is to remove any barrier which is caused by the data access constraints in the different relevant sectors of importance like finance, energy.

Public and Private Sector Cooperation

A final very important problem that is worthy of consideration in relation to the development of digital technologies in agriculture is the role of private and public sectors in commercialization and R&D. One of the main challenges in this segment is the inability of the public R&D agencies to recognize appropriate points to hand over the results of their work to private companies with the proper agreement so that they can develop commercial technologies that can be adopted by farmers. Thus, there is a need for significant reform in this issue.

REFERENCES

Alexandratos, N., & Bruinsma, J. (2012). *World agriculture towards 2030/2050: the 2012 revision*. Agricultural Development Economics Division, Food and Agriculture Organization of the United Nations.

Altieri, M. A., & Nicholls, C. I. (2020). Agroecology and the emergence of a post COVID-19 agriculture. *Agriculture and Human Values*, 1–2.

Banhazi, T. M., Lehr, H., Black, J. L., Crabtree, H., Schofield, P., Tscharke, M., & Berckmans, D. (2012). Precision livestock farming: An international review of scientific and commercial aspects. *International Journal of Agricultural and Biological Engineering*, *5*(3), 1–9.

Benke, K., & Tomkins, B. (2017). Future food-production systems: vertical farming and controlled-environment agriculture. *Sustainability: Science*. *Practice and Policy*, *13*(1), 13–26.

Cambra, C., Sendra, S., Lloret, J., & Garcia, L. (2017, May). An IoT service-oriented system for agriculture monitoring. In *2017 IEEE International Conference on Communications (ICC)* (pp. 1-6). IEEE. 10.1109/ICC.2017.7996640

Carolan, M. (2020). Automated agrifood futures: Robotics, labor and the distributive politics of digital agriculture. *The Journal of Peasant Studies*, *47*(1), 184–207. doi:10.1080/03066150.2019.1584189

De Clercq, M., Vats, A., & Biel, A. (2018). Agriculture 4.0: The future of farming technology. *Proceedings of the World Government Summit,* 11-13.

Deichmann, U., Goyal, A., & Mishra, D. (2016). *Will digital technologies transform agriculture in developing countries?* The World Bank. doi:10.1596/1813-9450-7669

Desa, U. (2017). *Population division*. World Population Prospects.

Eaton, R., Katupitiya, J., Siew, K. W., & Dang, K. S. (2008, April). Precision guidance of agricultural tractors for autonomous farming. In *2008 2nd annual IEEE systems conference* (pp. 1-8). IEEE. 10.1109/SYSTEMS.2008.4519026

Edan, Y., Han, S., & Kondo, N. (2009). Automation in agriculture. In *Springer handbook of automation* (pp. 1095–1128). Springer. doi:10.1007/978-3-540-78831-7_63

Gregorioa, G. B., & Ancog, R. C. (2020). Assessing the Impact of the COVID-19 Pandemic on Agricultural Production in Southeast Asia: Toward Transformative Change in Agricultural Food Systems. *Asian Journal of Agriculture and Development, 17*, 1-13.

Jha, K., Doshi, A., Patel, P., & Shah, M. (2019). A comprehensive review on automation in agriculture using artificial intelligence. *Artificial Intelligence in Agriculture*, *2*, 1–12. doi:10.1016/j.aiia.2019.05.004

Kamilaris, A., Fonts, A., & Prenafeta-Boldύ, F. X. (2019). The rise of blockchain technology in agriculture and food supply chains. *Trends in Food Science & Technology*, *91*, 640–652. doi:10.1016/j.tifs.2019.07.034

Kaur, G., Tomar, P., & Singh, P. (2018). Design of cloud-based green IoT architecture for smart cities. In *Internet of Things and Big Data Analytics Toward Next-Generation Intelligence* (pp. 315–333). Springer. doi:10.1007/978-3-319-60435-0_13

Kimle, K. L. (2018). *Building an Ecosystem for Agtech Startups*. Academic Press.

Klerkx, L., Jakku, E., & Labarthe, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS Wageningen Journal of Life Sciences*, *90*, 100315.

Kozai, T., Niu, G., & Takagaki, M. (Eds.). (2019). *Plant factory: an indoor vertical farming system for efficient quality food production*. Academic Press.

Krishnan, A., Banga, K., & Mendez-Parra, M. (2020). *Disruptive technologies in agricultural value chains*. Academic Press.

Lele, U., & Goswami, S. (2017). The fourth industrial revolution, agricultural and rural innovation, and implications for public policy and investments: A case of India. *Agricultural Economics*, *48*(S1), 87–100. doi:10.1111/agec.12388

Liang, Y., Lu, X. S., Zhang, D. G., Liang, F., & Ren, Z. B. (2003). Study on the framework system of digital agriculture. *Chinese Geographical Science*, *13*(1), 15–19. doi:10.100711769-003-0078-4

Lin, Y. P., Petway, J. R., Anthony, J., Mukhtar, H., Liao, S. W., Chou, C. F., & Ho, Y. F. (2017). Blockchain: The evolutionary next step for ICT e-agriculture. *Environments*, *4*(3), 50. doi:10.3390/environments4030050

Llewellyn, D. (2018). Does global agriculture need another green revolution. *Engineering*, *4*(4), 449–451. doi:10.1016/j.eng.2018.07.017

Mittal, S., Gandhi, S., & Tripathi, G. (2010). *Socio-economic impact of mobile phones on Indian agriculture* (No. 246). Working paper.

Palmer, T., & Darabian, N. (2017). M'chikumbe 212 A mobile agriculture service by Airtel Malawi. *GSMA mAgri*.

Parasher, Y., Kaur, G., & Tomar, P. (2019). Green Smart Environment for Smart Cities. In *Green and Smart Technologies for Smart Cities* (pp. 75–89). CRC Press. doi:10.1201/9780429454837-4

Parasher, Y., Kaur, G., Tomar, P., & Kaushik, A. (2020). Development of Artificial Neural Network to Predict the Concrete Strength. In *Smart Systems and IoT: Innovations in Computing* (pp. 379–389). Springer. doi:10.1007/978-981-13-8406-6_36

Parasher, Y., Kedia, D., & Singh, P. (2018). Examining Current Standards for Cloud Computing and IoT. In *Examining Cloud Computing Technologies Through the Internet of Things* (pp. 116–124). IGI Global. doi:10.4018/978-1-5225-3445-7.ch006

Parasher, Y., Singh, P., & Kaur, G. (2019). Green Smart Security System. *Green and Smart Technologies for Smart Cities*, 165-184.

Patrício, D. I., & Rieder, R. (2018). Computer vision and artificial intelligence in precision agriculture for grain crops: A systematic review. *Computers and Electronics in Agriculture*, *153*, 69–81. doi:10.1016/j.compag.2018.08.001

Rose, D. C., & Chilvers, J. (2018). Agriculture 4.0: Broadening responsible innovation in an era of smart farming. *Frontiers in Sustainable Food Systems*, *2*, 87. doi:10.3389/fsufs.2018.00087

Rotz, S., Duncan, E., Small, M., Botschner, J., Dara, R., Mosby, I., Reed, M., & Fraser, E. D. (2019). The politics of digital agricultural technologies: A preliminary review. *Sociologia Ruralis*, *59*(2), 203–229. doi:10.1111oru.12233

Seth, A. N. K. U. R., & Ganguly, K. A. V. E. R. Y. (2017). Digital technologies transforming Indian agriculture. *The Global Innovation Index*, 105-111.

Shepherd, M., Turner, J. A., Small, B., & Wheeler, D. (2018). Priorities for science to overcome hurdles thwarting the full promise of the 'digital agricultural revolution. *Journal of the Science of Food and Agriculture*.

Singh, P., Dixit, V., & Kaur, J. (2019). Green Healthcare for Smart Cities. *Green and Smart Technologies for Smart Cities*, 91-130.

Skvortcov, E., Skvortsova, E., Sandu, I., & Iovlev, G. (2018). Transition of agriculture to digital, intellectual and robotics technologies. *Economy of Region, 1*(3), 1014-1028.

Smith, M. J. (2020). Getting value from artificial intelligence in agriculture. *Animal Production Science*, *60*(1), 46–54. doi:10.1071/AN18522

Srinivasan, A. (Ed.). (2006). *Handbook of precision agriculture: principles and applications*. CRC press. doi:10.1201/9781482277968

Tang, S., Zhu, Q., Yan, G., Zhou, X., & Wu, M. (2002). About Basic Conception of Digital Agriculture. *Nongye Xiandaihua Yanjiu*, *3*(005).

Timilsina, B., Adhikari, N., Kafle, S., Paudel, S., Poudel, S., & Gautam, D. (2020). Addressing Impact of COVID-19 Post Pandemic on Farming and Agricultural Deeds. *Asian Journal of Advanced Research and Reports*, 28-35.

Tzounis, A., Katsoulas, N., Bartzanas, T., & Kittas, C. (2017). Internet of Things in agriculture, recent advances and future challenges. *Biosystems Engineering*, *164*, 31–48. doi:10.1016/j.biosystemseng.2017.09.007

UNICEF, OGAC, LSHTM, & MSF. (2018). *USAID. Key considerations for introducing new HIV point-of-care diagnostic technologies in national health systems*. Author.

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, *28*(2), 118–144. doi:10.1016/j.jsis.2019.01.003

Wang, H. H., Wang, Y., & Delgado, M. S. (2014). The transition to modern agriculture: Contract farming in developing economies. *American Journal of Agricultural Economics*, *96*(5), 1257–1271. doi:10.1093/ajae/aau036

Weltzien, C. (2016). Digital agriculture or why agriculture 4.0 still offers only modest returns. *Landtechnik*, *71*(2), 66–68.

World Bank Group. (2016). *The World Bank Group A to Z 2016*. World Bank Publications.

Yaghoubi, S., Akbarzadeh, N. A., Bazargani, S. S., Bazargani, S. S., Bamizan, M., & Asl, M. I. (2013). Autonomous robots for agricultural tasks and farm assignment and future trends in agro robots. *International Journal of Mechanical and Mechatronics Engineering*, *13*(3), 1–6.

Chapter 2
Artificial Intelligence and Its Applications in Agriculture With the Future of Smart Agriculture Techniques

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ABSTRACT

Agriculture is the oldest and most dynamic occupation throughout the world. Since the population of world is always increasing and land is becoming rare, there evolves an urgent need for the entire society to think inventive and to find new affective solutions to farm, using less land to produce extra crops and growing the productivity and yield of those farmed acres. Agriculture is now turning to artificial intelligence (AI) technology worldwide to help yield healthier crops, track soil, manage pests, growing conditions, coordinate farmers' data, help with the workload, and advance a wide range of agricultural tasks across the entire food supply chain.

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INTRODUCTION

Solutions for the future include AI (Hudson et. al., 2000) and Machine Learning (Pecht et. al., 2019). Artificial Intelligence stands for AI. Two types of AI— narrow and general (Togelius et. al, 2018) are different. Narrow AI is written software — often combined with hardware and sensor systems — that performs linear tasks. For agriculture, an autonomous farm car is something you find to use a specific AI, like a driverless tractor.

General AI is the second type of AI. We are intelligent beings who are self-aware and who can carry out a variety of tasks. Farmers are recruiting data firms using AI to track crops in areas such as pesticide monitoring. Additional examples are robots with human features including recognition of voice and decision-making to improve farmers ' production. The AI already used in agriculture today are examples of robots that sow seeds, can manage water, clean ground, pick cultivations. Where do we go about the future of AI in agriculture, the question is in the future?

Farming is the cornerstone of any economy's sustainability. Nonetheless, it can vary by countries and play a key role in long-term economic development and structural change. Farming was historically limited to the production of food and crops. Nevertheless, in the last two decades the production, manufacturing, marketing and distribution of crops and animal products has evolved(Jha et. al., 2019). Currently agriculture is the fundamental source of livelihood, improves GDP, constitutes a source of trade, reduces unemployment, produces raw materials in other industries and develops the economy. In order to provide innovative solutions to support and improve the farming activities, the global geometric population rise requires a review of agricultural practices. Other technological developments, including Big Data Analytics (Geng, 2017), Robotics (Hajja, 2016), the Internet of Things (Hassan, 2016), availability of cheap sensors and cameras and drone technology and even wide internet coverage in geographically scattered fields, will allow the introduction of AI in agriculture. AI systems can provide predictive insights about which crop to plant crop in a given year and the optimal date to seed / harvest in a given region to increase crop production and decrease the use of water, fertilizers, and pesticides by analysing soil-management data such as temperatures, weather, soil-analysis, soil moisture and historic crop performance. The effect on natural ecosystems can be minimized through the implementation of the AI technologies and safety of employees that increase, thereby keeping the food prices low and ensuring that food production keeps pace with the population increasingly.

BACKGROUND

Agriculture automation(Jha et. al., 2019) is a major concern and an evolving challenge for every region. The population worldwide is growing rapidly and the need for food is growing rapidly with the increase in population. Traditional methods used by farmers to serve growing demand are not enough and therefore they must hinder the soil through intensified use of harmful pesticides. This has a great influence on agriculture, and, at the end of the day, the earth remains unfertile. There are fields that affect agriculture issues such as crop pests, lack of storage space, pesticide control, plant management, irrigation and water management. Artificial intelligence will overcome all of this.

The history that follows covers AI state-of - the-art and agriculture's potential.The expert systems focused on smart agriculture systems were developed by (Shahzadiet al., 2016). The IoT concept in this system consisted of sending the data to the server in order to make appropriate decisions by the actuators in the field.

In order to estimate soil moisture in Paddy areas (Arifet al., 2012) built two ANN models with substantially less weather data. The analysis of measured soil and calculated soil humidity values has corroborated and tested all models.

The (Hinnellet al., 2012) address neuro-drip irrigation systems in which ANNs have been established to simulate the spatial surface water flow. Water distribution at the lower level of the soil is of major importance for the proper operation of the irrigation system. Here, ANNs makes the prediction that is useful to the user and leads to a rapid decision-making process.

The new field of embedded intelligence analysis (EI) was founded by (Yong et al., 2018). Smart planting, smart field production, smart irrigation and sophisticated greenhouses are part of the agricultural embedded intelligence. For a nation to be able to grow these growing technologies in the agriculture sector, many sectors depend on agriculture.

The use of Losant framework to track farmland and to inform farmers of any anomaly observed by the system was presented by the company's (Kodaliet. al., 2016) via SMS or e-mail. Losant is a simple technology platform based on IOT.

The automatic irrigation system was developed by (Gutiérrez et al., 2014) and used the GPRS module as a communication device. The device is built into a portal that regulates the amount of water. Water saving was 90% higher than conventional irrigation systems. It has been demonstrated.

For the sensing and control of irrigation from a remote location, (Kim et. al., 2008) used a distributed Wireless network.

The apps in which (Gondchawar et. al., 2016) pose themselves are highlighted are the smart remote GPS-based robot for tasks like spinning, spraying, detecting rain, scaring, watching over birds or livestock, etc.

The use of robot in agriculture was explored by (Katariya et.al., 2015). The robot is designed to follow the white line path where a work is required, with a black or brown surface. The device is used to spray fertilizer, drop plants, provide water and ploughing.

The use of R-CNN for the fruit identification of orchards is the topic of (Bargoti et. al., 2017), while the training of the network inputs is subjective in three channel colour images (BGR).

The (Chen et al., 2012) proposed an automatic driving system to control undesirable pesticide sprinkling on plants. Chen et al. Using the depth sensor, the plant height is measured.

The (Spoorthi, et al., 2017) proposed a drone system. The farmer operates a quad-copter system utilizing Wi-Fi via smartphone program. Drone systematically sprays chemicals on farm crops.

The (Ozgul, et al., 2018) suggested an X-boat robot device made up of different spray mechanism parts, an insect repellent machine.

The (Diao, et al., 2017) suggested a system designed to spray pesticides on wheat using a digital image capture camera module.

In order to spray the pesticide along with prediction of diseases, the proposed eAGROBOT robot system is built by (Pilli, et al., 2015).

In order to detect soil moisture and spray water, (Patil, et al., 2016) suggested wireless technology that would use the Arduino as a base microcontroller. Once plants are watered, the farmer gets the message.

The (Srisruthi, et al., 2016) proposed to detect a robot only in leaf colour that would detect the temperature, heat moisture and light needed by the plant, along with a sprinkling pesticide or fertilizer.

The (Lal, et al., 2017) proposed a system where robots could identify a way to spray the pesticide through the field into all the field-infected plants.

The (Ko, et al., 2016) also suggested a steering and speed engine system. This paper addresses the work and application of strategic navigation in the mechatronics robot architecture sense of advanced automation and management schemes.

The robot device designed for watering the plant was suggested by (Yang, et al., 2017). This will be tested by the robot and the borer bug found on tomato plants. A high-speed video processing algorithm for the identification of infected plants was created.

The (R. Rafia et al., 2016) suggested a framework for robot water sprays, for monitoring water levels, and for counting trees to indicate that water levels are less than the threshold level. a

The (Singh et. al., 2005) have demonstrated a robot system which uses the use of complex algorithms based on fugitive logic to generate a spraying process.

The (Tan, 2016) says that the farmer plays the key role, because he can monitor the data in real time and control the entire machine via software. The pesticide will be applied in a defined quantity by devices such as a spray device. In the same manner, the irrigation controller assists for controlling the irrigation system. DSAS deals with data provided by various sensors such as soil humidity sensor, nitrogen sensor, and so on.

In order that the percentage of soil ingredients and wireless sensory-based irrigation system grew, (Kumar, 2014) used fertility and pH meter.

IC 89c52 has been used in the development of an intelligent irrigation system by (Ingale et. al., 2012). Only if humidity and humidity drop below a fixed standard value does the prototype supply water and therefore conserve water to some degree.

MAIN FOCUS OF THE CHAPTER

Small and Fragmented Land-holdings

The seemingly large number of net sown lands of 141,2 million hectares and a gross agricultural region of 189,7 million hectares (1999-2000) is marginal when you see that it is split into tiny and dispersed assets that are economically unsustainable.

In 1970-71, average farm size was 2.28 ha, but declined by 1980-81 to 1.82 ha and by 1995-1996 to 1.50 hectares.

Sub-splitting and division of farms are one of the main causes of our low productivity in agriculture and backwardness. Some time and effort is expended in shifting crops, compost, machinery and bovine animals from piece to piece of land.

In such limited and scattered regions, irrigation (Vishwakarma et. al., 2011) is becoming challenging. In fact, much fertile land is lost unless borders are established. The farmer cannot focus on improvement in such circumstances.

Seeds

Seed (Litvinov et. al., 2019) is a significant and important element for the achievement of increased crop yields and sustainable farm output growth. The distribution of guaranteed seed quality is as essential as the manufacture of these seeds. Regrettably, the majority of farmers, especially small-scale and minor farmers, do not have access to good quality seeds because of exorbitant prices of better seeds.

In 1963 and 1969 the State Farmers Corporation of India (SFCI) were established by the Government of India to address this problem. In order to increase the supply of improved seeds to farmers, thirteen SSCs have also been created.

Manures, Fertilizers and Biocides

Over thousands of years Indian soils have been used to farm crops without much attempt to replenish them. A low productivity has culminated in degradation and enhancement of the soils. Almost all crops have an average return that is the lowest in the world. This is a significant issue to be addressed using additional fertilizers and compost.

Fertilizers and manure (Hampannavar et. al., 2018) play the same role as good food for the body in soils. Just as a good body can do good work, a well-nourished field will produce good returns. The rise in fertilizer use has been calculated at about 70% of the increases in agricultural production.

The growth in fertilizer use is therefore an agricultural success barometer. Nevertheless, in all areas of an Indian-sized world populated by poor farmers there are practical problems to provide enough manure and fertilizer. The perfect compost for the fields is the cow dung.

It is reduced, though, because much cow dung is used in the form of dung cakes as a kitchen fuel. The situation has been compounded further by the decline in the availability of firewood and increased demand for fuel in rural areas. Chemical fertilizers are expensive and often beyond poor farmers ‘ reach. Consequently, both simple and nuanced are the fertilizer issues.

Irrigation

While India is after China the world's second largest irrigated region, only one third of the cultivated area is irrigated. Irrigation (Vishwakarma et. al., 2011) is the major agricultural input in a tropical mountainous country such as India, when rainfall is uncertain and unreliable and erratic and Indian agriculture can not continue unless and until more than half of the cultivated area has been irrigated.

The successes of agriculture in Punjab Haryana and west of Uttar Pradesh are testament to this reality! About half of the agricultural field is irrigated! Large tracts are still waiting to be irrigated to improve agricultural production.

Lack of Mechanisation

Despite the large-scale agricultural mechanization in some parts of the country, most farms are carried out by people in larger parts utilizing plain and manual methods as well as devices such as wooden plough, sickling etc.

Machines are little or no use to insert, cultivate, irrigate, thin and chop, weaven, thresh and carry cultivations. Machinery is very small. Small and marginal farmers are the case. This leads to enormous waste of time and low returns per user.

Agricultural processes must be mechanized urgently(Hampannavar et. al., 2018) in such a way as to discourage wasting of labor and to render cultivation comfortable and effective. Agricultural machinery is a key input for efficient, timely farming, facilitates multiple cultivation and thereby increases production.

Soil Erosion

Wind and water are triggering soil erosion on large parts of productive soil(Hancock et. al., 2020). This field needs to be treated correctly and its initial fertility returned.

Agricultural Marketing

Marketing of agriculture (Agbo et. al., 2015) in rural India is still badly developed. Farmers will depend on local merchants and intermediaries for disposal of farm produce that is marketed at a discounted price in the absence of sound marketing facilities.

Such farmers are mostly forced to sell their goods in poverty, under socio-economic conditions. In most small towns, farmers offer their produce to the money lender they usually borrow from.

POTENTIAL SOLUTIONS AND RECOMMENDATIONS

The use of AI in farming allows farmers to grasp knowledge on temperature, plaster, wind speed and solar radiation. The study of historical values provides a better assessment of the desired results. The best part of AI in agriculture is that it does not destroy the work of human producers, but rather strengthens their operations. Some of the benefits of AI in farming are,

- AI offers more effective ways in which essential crops are produced, harvested and sold.
- Emphasis on AI's implementation to monitor faulty crops and to increase stable crop production potentials.
- Expansion in artificial intelligence technologies has increased the productivity of agro-based companies.
- AI is used in applications such as automated weather forecasting machine adaptations and disease identification or pest identification.
- AI can thus improve the activities of crop management by encouraging other technology companies to invest in agriculture-enhanced algorithms.
- AI solutions that solve challenges faced by farmers, such as climate change, pest and weed infestation that decrease yields.

IMPACT OF ARTIFICIAL INTELLIGENCE IN AGRICULTURE:

AI technology easily corrects issues and advises specific actions to resolve the problem. In order to find answers efficiently, AI becomes effective in tracking details. Let's see how AI is used to improve results in agriculture at reduced environmental costs. An illness with 98 percent specificity can be detected by AI. Through the adaption of the light for increased growth, AI lets farmers track fruit and green goods.

Forecasted Weather Data

AI lets the farmer keep up to date with weather forecasting data(Kuniumon et. al., 2018) in an advanced way. Farms can increase their yields and profit without risking their crop by the predicted data. The analysis of the produced data enables the farmer to take precautions by AI awareness and learning. By using these methods, an intelligent decision can be made on time.

Monitoring Crop and Soil Health

AI is an efficient means by which potential soil defects(Gobhinath et. al., 2019) and nutrient deficiencies are detected or tracked. AI detects possible flaws of photographs captured by the camera with the image recognition method. With the aid of Al profound science, flora variations are studied in agriculture. Tools such as AI help the perception of soil deficiencies, plant pests and diseases.

Decrease Pesticide Usage

AI is accessible to farmers via computer vision, robotics and software education to control weeds. Information are obtained using AI to test the plant, so that farmers can only spread chemicals where the weeds are. The use of the solvent watering the entire field was thus immediately reducing. Therefore, AI compared decreases the amount of chemical in the sector.

AI Agricultural Bots

AI-friendly technology lets farmers find more efficient ways of protecting their crops from weeds. It helps to solve the problem of jobs. AI bots (Rafia, et. al., 2016)can harvest crops at higher volumes and faster pace than workers in the agricultural sector. By using computer vision, weed monitoring and spraying helps. It lets growers discover more efficient ways of protecting their crops from weeds. Artificial Intelligence.

Farm Data Accessed by AI

Hundreds of thousands of datasets are produced by farms on the land. However, with the help of AI, farmers can now analyse several things in real time. You will be able to assess the season, temperature, water or soil conditions gleaned from your farm to explain your choices. For starters, Taranis, a leading agricultural intelligence company, partners with farms across four continents and provides farmers with the eye on high-definition cameras. AI-driven innovations thus help farmers maximize their plans to produce more generous yields by crop choices, best hybrid seed choices and optimization of capital.

Improving Harvest Quality

Today, AI systems help farmers enhance the quality and precision of their harvests with precision farming. This utilizes AI to help identify weed, insect, and low plant nutrient diseases in crops (Rupanagudi et. al., 2015). In the right buffer area, AI sensors can detect and target weeds to decide which herbicides to use. This helps prevent the use of herbicides and serious contaminants in crops today. For example, an AI for the identification of plant diseases was developed by the research team. TensorFlow, an open-source library of Google, created a library of 2,756 images of manhook leaves from plants in Tanzania. The team used the method, transfer of learning to teach AI to identify harvest disease and plague damage. In this case, the disease with 98% precision has been detected by AI.

Computer Vision Enabled Farming

Computer vision and deep learning algorithms are used by farmers to monitor their farms to capture data from drones that fly over their fields. AI-powered cameras can capture images of the farm in almost real time and evaluate images in order to identify problems and potentially improvements from drones. Records revealed that, at the onset of an African swine fever epidemic in China, many major industrial farms had, for example, attempted to identify and confiscate infected pigs using computer vision(Kapoor et. al., 2016). Therefore, in much less time than humans, drones can capture much more ground.

Indoor Farming

New technology farmers today are optimistic and are switching to indoor cultivation. Indoor Farming (Sabri et. al., 2005) is a technique of growing cultures or plants in a crowded setting, typically on a large scale. The farm also utilizes cultivation techniques such as hydroponics and uses artificial luminaires to provide plants with the required growth nutrients and light levels. Indoor agriculture fuelled by IA is now enticing an entire new generation of farmers. For starters, the first fully automatic interior cultivation facility in the world opened last year at 80 Acres Farms, a leader in indoor production. Every step of the increasing process is monitored by the IA-driven technologies.

The use of AI in farming makes it easier for farmers around the world to operate and allow farms of all sizes to keep their food worldwide.

Food Quality and Quantity

Let us first look at the growing food quality concern. This covers food safety, pesticides and food products ‘ nutrition claims. The automated sorting process of products called optical sorting is one way of improving food quality. The study of substance at the chemical level allows the system to spot secret defects is focused on hyper-spectral cameras Optical sorting systems, especially in the potato industry and for various vegetables, fruits and noodles, were increasingly being used. These systems both increase efficiency and food safety by improving the accuracy of the detection of infected items. In pesticide usage, robotics are generally able to improve the current situation by selecting the appropriate region of use more accurately, i.e. enhancing spot spraying. Automatic machines for lettuce dilution, weeding and spot spraying were built and their findings were promising.

UAV (Unmanned Aerial Vehicle) is the key breakthrough in increasing food production. We will address many big farms problems by checking large areas for soil analysis, population count of plants, plant diseases, disease detection, etc., in real time.

These can also be used to spray chemical successfully on seeds. The main advantages of UAVs are that they can leave and landing vertically and that they can travel at low altitudes, rendering them ideal for the most ground and plant forms. A second series of solutions is equipped with sensor networks to maximize or at least secure food supply. A stand-alone early warning system has been developed for fruit fly outbreaks. Through wireless sensor network and GSM networks and predictive maps (two machine-learning techniques), when the fruit population flies over a certain level, it can automatically send warning text messets to farmers and government officials. This method often improves the quality of food by rising pesticide requirements. Greenhouse temperature sensors are another feature of sensor network. It also increases the quality of the food through the elimination of the pesticide requirement. Greenhouse temperature sensors are another feature of sensor network. For a while, sensors have been included in greenhouse climate control but the introduction to traditional systems of AI-based technologies such as neural networks or genetic algorithms has increased the returns and reduced water and energy usage.

Lack of Human Labour

Most of the above-mentioned innovations help reduce the need for human work in farming. The effective human movement of optical sorting devices, automatic spot spraying machines and autonomous UAVs has been performed for this purpose only. This is the case, for starters, with electric harvesters, driverless tractors and robots(Singh et. al., 2005). As for the latter, I would take the Belgian example of Robovision if I can be a little nationalist. Located in Ghent, this company offers deep learning technologies and applications for various industries, such as agriculture. A system utilizes deep neural networks and is in a position to know how to plant a new plant form within a few minutes. Several institutions united on the other side of the Atlantic to set up a powerful automated harvesting machine known as Demeter. It uses two navigation systems complementary, one based on GPS and one based on camera. "Demeter is able to plan harvesting operations for a whole field and then carry out its scheme by cutting crop line, cutting consecutive rows, repositioning itself in the sector, and finding unforeseen obstacles."

Water and Land Management

In many universities and research bodies more efficient irrigation schemes have been established and AI techniques in this field have been successful. Most of the groundbreaking solutions are focused on sensors and modeling parameters. The Enorasis project, a project funded by the European Union which developed an intelligent irrigation system combining a weather analyser and a wireless sensor network to offer farmers and water management organizations optimized and sustainable water management. The business ConserWater achieved another impressive achievement in this respect. For machine-learning soil moisture it has created an algorithm. It therefore only uses satellite data, historical weather data and a variety of other factors without ground sensors. More than 100 farmers in several countries have already been shown to be very effective and useful. The handy way it is distributed to customers can also explain its success: a smartphone application available on Android and iOS. Increasing yields could be a means of reducing the need for farmland. This can be achieved on many platforms (improving fruit and vegetable sorting systems by using sensor networks in fields and greenhouses and so on) some of these are already mentioned in this article. FarmView, a research team at the Carnegie Mellon School of Computer Science (USA), specialized in increasing crop yield, is also exploring the plant breeding channel.

THE POSSIBLE IMPACT OF THE AI (R)EVOLUTION

All these advances could improve the efficiency of agriculture to unprecedented levels that are needed to overcome the many challenges facing the sector. But it is important to emphasize that these mainly focus on big farmers ' needs and that they are actually prohibitively expensive even if they could be beneficial for small producers. They have to note that agriculture in Europe is highly heterogeneous. Therefore, developing new innovative tools could broaden the already growing gap between two agriculture styles by increasing production concentration and obliging small-scale farmers in niches on food markets to survive. The concentration trend has been seen for more than a decade: the number of small-scale farms dropped significantly during the period 2005–2013, and the number of larger farms slightly increased.

It's not inherently bad, but the transition must be monitored and managed carefully. This could also happen across countries inside nations. In reality, AI technology does not just reflect expensive investments for farmers in purchase costs but also in research and development for public institutions. Moreover, R&D for AI appears to be largely conducted in rich countries. Even if developing countries adopt technology from other nations, they may not be enough for their specific agricultural sector. So it is reasonable to think that developed countries are going to import food rather than technology. Over and above the problem of various agricultural structures, developing countries may fail to implement AI technologies in their agriculture sector due to a lack of well-educated workers in managing these cutting-edge instruments. Nonetheless, having sufficient training for farmers should be of great importance to every state that is prepared to modernize its agricultural sector, as is important to optimize future productivity growth and competitiveness for investment.

The European Union appears to be aware of future developments in farming and, more importantly, its possible consequences. In agricultural policy but also in education and general trade policies this situation requires subtle responses. Nevertheless, it remains unclear to date what context the traditional agricultural policy for innovation will provide for post-2020.

Precision farming is one of the most disserted fields of agriculture today in the current world scenario. Drone imagery may lead to a comprehensive field study, crop monitoring and farm testing. The Drone Data and IoT will make sure that farmers take quick steps by combining computer vision technology. Data from the drone picture will produce real-time warnings to speed up precise farming. Commercial drone manufacturers including Aerialtronics for time image analysis have incorporated IBM Watson's IoT Framework and the Visual Recognition API. The vision processing and interpretation means that the photos of the plant leaf are broken into areas such as the setting, the sickness region or the non-diseased portion of the bladder. The contaminated or diseased region is then treated and sent for further testing to the laboratory. This will also help to identify disease and deficit in the sensing of nutrients. Identify the readiness of crops maturity of the green fruits is tested by photographs of different plants taken under white and UVA illumination. Based on these analyses, farmers could produce different levels of fruit or crop readiness. And attach them to different stacks before they are delivered to the sector. Farm management Real-time forecasts can be obtained by farm mapping and identifying areas where crops are required for fuel, fertilizers and pesticides utilizing high-definition imagery from drone and copters systems. It strongly facilitates the utilization of capital. The best choice for plant and hybrid seeds based on several criteria such as soil quality, weather forecast, crop form and plague infestation in specific areas is suggested to farmers for optimum combination for agricultural products Cognitifer Solutions recommend farmers. A tailored suggestion focused on the farm's requirements, local conditions and previously successful farming results. Farmer decision-making could also include other external factors such as market trends, agricultural costs, consumer demands, specifications and aesthetics. Remote sensing (RS) techniques and 3D laser scanning are essential for constructing crop metrics over thousand acres of cultivable soil. It can contribute to a radical change in how agriculture is managed both in time and effort by growers. It system is also used during their entire life cycle for tracking seeds, including recording in the event of abnormalities. Irrigation is one of the working concentrated methods of cultivation, helping farmers to irrigate.AI-structures will optimize irrigation and improve overall output, as they are informed of historical weather pattern, sole condition and plants to cultivate. Around 70 percent of the freshwater supplies worldwide are used for irrigation, which can conserve water and help farmers control their water samples. Significant drone total market potential for drone related products in the world is $127.3 billion, according to the latest PWC (Price Water House Coopers) report. Yet cultivation is $32.4 billion. Of livestock. Such Drone based solutions have many implications in the agricultural sector, such as dealing with adverse weather, productivity gains, precise farming and management of crop yields.

Precision agriculture Farming precision is a more precise and regulated farming technique which, in addition to providing guidance about crop rotation, substitutes for repetitive, hard-working farming. High-precision farming, geological mapping, remote sensing, integrated electronic communication, variable rate technology, optimal plants and harvest time calculator, management of water resources, plant and soil nutrient management, attacks on pesticides and rodents are key technologies. This enables the production of high-precision crop production. Objectives in precision agriculture Return on investment Recognizes the strategic value of products and industries focused on expense and gross income. Efficiency Improved, quick and cheap farming resources can be used by bringing in an efficient algorithm. This allows effective total capital utilization. Sustainability In each season, improved additivity for all performance indicators is ensured through the better economic and environmental operation. Precision farmer cases handle the calculation through high resolution images and numerous sensor data by AI, of the various stress levels in a field. This whole dataset produced from several sources must be used for AI machine learning as an input data. It enables the integration of these data and recognizes plant stress identification parameters. The developed AI machine learning models are educated on a variety of plant photos and can identify different plant stress levels. The cumulative strategy can be divided into four concurrent steps in which better and better choices can be defined, graded, quantified and predicted. Yield Management using AI With the development of futuristic technologies such as artificial intelligence, ML, satellite imaging and advanced analytics, a smart, efficient and sustainable agricultural environment has been developed. The merger of these technology allows farmers to achieve a higher yield per hectare and a more effective control of food grain prices to ensure that they continue to benefit. Microsoft Corporation is currently in India, in the State of Andhra Pradesh, working with farmers rendering farm consultancy services through Cortana's intelligence suite, including machine learning and power BI. It pilot project utilizes AI-based sowing, proposing a sowing date, cultivable land planning, fertigation driven on soil analysis, FYM necessity, seed treatment and picking, incorporating farmers ' recommendations for seed volume, resulting in a 30 percent higher average crop per ha. AI models can also be used to classify optimum crop seasonal factors, statistical climate data, real-time Moisture Adequacy data (MAIs), statistical rainfall data and soil moisture to build prediction diagrams and carter inputs to farmers on the best seed time. Microsoft is designing a Pest Detection Software Interface in partnership with United Phosphorus Limited and offers a strategic advantage of IA and machine learning in advance, which is a possible pest threat. In accordance with United Phosphor Limited. Based on the atmosphere, the stage of crop growth on the farm, pest attacks are expected to be large, medium or low.

FUTURE RESEARCH DIRECTIONS

While AI provides huge opportunities in agriculture, a lack of familiarity with sophisticated high-tech machine learning solutions still prevails across farms around the world. Exposure of farmers to external factors, such as temperature, soil and pest-attack susceptibility, is strong. At the beginning of harvesting a crop raise program planned at the beginning of the season may not seem appropriate because of external parameters. To take reliable projections or estimates, AI systems too require a great deal of data for training machines. Just when the regions are very growing, spatial data can be quickly obtained whilst it is difficult to gather temporal data. Only once a year when the plants are grown can the various crop specific data be obtained. As the software needs time to mature, a stable AI machine learning model is built over a considerable period. This is a significant reason for the use of AI as seeds, fertilizers and pesticides in agronomic products rather than as field-precision solutions. Eventually, the sustainability of agriculture in the future depends primarily on the application of cognitive approaches. While extensive research is still ongoing and many solutions are currently available, there is still no service available to the agriculture industry. While the problems and demands faced by farmers are being addressed, AI decision-making tools and quantitative approaches are being used to address them, AI farming is just starting. Frameworks in agriculture should be more reliable in order to exploit the immense potential of AI. It will then be able to deal with frequent changes and shifts in external conditions on its own. This would allow decision-making in real time and sequence the correct model / program for efficient collection of contextual data. The other important aspect is the extortionate quality of the different cognitive approaches available on the market for farming. To order to ensure that development hits the farming community, the AI technologies have to become feasible. When AI cognitive technologies are delivered in an open source environment, solutions would be inexpensive, resulting in faster implementation and a better understanding among farmers.

CONCLUSION

Today, AI research is used to address the problems of several sectors. In the fields of banking, infrastructure, education, and now agriculture, AI is being used. AI helps farmers to track their crops without having to watch the field directly. Most start-ups and businesses look forward to agricultural AI production. The conventional agriculture model is being redefined by AI. AI's vision of agriculture is far ahead of offering innovative solutions to radical changes.

The purpose of the article was to provide an analysis of the latest AI and Agricultural robotics developments as well as their ability to better transform this age-old and critically significant human activity and to address the implications. But AI is not the only solution, even though it is a fantastic way to overcome the challenges of the changing situation. Certain approaches to achieve sustainability, such as permaculture, will dramatically improve food production while improving quality and reducing the need for resources such as water and energy. Urban agriculture also provides a viable solution to the problem of urbanization by moving part of the production of food closer to the working people as well as to customers. It also helps to strengthen the picture of agricultural production by stressing the role of growing food in the climate and the society. This optimizes land use, finally. There is a bright future for agriculture, but the farmers of history may not.

REFERENCES

Agbo, M., Rousseliere, D., & Salanie, J. (2015). Agricultural marketing cooperatives with direct selling: A cooperative-non-cooperative game. *Journal of Economic Behavior & Organization, 109*.

Arif, C., Mizoguchi, M., Setiawan, B. I., & Doi, R. (2012). Estimation of soil moisture in paddy field using Artificial Neural Networks. *International Journal of Advanced Research in Artificial Intelligence.*, *1*(1), 17–21. doi:10.14569/IJARAI.2012.010104

Bargoti, S., & Underwood, J. (2017). Deep Fruit Detection in Orchards. *IEEE International Conference on Robotics and Automation (ICRA)*, 3626–3633. 10.1109/ICRA.2017.7989417

Chen, T., & Meng, F. (n.d.). Development and Performance Test of a Height Adaptive Pesticide Spraying System. *IEEE Access*, 12342-12350.

Diao, Z., Diao, C., & Wu, Y. (2017). Algorithm of Wheat Disease Identification in the Spraying Robot System. *9th International Conference on Intelligent Human-Machine Systems and Cybernetics (IHMSC)*, 316 – 319. 10.1109/IHMSC.2017.183

Geng, H. (2017). *Data analytics and predictive analytics in the era of big data*. Wiley Telecom.

Gobhinath, S., Darshini, M., Durga, K., & Priyanga, R. (2019). Smart irrigation with field protection and crop health monitoring system using autonomous rover. *IEEE 5th International Conference on Advanced Computing & Communication Systems*. 10.1109/ICACCS.2019.8728468

Gondchawar, N., & Kawitkar, R. S. (2016). IoT based smart agriculture. *International Journal of Advanced Research in Computer and Communication Engineering*, *5*(6), 838–842.

Gutiérrez, J., Medina, J. F. V., Garibay, A. N., & Gándara, M. A. P. (2014). Automated irrigation system using a wireless sensor network and GPRS module. *IEEE Transactions on Instrumentation and Measurement*, *63*(1), 1–11. doi:10.1109/TIM.2013.2276487

Hajjaj, S., & Sahari, K. (2016). Review of agriculture robotics: Practicality and feasibility. *IEEE International Symposium on Robotics and Intelligent Sensors (IRIS)*. 10.1109/IRIS.2016.8066090

Hampannavar, K., Bhajantri, V., & Totad, S. (2018). Prediction of crop fertilizer consumption. *IEEE Fourth International Conference on Computing Communication Control and Automation (ICCUBEA)*. 10.1109/ICCUBEA.2018.8697827

Hancock, G., Ovenden, M., Sharma, K., Walter, W., Gibson, A., & Wells, T. (2020). Soil erosion- The impact of grazing and regrowth trees. In *Geoderma* (Vol. 361). Elsevier. doi:10.1016/j.geoderma.2019.114102

Hassan, Q. (2018). *Introduction to Internet of Things*. Wiley-IEEE Press. doi:10.1002/9781119456735

Hinnell, A. C., Lazarovitch, N., Furman, A., Poulton, M., & Warrick, A. W. (2010). Neuro-drip: Estimation of subsurface wetting patterns for drip irrigation using neural networks. *Irrigation Science*, *28*(6), 535–544. doi:10.100700271-010-0214-8

Hudson, D., & Cohen, M. (2000). *Artificial Intelligence*. Wiley-IEEE Press.

Ingale, H. T., & Kasat, N. N. (2012). Automated irrigation system. *Int. J. Eng. Res. Dev.*, *4*(11), 51–54.

Jha, K., Doshi, A., Patel, P., & Shah, M. (2019). Ä comprehensive review on automation in agriculture using artificial intelligence. *Artificial Intelligence in Agriculture*.

Jun, Y., Weiwei, C., Yu, L., Jinmin, H., Jiannan, D., & Wenjie, L. (2011). Grey relevant analysis and prediction on agriculture mechanization of china. *IEEE Fourth International Conference on Intelligent Computation Technology and Automation*. 10.1109/ICICTA.2011.315

Kapoor, A., Bhat, S., Shidnal, S., & Mehra, A. (2016). Implementation of IoT and Image processing in smart agriculture. *International Conference on Computation System and Information Technology for Sustainable Solutions (CSITSS)*, 21-26. 10.1109/CSITSS.2016.7779434

Katariya, S. S., Gundal, S. S., Kanawade, M. T., & Mazhar, K. (2015). Automation in agriculture. *International Journal of Recent Scientific Research*, *6*(6), 4453–4456.

Kim, Y. J., Evans, R. G., & Iversen, W. M. (2008). Remote sensing and control of an irrigation system using a distributed wireless sensor network. *IEEE Transactions on Instrumentation and Measurement*, *57*(7), 1379–1387. doi:10.1109/TIM.2008.917198

Kodali, R. K., & Sahu, A. (2016). An IoT based soil moisture monitoring on Losant platform. *2nd International Conference on Contemporary Computing and Informatics*, 764–768. 10.1109/IC3I.2016.7918063

Kumar, G. (2014). Research paper on water irrigation by using wireless sensor network. *International Journal of Scientific Engineering and Technology*, 123–125.

Kunjumon, C., Nair, S., Rajan, D., Suresh, P., & Preetha, S. (2018). Survey on weather forecasting using data mining. *IEEE Conference on Emerging Devices and Smart Systems (ICEDSS)*. 10.1109/ICEDSS.2018.8544326

Litvinov, M., Moskovskiy, M., Pakhomov, I., & Smirnov, I. (2019). Interface and software for the system of automatic seeding of grain crops. *IEEE East-West Design & Test Symposium (EWDTS)*. 10.1109/EWDTS.2019.8884425

Ozgul, E., & Celik, U. (2018). Design and Implementation of Semiautonomous Anti-pesticide Spraying and Insect Repellent Mobile Robot for Agricultural Applications. *5th International Conference on Electrical and Electronic Engineering*, 233-237.

Patil, A., Beldar, M., Naik, A., & Despande, A. (2016). Smart Farming Using Arduino and Data mining. *3rd International Conference on Computing for Sustainable Global Development (INDIA Com)*.

Pecht, M., & Kang, M. (2019). *Machine Learning: Fundamentals*. Wiley-IEEE Press.

Pilli, S., Nallathambi, B., George, S., & Diwanji, V. (2015). eAGROBOT- A Robot for Early Crop Disease Detection using Image Processing. *2nd International Conference on Electronics and Communication System (ICECS)*, 1684-1689. 10.1109/ECS.2015.7124873

Rafia, R., Dasb, S., Ahmed, N., Hossaind, I., & Reza, S. (2016). Design and Implementation of a Line Following Robot for Irrigation Based Application. *19th International Conference on Computer an Information Technology (ICCIT)*, 480-48. 10.1109/ICCITECHN.2016.7860245

Rupanagudi, S., Ranjani, B., Nagaraj, P., Bhat, V., & Thippeswamy, G. (2015). A novel cloud computing based smart farming system for early detection of borer insects in tomatoes. *International Conference on Communication, Information and Computing Technology (ICCICT)*. 10.1109/ICCICT.2015.7045722

Sabri, F., Hanif, N., & Janin, Z. (2018). Precision crop management for Indoor Farming. *IEEE 5th International Conference on Smart Instrumentation, Measurement and Application (ICSIMA)*. 10.1109/ICSIMA.2018.8688791

Shahzadi, R., Tausif, M., Ferzund, J., & Suryani, M. A. (2016). Internet of things based expert system for smart agriculture. *Int. J. Adv. Comput. Sci. Appl.*, *7*(9), 341–350. doi:10.14569/IJACSA.2016.070947

Singh, S., Burks, T., & Lee, W. (2005). Autonomous robotic vehicle development for greenhouse spraying. *Transactions of the ASAE*, 48. 10.13031/2013.20074

Spoorthi, S., Shadaksharappa, S., Suraj, S., & Manasa, V. (2017). Freyr Drone Pesticide/Fertilizers Spraying Drone – An Agricultural Approach. *2nd International Conference on Computing and Communications Technologies (ICCCT)*, 252-255. 10.1109/ICCCT2.2017.7972289

Srisruthi, S., Ros, G., & Elizabeth, E. (2016). Sustainable Agriculture using Eco-friendly and Energy Efficient Sensor Technology. *IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT),* 1442-1446. 10.1109/RTEICT.2016.7808070

Tan, L. (2016). Cloud-based decision support and automation for precision agriculture in orchards. *IFAC-PapersOnLine*, *49*(16), 330–335. doi:10.1016/j.ifacol.2016.10.061

Togelius, J., Juul, J., Long, G., Uricchio, W., & Consalvo, M. (2018). *What is "(Artificial) Intelligence?"*. MIT Press.

Vishwakarma, R., & Choudhary, V. (2011). Wireless solution for irrigation in agriculture. *IEEE International Conference on Signal Processing, Communication, Computing and Networking Technologies*.

Yang, Y., & Miao, Y. (2017). A path planning method for mobile sink in farmland wireless sensor network. *IEEE 2nd Information Technology, Networking, Electronic and Automation Control Conference (ITNEC)*. 10.1109/ITNEC.2017.8284957

Yong, W., Shuaishuai, L., Li, L., Minzan, L., Arvanitis, K. G., Georgieva, C., & Sigrimis, N. (2018). Smart sensors from ground to cloud and web intelligence. *IFAC-PapersOnLine*, *51*(17), 31–38. doi:10.1016/j.ifacol.2018.08.057

Chapter 3
Artificial and Natural Intelligence Techniques as IoP- and IoT-Based Technologies for Sustainable Farming and Smart Agriculture

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ABSTRACT

In this chapter, the author describes the main new challenges and opportunities of blockchain technology for digital economy in Russia. The study in Russia showed that the Russian research community has not addressed a majority of these challenges, and he notes that blockchain developer communities actively discuss some of these challenges and suggest myriad potential solutions. Some of them can be addressed by using private or consortium blockchain instead of a fully open network. In general, the technological challenges are limited at this point, in terms of both developer support (lack of adequate tooling) and end-user support (hard to use and understand). The recent advances on developer support include efforts by of the towards model-driven development of blockchain applications sliding mode in intellectual control and communication and help the technological challenges and created tools. The chapter shows how avatars may communicate with each other by utilizing a variety of communications methods for sustainable farming and smart agriculture.

INTRODUCTION

The degree of development of industrialization and the widespread introduction of new technologies unquestionably lead to the transition of the world into a new digital era. This period is characterized by the rapid development of high technologies that penetrate into all spheres of our life. The widespread use of cloud technology, the Internet of Things (IoT), virtual and augmented reality, 3D printing, and

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the development of quantum technologies, robotics and other technologies as a result has become the driving force of the Fourth Industrial Revolution, also known under the term "Industry 4.0 ".

If at the turn of the century not a single farm around the world used sensor technologies, then by 2025 their use is expected to increase to more than 500 million sensors, and by 2050 - more than 2 billion smart agro sensors. Moreover, it is expected that for the period 2017–2022. The aggregate average annual growth rate of the Internet of things market in the agro-industrial complex (agriculture IoT, AIoT) will be 16-17%. According to the PwC (Price water house Coopers) forecast, the minimum economic effect of introducing IoT technologies into the agro-industrial complex by optimizing personnel costs and reducing crop losses and fuels and lubricants by 2025 could amount to 469 billion rubles.

If we talk about the long-term effect of the introduction of IoT technologies in agriculture, then it will be primarily associated with significant savings in materials and resources and, as a result, optimization of the costs of agricultural enterprises. In addition, new technologies will increase yield and, as a result, increase revenue. All this in the future will have a direct impact on the marginality and competitiveness of enterprises. According to forecasts of the development of the world food market by 2050, in connection with an increase in the population of the Earth (by about 2.3 billion people (about 33%) and an increase in its well-being, consumption will naturally occur, moreover, in favor of agricultural products. The country in terms of potential for increasing the arable land necessary for food production is, of course, the Russian Federation. Thus, against the backdrop of ongoing changes and taking into account the main trends of world development, the search and implementation of new methods, methods and technologies in the agro-industrial complex is one of the paramount tasks. At the state level, this issue is being actively discussed and worked out. As part of the National Technology Initiative (STI), the concept of a FoodNet market roadmap is currently being developed. The FoodNet market is a market for the production and sale of nutrients and final types of food products (personalized and general, based on traditional raw materials and their substitutes), as well as related IT solutions (for example, providing logistics and selection services individual nutrition). The key market segments will be "smart" agriculture, accelerated selection, new sources of raw materials, affordable organics, personalized nutrition. Ultimately, according to NTI, it is planned to create such services and products that will occupy from 5 to 15% of the global market (depending on the segment). The basis for the development of the above segments of the FoodNet market is the use of Internet of things technology.

As part of the execution of the order of the Deputy Prime Minister of the Russian Federation A.V. Dvorkovich dated October 21, 2016 in accordance with the Decree of the President of Russia Vladimir Putin dated July 21, 2016 "On measures to implement the state scientific and technological policy in the interests of agricultural development" "In order to implement the" Strategy for improving the quality of food products until 2030 " A draft roadmap was developed for the development of the Internet of Things (IoT) in the Russian agro-industrial complex (AIC). The development of this document was carried out by experts of the Internet Initiatives Development Fund (IIDF) with the participation of the Open Government, the Internet of Things Association (IoTA), the Department of Information Technology (DIT) and the Russian Ministry of Agriculture. According to the draft roadmap, by 2020 the share of developments in the domestic component base for creating equipment in the field of the Internet of Things should be 14% (today it is 7%), the share of agricultural enterprises using IoT solutions should reach 30%. In addition, by the same time, it is planned to implement at least 20 pilot projects for the implementation of IoT technologies in the agricultural sector.

MATERIALS AND METHODS

The blockchain technology won the interest of many individuals and corporations due to its technological capabilities and scalability for various use cases. This led towards the disruption of traditional internet / intranet, business models alongside services such as the way we conduct business, transactions and managing information in effective and secure ways. These use cases clearly communicate a message for systems and experience designers to get equipped with relevant skills and to keep polishing them as the technology grows. Following the evolution brought by this rapid introduction, the blockchain technology nowadays consists of three types being the 'public', 'private' and 'federated / consorted'. In a nutshell these block chains share similar functionalities. In terms of differences, pretty much they rely on the use cases, permission levels and privacy. The blockchain within the business context brings several advantages such as time saving over work processes, minimizing costs, risk reduction and increase in trust. By learning these values and benefits, we designers will have the ability to foresee how this technology can reshape our clients' businesses notwithstanding the knowledge and confidence we need to guide and proposing right solutions fitting their needs. However for that to happen, the business must have a network of some kind in order to ensure a solid foundation of a good blockchain use case. It is often said that 'with great power comes great responsibility'. This statement is heavily applicable when it comes to this technology. The blockchain restores control and ownership of information back to its rightful owner thus eliminating dependencies on central authorities and third parties (Mkrttchian & Aleshina, 2017).

BACKGROUND

The Internet of things is one of the key technologies that can radically change the economy of the country and the world at the present stage. The agro-industrial complex, in view of numerous causes and global trends, is the most important area where these technologies can and should be implemented. The rapid development of information and communication technologies and their widespread use largely determine the fundamental social transformations. New social realities are also characterized by the increasing role of human capital as the basis for the development of the knowledge economy. The most important factor in the formation of social capital is the development of science and education. In order to be a successful and highly qualified professional today, a person needs to be able to competently navigate in a rapidly changing environment, quickly make the right and informed decisions, which is only possible if he is able to constantly replenish and update his knowledge and develop skills, and gain experience. This suggests that his studies do not end with the walls of an educational institution and receive an appropriate diploma. A person simply needs to learn throughout his life, in addition, the age of information technology provides unlimited opportunities for this. Of particular relevance is the idea of lifelong learning. Being one of the key trends in the development of education, along with information, individualization, differentiation, diversification, multivariate and multi-level, the possibility of obtaining continuing education is impossible without the use of ICTs that can provide the maximum flexibility and variety of forms. Let us examine in more detail how the development of information and communication technologies influenced education and was reflected in the change in various forms of training. It is worth noting here that it is not the forms of training themselves that are changing to a greater extent, but rather the forms of representing educational resources, visual and technical teaching aids.

The development of technical means was reflected in the changes associated with the visualization of educational information. So, from paper visual materials, one can trace the transition to their electronic form, then to the use of various technical demonstration tools. The development of the Internet has significantly expanded the possibilities for exchanging educational materials, first through e-mail, later chat and, of course, social networks, including providing the opportunity to work with a large number of students simultaneously. The following types of information educational technologies can be distinguished: electronic technologies, computer technologies, multimedia technologies, distance technologies, Internet technologies, and video conferencing technologies. The development of educational information technologies is associated with the introduction of personal computers in the educational process. Electronic technologies that appeared in the 70s of the XX century were based on the use of computers and information retrieval systems, but already in the 80s they were replaced by computer technologies. It was during this period that the personal computer became a learning tool.

THE ANALYSIS OF WORLD EXPERIENCE IN TRANSFORMING INDUSTRY INTO THE DIGITAL ECONOMY AND THE TRANSITION TO CYBER-PHYSICAL SYSTEMS OT THE INTERNET OF THINGS

In analysis of world experience in transforming industry into the digital economy and the transition to Industrial IoT shows that work is being carried out in accordance with the concept of the fourth industrial revolution Industry 4.0 as part of the transition to the digital economy and the introduction of Smart Manufacturing, Digital Manufacturing, Internet of Manufacturing, Open Manufacturing technologies (Abubakar, et all, 2017).

The foundations of the transition to the digital economy have been described for a long time in the writings of Tapscott, D. (1996) (Baliga, et all, 2011). . Digital economy - various the way to effective application of technologies (BIM, PLM, CAD, IOT, Smart City, BIG DATA and others). The International Journal of Open Information Technologies, 4 (1)) on the digital economy was devoted to the importance of the integrated application of technology. It noted, for example, that the joint use of building information modeling (BIM) technology and geographic information technology (GIS) is the path to building systems that work efficiently in the life cycle of the design, construction and operation of a building. This is a conclusion made by leading world experts and practitioners (Kopytko, et all,2018).

The essence of cyber-physical systems is that they connect the physical processes of production or other other processes (for example, transmission and distribution control of electric power), which require the practical implementation of continuous control in real time, with software and electronic systems. This is a rather little studied topic in Russian literature. At the same time, its importance is obvious (Babu, et all, 2016), (Blanco-Nova, et all, 2017).

Cyberphysical systems are characterized by multidimensionality, structural and functional complexity. Research in this area lies at the intersection of many disciplines and is still in the initial stage of development. All this determines the need to develop adequate methods for their design. The most promising approach is the model-based approach. A review of the design methods, modeling and integration of CFS, as well as signs of their use are presented. The diversity of descriptions of such systems, consisting of physical, cybernetic and communication parts, requires a certain unified approach to the description, which would allow simple integration of parts into a single whole, reuse of parts, and also support portability and interoperability. These requirements can be satisfied to some extent using the languages

UML, SysML, XML. However, the disadvantage of these languages is either a focus on the presentation of syntactic information, or limited semantics. Semantic Web technologies offer much greater opportunities. For example, descriptions based on ontologies make it possible to present semantic information in addition to syntactic information. In addition, there is the possibility of ontological rezoning, which is useful in the analysis, verification and validation of the ontological model (Guo, et all, 2019).

The models and methods proposed in the project correspond to the world level of scientific research, which is confirmed by the increase in the number of scientific publications in recent years in the field of creation and development of intelligent cyberphysical systems such as "Smart Energy Grid", "Smart Road", "Smart city" (Smart City). These systems are developed on the basis of technologies for distributed processing of big data, methods of intellectual analysis and machine learning, M2M interaction of cyberphysical devices in the network of the industrial Internet of things, etc. In recent years, many foreign publications have appeared in a similar field (Kailas, et all,2012).

An example of the smart environment for Smart City is the Smart Road. Therefore, research and development in this area occupy a large place. For such environments, the main component is an intelligent transport infrastructure monitoring system; Smart City Road Monitor by Imagem and Antea Group wins Geospatial World Excellence Award. http://geoinformatics.com/smart-city-road-monitor-wins-award/]. An example of research on the analysis of streaming information and forecasting the development of situations in this area is the development of a road traffic modeling system for forecasting traffic incidents with coordinate reference to digital map layers. To process sensory data in cyberphysical systems, it is proposed to use nodes of sensory networks (a layer of "foggy" computing). Wireless sensor networks are now widely used in various fields of human activity, which determines the huge interest in them from scientists and research to create new innovative developments. Leading developers of software and hardware, for example, NXP, offer innovative developments in terms of integrating several network technologies and protocol stacks (technological and network convergence), for example, the connected ZigBee and Bluetooth modules in the sensor node. Examples of publications in the field of wireless sensor network application research. The fog computing platform is a variation of the cloud computing model, which differs in that the computing nodes for distributed data processing are not servers, but sensor nodes with limited computing and energy resources. Ontologies and ontological models began to be used in modeling cyberphysical systems relatively recently proposes a semantic framework based on the use of models for system design, tracking requirements, simulation and assessment of cyberphysical systems. In this paper, domain ontologies are used for computing and decision making (Li, & Li, 2015).

Work is associated with the development of knowledge structures to support the correct ("correct-by-design") design of cyber-physical systems (CFS). This article presents a new ontological knowledge base and logical conclusion to support decision-making for cyber-physical systems. This allows the development of deterministic, provable and feasible models of cyberphysical systems supported by reliable semantics, which strengthens the approach to the design of cyberphysical systems based on model management (Leslie, et all,2012).

An approach is proposed to develop a digital representation of all information available about an object and from an object, which can be a hardware system or software platform. Digital presentation is based on semantic knowledge presentation formalisms such as RDF, RDF Schema, and OWL. In this paper, we also introduce the concept of the Semantic I4.0 component, which solves the problems of communication and understanding in the scenarios of Industry 4.0 using semantic technologies.

The brief overview given above testifies to the facts of using ontological models for modeling structures of cyberphysical systems, contexts of cyberphysical systems, verification of projects of cyberphysical systems, decision-making in the design process, and presentation of information about an object. At the same time, it can be stated that at the moment there are no works that use dynamic ontological models in which changes would be incorporated into their semantics (Nagy,et all,2016).

Currently, the ontological approach is used in combination with model-oriented design, and in the future it can completely replace. In general, ontology-based software development refers to new methods by which ontologies can help improve models, techniques and software development processes. Benefits include optimal verification of program code, reusability of artifacts, and increased levels of interaction and integration of software system components (Peffer, et all, 2015).

The direction of development of management methods and forecasting the behavior of cyberphysical systems and processes are technologies for extracting knowledge and the intellectual analysis of big data. Big data has a number of properties . High speed of generation and processing of data in real time, which allows you to make the most appropriate decisions regarding specific impacts on the control process. C) Diversity - a wide range of information generated from various sources in various formats, with different structure and size, sorted into different categories related to all aspects of the management process, which allows preparing classifications, groupings, correlations. D) The complexity of processing and data management - the heterogeneity of data that are taken from various sources requires a comprehensive and heterogeneous data processing methodology (Philips Lighting Catalog., 2014).

The method of deep analysis of processes (Process mining) can be considered as the development of the method of deep analysis of data (Data mining), but as a result of the use of Process mining, an output is obtained that describes the dynamics of the system. The ancestor of the Process mining method is Wil van der Aalst. This method is actively developing in its group. The basic principles of the Process mining method are described. The process mining method begins to be actively used in monitoring systems (Roman, et all,2013).

A new approach to the automatic generation of trust properties obtained as a result of studying and analyzing the system using the Process mining method and comparing with the formal specification of the tested system is proposed (Stojkoska, & Trivodaliev, 2017).

The use of the Process mining method in an online and traditional audit system is proposed. Moreover, a continuous information monitoring system is proposed, which can identify and prevent risks in the big data environment in advance by monitoring risk factors in organizations and enterprises. The aim of this work is to develop a preliminary risk factor verification system using practical examples of sales audits.

A promising direction is the expansion of the Process mining method of the semantic component. An attempt in that direction was made. This study examines the learning process - how data from various process areas can be extracted, semantically prepared and converted into executable mining formats to support real-time detection, monitoring and improvement of processes. At the same time, the proposed method allows predicting individual patterns / behavior through further semantic analysis of the generated models. The article proposes the formalization of the so-called "Semantic Learning Process Mining (SLPM)", technically implemented as a "fuzzy semantic miner" (Semantic-Fuzzy Miner), (Singh, Khosla., & Mittal, 2019).

An analysis of the literature on the use of the Process mining method in monitoring systems showed that a promising, but not yet explored segment is the extension of the Process mining method of the semantic component based on the use of ontologies (Shie, Lin, Su, Chen, & Hutahaean, 2014).

In conclusion, we note that a review of the scientific literature and existing design studies in this field of knowledge showed that there are a number of problems, which include the lack of adequate mathematical models for the analysis of large sensory data and the in-depth analysis of processes in cyberphysical systems, the imperfection of technologies for accounting for hidden patterns in time series and event logs, taking into account the influence of external factors and random fluctuations on the behavior of the cyberphysical system, the complexity of automation to accept I make decisions in the process of monitoring and process control in cyber-physical systems. This confirms the relevance of the proposed project, aimed at developing new models and methods for modeling and designing cyberphysical systems (Singh, et all, 2019).

The Main Scientific Competitors

The most widespread research in the field of knowledge related to the development of cyberphysical systems and technologies of the Internet of things is conducted in the countries of the USA, EU, China, Japan and Korea by research institutes, universities with the support of public authorities. Let's consider some projects in this area (Tsai, et all, 2014).

1. Intel is developing models, methods and technologies of cloud and GRID computing to increase the efficiency of distributed computing, reduce the complexity of the practical use of cloud solutions and increase the security and stability of distributed computing systems. The main focus is the development of solutions and tools for cloud data centers.
2. Toshiba is working in the field of combining cloud computing, big data and smart technologies to support the work of the energy sector, healthcare and services as part of the implementation of the "Smart Human Community" concept.
3. Cisco is developing Internet of Things technologies using the network infrastructure of multiple sensors and distributed data processing systems based on a fog and cloud computing model. Toshiba and Cisco are conducting joint research on the Internet of Thing, creating the ubiquitous wireless Internet, machine communications, fog and cloud computing in a wide range of devices for managing multimodal transport and smart cities. The main goal is to increase the efficiency of technological processes, productivity and functional capabilities of production, transport and the urban environment. The basis is the development of the ubiquitous Internet (Internet of Everything) by combining the infrastructure of the Cisco Fog Computing network with Toshiba Group technologies in the area of network point management. This will allow you to track and maintain geographically remote devices, to develop distributed computing technologies.

Scientific research in terms of the creation and development of an industrial Internet of things network for cyberphysical systems, smart energy grids (Smart Energy Grid), and the use of fog computing are carried out by:

1. A research team led by Professor Ivan Stojmenovic from Deakin University, Burwood, Australia and University of Ottawa, Canada. It discusses the use of the fog computing paradigm for building hybrid control systems for distributed monitoring systems and creating smart traffic lights & connected vehicles and smart roads for unmanned vehicles (smart road trip & smart car).
2. A scientific group of researchers led by Professor Umakishore Ramachandran (Georgia Institute of Technology, USA), which offers the concept of creating a mobile fog based on building a computing environment based on mobile communication devices that will simultaneously solve distributed data processing tasks in the background by analogy with construction of GRID computing systems

based on stationary computers connected to the Internet. A group of researchers is developing a migration model of distributed data processing based on the migration of cloud and fog computing models. This allows you to use cloud-fog resources in dynamic mode, for example, to perform calculations either in the cloud or in a foggy environment, depending on the resources provided at the current time when changing the ability to access resources, changing bandwidth, etc.

3. The research team led by Professor Alois Zoytl. He is currently a professor in the field of cyber-physical systems for design and production at Johannes Kepler University, Linz, Austria. He is also a part-time professor at the Fortiss Research Institute, Munich, Germany, where he led the Industry 4.0 area of expertise. 4. The research team led by Professor Thomas Strasser (Thomas Strasser). He is currently a Senior Fellow at the Center for Energy, AIT of the Austrian Institute of Technology, Vienna, Austria. His main responsibilities include strategic development of Smart Grid automation projects and validation of research projects.

To scientific competitors in this field of knowledge can also include:

1. Jose Martinez Lastra - Professor, Tampere University of Technology, Tampere, Finland. His research is related to the use of information and communication technologies in the areas of industrial automation and industrial systems. He leads the FAST lab at Tampere University of Technology, whose goal is to integrate human and machine knowledge. He has participated in several European R&D projects, for example, Arrowhead (2013-2017), C2NET: Cloud Collaborative Manufacturing Networks (2015-2017), Movus: S ICT Cloud-based platform and mobility services: available, universal and safe for all users (2013-2016).
2. Mark Austin - Associate Professor, University of Maryland, USA. Currently, his research interests are: a) system design and integration of cyberphysical systems based on ontological models; b) Modeling, analysis and design of cyberphysical systems; c) Semantic approaches to modeling the behavior of distributed cyberphysical systems.
3. Birgit Vogel-Heuser - Professor at the Technical University of Munich (TUM), Germany. Her research is aimed at developing cyberphysical systems and software, modeling distributed embedded and production systems, and is also related to the development of computational technologies for production, automation of production, the creation of cyberphysical control systems, formal specifications of cyberphysical systems, data mining, and the synthesis of systems based on knowledge, multi-agent systems, programmable controllers.
4. Edward A. Lee is a professor at the University of California, Berkeley, USA. His research interests are focused on the development, modeling and design of real-time cyber-physical systems. He is the Director of the Berkeley Center for Hybrid and Embedded Software Systems, as well as the Director of the Berkeley Ptolemy Project.
5. Wil van der Alst - Professor, RWTH Aachen University, Germany. He leads a research team focusing on in-depth analysis of processes and data science. His main research interests are data science, in-depth analysis of processes, data mining, business process management, compliance checking and simulation.

MAIN FOCUS OF THE CHAPTER

Issues, Controversies, Problems, Solutions and Recommendations

The theoretical basis of this work was the research works of Russian and foreign authors devoted to the theoretical and methodological aspects of the using Internet of things technology in the agro-industrial complex, publications on the topic of research in the periodical press and the Internet. Methodological basis is classic general scientific research methods: analysis, syn thesis, induction, deduction, generalization and classification, as well as comparative and systematic analysis. The concept of the Internet of things is that materials are able to identify themselves using their own tags (for example, in the form of a barcode), i.e. any part contains information about where it was produced, what it is intended for, etc. The concept of "Internet of things" appeared in 2009, when the number of devices connected to the Internet exceeded the population of the Earth (Mkrttchian, 2019a).

When discussing the IoT market, this technological phenomenon is often identified with solutions that support machine-to-machine (M2M) interoperability, such as telemetry or monitoring the status of production facilities. These solutions have a pronounced industrial affiliation and are closed systems, often implemented on special equipment with built-in software (Mkrttchian, 2019b).

All stages of the development of the Internet of things and the interaction between systems are supported by a comprehensive set of technologies and solutions from a large number of suppliers that are part of the ecosystem of the industrial Internet of things market (Mkrttchian, 2020).

According to the research results of various consulting companies, the introduction of the Internet of Things in the agro-industrial complex will contribute to improving production efficiency, improving the quality of life of the population, solving environmental problems, thus ensuring sustainable development of the industry (Mkrttchian, 2021a).

The agricultural sector is traditionally exposed to a huge number of problems, many factors inaccurate forecast data and improper irrigation to the application of erroneous planting and harvesting methods and poor soil quality. All of this, of course, negatively affects the overall performance (Mkrttchian, 2021b).

Using the Internet of things in agriculture can significantly reduce such risks of modern receive high-precision data in real time from the fields on which they are installed. Based on the information received, specialists can make key decisions, for example, when to irrigate, harvest, etc. Organized in this way, the necessary risks and allows farmers to make more accurate decisions, not only in the production process, but also in planning.

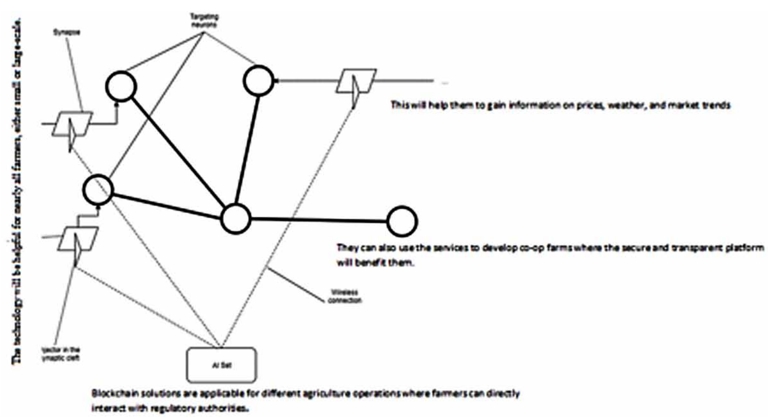
Such a system for managing crop productivity, based on the use of a complex of satellite and computer technologies, is called the concept of precision agriculture ("precision agriculture" (PA), "Satellite farming" or "site specific crop management" (SSCM)).

If in 2018 the average agricultural farm had at its disposal no more than 200,000 data points, then, according to forecasts, this reach. Thus, with each year, "connected farms" will grow as quickly as possible. Against this background, the maximum orientation to the data and their processing will contribute to more accurate tracking and control of the necessary parameters (properties and quality of soil, plants, degree of infection with diseases, pests, condition of agricultural machinery, etc.). In this case, we are talking about the growing popularity of big data technology ("Big Data").

The use of unmanned aerial vehicles (UAVs, agricultural drones), which are used, as well as create detailed 3D field maps, is becoming increasingly important in the agro-industrial complex. The 3D modeling method is especially. Continuous control and monitoring is extremely. The value of the global agro-industrial sector already exceeds $ 32 billion, and it is expected that this figure will increase sharply over the next half of the decade.

Another important factor that negatively affects farm productivity is the lack of proper water management. According to studies, almost 60% of the water allocated to agriculture is wasted due to oversaturation, pollution, and other related problems. Cases of damage to crops as a result of insufficient or excessive irrigation are frequent. These problems are quite effectively solved using OGC data services from sensors that collect information from tank filling operations in order to optimize irrigation schedules and manage this process. The information obtained is also evaluated along with data on soil moisture and acid content. All this together contributes to a more efficient use of limited water resources. According to various sources, the use of the described technologies saves from 30 to 50 billion gallons of water per year. The use of IoT technology in the agro-industrial complex has opened new opportunities for the development of intensive agriculture, characterized by low crop rotation and a high level of resource use. The open source platform allows for the rapid collection and instant data exchange of one medium used as a "climate recipe" for its subsequent scaling by creating similar environments based on the data obtained. Thus, farmers are able to artificially create conditions conducive to the growth of any particular type of crop. Many modern farms are already equipped with self-propelled tractors and machines. In addition to collecting land and Automated tractors are still relatively new and may become more powerful in the foreseeable future (fig. 1).

Figure 1. In addition to collecting land and Automated tractors



FUTURE RESEARCH DIRECTIONS

Of course, the use of Internet of things technologies is not limited to use only in crop production. The systems of water, food and stock quality control in real time already considered above allow farmers to receive accurate and reliable information and make more effective and efficient decisions. For example, the use of the Internet of things allows timely detection of animal diseases and timely assistance. In order to reduce crop losses caused by various pests, farmers can use specialized sensors that test agricultural plant growth problem areas with pests (Yu, et all, 2016), (Y2018agoob, et all, 2017), (Zaidan, et all, 2018).

CONCLUSION

As a result of the research, key technologies of the of "Industry 4.0" era were identified, their characteristics and role in use were given. Conclu- sions are made that the introduction of these technologies will favorably affect productivity, revenue growth, employment and investment. In the conclusion the detailed description of various areas of using the Internet of things in activity of the agricultural organizations is resulted. The study allows us to conclude that the digitalization of the agricultural sector will entail the release of better products. In addition, Industry 4.0 will lead to the creation of more flexible systems, the participants of which will exchange information via the Internet, which in turn will significantly increase labor efficiency and reduce costs in production processes.

Digitalization is an absolutely logical process that takes place in all areas of the economy: in marketing, in retail, and in service. Modern information systems and neural networks will be able to analyze more factors and significantly increase the efficiency of any business process. Of course, this also applies to agriculture.

Any agricultural producer in the competitive market has two main tasks: to minimize the cost of production and increase the resulting net revenue, while maintaining product quality at a consistently high level. To solve them, at all stages of the production process must be fully manageable and transparent. For example, you need to clearly, gradually monitor the value chain for each unit of production. For this, a single information space is being created at the agricultural enterprise, where high-tech equipment, analytical and management IT systems non-stop exchange data.

The study showed that using the Internet of things technology can radically change farm management. The introduction of various kinds of sensors and sensors, the introduction of big data technology, as well as the use of unmanned aerial vehicles and self-propelled tractors and machines today can transform traditional farms into new generation farms, Smart farms.

Blockchain solutions are applicable for different agriculture operations where farmers can directly interact with regulatory authorities. This will help them to gain information on prices, weather, and market trends. They can also use the services to develop co-op farms where the secure and transparent platform will benefit them. The technology will be helpful for nearly all farmers, either small or large-scale. Subsequently, the technology will be used to track food through supply chain based contracts.

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REFERENCES

Abubakar, I., Khalid, S. N., Mustafa, M. W., Shareef, H., & Mustapha, M. (2017). Application of load monitoring in appliances' energy management—A review. *Renewable & Sustainable Energy Reviews*, *67*, 235–245. doi:10.1016/j.rser.2016.09.064

Babu, V. S., Kumar, U. A., Priyadharshini, R., Premkumar, K., & Nithin, S. (2016). An intelligent controller for smart home. In *Proceedings of international conference on advances in computing, communications and informatics (ICACCI)* (pp. 2654–2657). IEEE.

Baliga, J., Ayre, R., Hinton, K., & Tucker, R. (2011). Energy consumption in wired and wireless access networks. *IEEE Communications Magazine*, *49*(6), 70–77. doi:10.1109/MCOM.2011.5783987

Blanco-Novoa, Ó., Fernández-Caramés, T. M., Fraga-Lamas, P., & Castedo, L. (2017). An electricity price-aware open-source smart socket for the internet of energy. *Sensors (Basel)*, *17*(3), 643. doi:10.339017030643 PMID:28335568

Caivano, D., Fogli, D., Lanzilotti, R., Piccinno, A., & Cassano, F. (2018). Supporting end users to control their smart home: Design implications from a literature review and an empirical investigation. *Journal of Systems and Software*, *144*, 295–313. doi:10.1016/j.jss.2018.06.035

Guo, X., Shen, Z., Zhang, Y., & Wu, T. (2019). Review on the application of artificial intelligence in smart homes. *Smart Cities*, *2*(3), 402–420. doi:10.3390martcities2030025

Kailas, A., Cecchi, V., & Mukherjee, A. (2012). A survey of communications and networking technologies for energy management in buildings and home automation. *Journal of Computer Networks and Communications*, *2012*, 1–12. doi:10.1155/2012/932181

Kopytko, V., Shevchuk, L., Yankovska, L., Semchuk, Z., & Strilchuk, R. (2018). Smart home and artificial intelligence as environment for the implementation of new technologies. *Traektoriâ Nauki = Path of Science,4*(9), 2007–2012.

Leslie, P., Pearce, J. M., Harrap, R., & Daniel, S. (2012). The application of smartphone technology to economic and environmental analysis of building energy conservation strategies. *International Journal of Sustainable Energy*, *31*(5), 295–311. doi:10.1080/1478646X.2011.578746

Li, M., & Lin, H. J. (2015). Design and implementation of smart home control systems based on wireless sensor networks and power line communications. *IEEE Transactions on Industrial Electronics*, *62*(7), 4430–4442. doi:10.1109/TIE.2014.2379586

Mkrttchian, V. (2019a). New Tools for Cyber Security Using Blockchain Technology and Avatar-Based Management Technique. In *Machine Learning and Cognitive Science Applications in Cyber Security* (pp. 105–122). IGI Global; doi:10.4018/978-1-5225-8100-0.ch004

Mkrttchian, V. (2019b). Machine Learning With Avatar-Based Management of Sleptsov Net-Processor Platform to Improve Cyber Security). In Machine Learning and Cognitive Science Applications in Cyber Security (pp. 139-153). IGI Global. Doi:10.4018/978-1-5225-8100-0.ch004

Mkrttchian, V. (2020). Human Capital Management in the Context of the Implementation of Digital Intelligent Decision Support Systems and Knowledge Management: Theoretical and Methodological Aspects. In Knowledge Management, Innovation, and Entrepreneurship in a Changing World (pp.123-148). IGI Global. Doi:10.4018/978-1-7998-2355-1.ch006

Mkrttchian, V. (2021a). Avatars-Based Decision Support System Using Blockchain and Knowledge Sharing for Processes Simulation a Natural Intelligence: Implementation of the Multi Chain Open Source Platform. *International Journal of Knowledge Management*, *17*(1), 5. Advance online publication. doi:10.4018/IJKM.2021010105

Mkrttchian, V. (2021b). Digital Intelligent Design of Avatar-Based Control with Application to Human Capital Management. *International Journal of Human Capital and Information Technology Professionals*, *12*(1), 2. Advance online publication. doi:10.4018/IJHCITP.2021010102

Mkrttchian, V., & Aleshina, E. (2017). *Sliding Mode in Intellectual Control and Communication: Emerging Research and Opportunities*. IGI Global., doi:10.4018/978-1-5225-2292-8

Nagy, Z., Yong, F. Y., & Schlueter, A. (2016). Occupant centered lighting control: A consumer study on balancing comfort, acceptance, and energy consumption. *Energy and Building*, *126*, 310–322. doi:10.1016/j.enbuild.2016.05.075

Peffer, T., Blumstein, C., Culler, D., Modera, M., & Meier, A. (2015). Software-defined solutions for managing energy use in small to medium sized commercial buildings (No. EE0006351). Berkeley, CA: Regents of the University of California.

Philips Lighting Catalog. (2014). *Document Number 919002151397*. Amsterdam: Koninklijke Philips Electronics N.V.

Roman, R., Zhou, J., & Lopez, J. (2013). On the features and challenges of security and privacy in distributed internet of things. *Computer Networks*, *57*(10), 2266–2279. doi:10.1016/j.comnet.2012.12.018

Shie, M. C., Lin, P. C., Su, T. M., Chen, P., & Hutahaean, A. (2014). Intelligent energy monitoring system based on ZigBee-equipped smart sockets. In *Proceedings of IEEE international conference on intelligent green building and smart grid (IGBSG)* (pp. 1–5). IEEE. 10.1109/IGBSG.2014.6835281

Singh, P. P., Khosla, P. K., & Mittal, M. (2019). Energy conservation in IoT-based smart home and its automation. In M. Mittal, S. Tanwar, B. Agarwal, & L. M. Goyal (Eds.), *Energy conservation for IoT devices. Studies in systems, decision and control* (Vol. 206, pp. 155–177). Springer. doi:10.1007/978-981-13-7399-2_7

Stojkoska, B. L. R., & Trivodaliev, K. V. (2017). A review of Internet of Things for smart home: Challenges and solutions. *Journal of Cleaner Production*, *140*, 1454–1464. doi:10.1016/j.jclepro.2016.10.006

Tsai, K. L., Leu, F. Y., & You, I. (2016). Residence energy control system based on wireless smart socket and IoT. *IEEE Access: Practical Innovations, Open Solutions*, *4*, 2885–2894. doi:10.1109/ACCESS.2016.2574199

Yaqoob, I., Ahmed, E., Hashem, I. A. T., Ahmed, A. I. A., Gani, A., Imran, M., & Guizani, M. (2017). Internet of things architecture: Recent advances, taxonomy, requirements, and open challenges. *IEEE Wireless Communications*, *24*(3), 10–16. doi:10.1109/MWC.2017.1600421

Yu, H., Sun, Q., Sheng, K., & Wang, Z. (2016). Intelligent street lamp control system using ZigBee and GPRS technology. *International Journal of Simulation-Systems, Science & Technology, 17*(35), 36.1–36.13.

Zaidan, A. A., Zaidan, B. B., Qahtan, M. Y., Albahri, O. S., Albahri, A. S., Alaa, M., Jumaah, F. M., Talal, M., Tan, K. L., Shir, W. L., & Lim, C. K. (2018). A survey on communication components for IoT-based technologies in smart homes. *Telecommunication Systems*, *69*(1), 1–25. doi:10.100711235-018-0430-8

KEY TERMS AND DEFINITIONS

Big Context: Is defined as a better understanding of how entities.

Big Data: Is extremely large data sets that may be analyzed computationally to reveal patterns, trends, and associations, especially relating to human behavior and interactions.

Context: Is the circumstances that form the setting for an event, statement, or idea, and in terms of which it can be fully understood.

Internet of Everything: Is a broad term that refers to devices and consumer products connected to the internet and outfitted with expanded digital features.

Internet of People and Things: 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.

Internet of Signs: Is categories of signs, including written language, natural language, cultural codes, aesthetic codes, codes of tastes and a number of others.

Internet of Things: Is the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data.

Semiotics: Is the study of signs and symbols and their use or interpretation.

Chapter 4
Digital Technologies for Smart Agriculture

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ABSTRACT

This chapter will provide the reader with an introduction to the modern emerging technologies like cloud computing, machine learning, and artificial intelligence used in agriculture. Then a glimpse of complete crop cycle follows, including seven steps, namely crop selection, soil preparation, seed selection, seed sowing, irrigation, crop growth, fertilizing and harvesting; and how these digital technologies are helpful for the crop cycle is also explained in this chapter. The rest of the chapter will explain the merger of the modern digital technologies with the agricultural crop cycle and how the future farming will work.

1. INTRODUCTION

By year 2050 world population is expected to hit a number of 960 crores (World Resources Report 2013–14). It will be required to produce double the quantity of food than now being produced. This will test the agricultural innovations being made which will help us to achieve this goal. To fulfill the human requirements, it will be required to revolutionize a new agricultural era by introducing advanced technologies to the field and bringing them on same platform by using modern digital technologies. The industry has undergone major developments over the last century.

In 1990 it was required to put 37 percent of the total labour force of America, to plough 5.7 million farms, to bring meals to the tables of 76 million people, whereas in year 2005 this percentage has reduced to 2.5 percent to feed 321.4 million of American population (World Resources Report 2013–14).

These changes have allowed human beings to excel in other fields of life as well, than to restrict themselves to the farm fields working day and night to fulfill the basic necessity of food. World is head-

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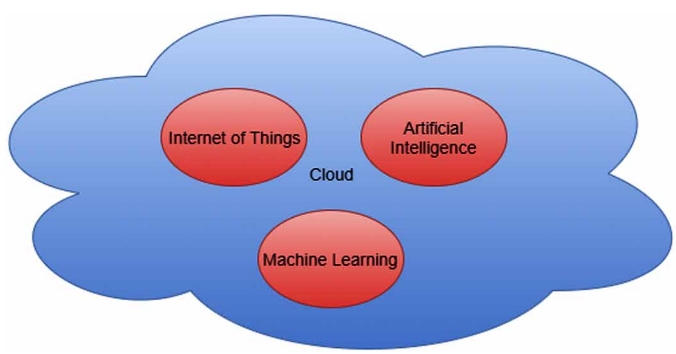
ing towards an era of smart farming where machines will grow crops for human beings and that too without human intervention. Growth of crop will be monitored by small sensors and cameras position in the field, data gathered from these sensors will be collected and processed by the processors and data in easy to understand form is provided to the farmers on their interface devices or smart phones in the form of alerts and analysis reports. To deal with problems like weeds drones and robots will be used to identify them and shoot them with a beam of laser or streak of pesticides. This process will reduce the use of chemicals on the crops by up to 90% as compared to conventional process of blanket spraying. Current advancements and innovations have reached to the level of autonomous pickers and gatherers of strawberries and few vegetables, but these are separate for different crops. Now the addition of next echelon will be creation of plucking robots that can switch between different crops by selecting the appropriate program. The everlasting thrust of human being for progression and development in all the fields of life has not left the vast area of agriculture untouched. It was just a couple of years back, when the common man had got access to the GPS technology and the electronic control system had made their way to the vast arena of agriculture. Different sensors were deployed in the field to sense different agricultural parameters and provide information to the farmers and scientists about growth of crop and related problems, like poor crop quality in an area, presence of pests and weeds, improper/ excessive irrigation and imbalance of the chemical composition of soil. Though now a lot of data was available to the farmer, but still the major task of collecting all this data, maintaining record of the same and further collating all the available data (on basis of different crops, geographical areas, different weathers and different type of different types of seeds, fertilizers and pesticides used) and finally to thread all these datum beads into a string to fruitfully use them, (Singh, P., Dixit, V., & Kaur, J. 2019) (Parasher, Y., Singh, P., & Kaur, G. 2019)

Figure 1. Digital Technologies used in Agriculture



2. DIGITAL TECHNOLOGIES USED IN AGRICULTURE

However, it still cannot be claimed that precision agriculture has been widely established in crop production, but is moving on to achieve it at a good pace by making use of advanced digital technologies. Different technologies being adapted for agricultural advancements are as shown in Figure 1.

1. Internet of things (IoT)

2. Artificial intelligence
3. Machine learning.

More light will be thrown on these technologies in the subsequent paragraphs.

3. IoT IN AGRICULTURE

Internet of Things (IoT) is one of the digital technology that is used to enhance the agricultural productivity with minimizing the technological barriers. Today, IoT is capable enough to transform the agriculture industries and also motivating the farmers to face the technological challenges as they are now well aware with new technological developments and have sufficient knowledge through IoT.

Farmers can enhance their productivity by keeping continuous watch on acidity level of soil, temperature, weather and many other factors using IoT. Along with this, farmers can keep a watch on their livestock also by using the IoT based devices. IoT based sensors are proficient enough to provide crucial information like rainfall, crop yields, pest infestation, and soil nutrition to the farmers which are invaluable to production and offer precise data which can be used to improve farming techniques over time. IoT provides accurate, real-time and shared characteristics bringing great changes in the agricultural supply chain and offers a crucial technology for establishing a smooth flow of agricultural logistics (Deeksha Jain, P. Venkata Krishna and V. Saritha, 2012). The main advantages of IoT in advancement of farming are as given below:

1. Management of water through IoT sensors can efficiently done.
2. IoT enables continuous monitoring of land so that any required precautionary measures can be done at prior stage only.
3. It helps the farmers to reduce the manual work making the farming efficient and less time consuming task.
4. Management of soil like pH and moisture level can be done easily through IoT which helps farmers in sowing of seed according to soil level.
5. RFID chips and sensors are the important tools which are used in the identification of plant and crop diseases. RFID tags are used to read the information and transmit that to the respective reader over the internet. This information can be accessed by the concerned farmer/ scientist and necessary precautionary action could be taken from the remote areas, which will save the crops from the prevailing diseases (Xiaohui Wang and Nannan Liu, 2014).
6. Sales of crop will be increased in global market because farmer can now easily associate with global market from any geographical area.

3.1 Applicability of IoT in Agriculture

IoT implementation in agriculture has turned it as smart farming and has eliminated the need of physical work of farmers and which in turn has increased the productivity in all respect. IoT in agriculture has transformed the whole farming practices because it provides the real time monitoring of the fields with the help of sensors and their interconnectivity keeping constant watch on crucial parameters like humidity, temperature, soil etc. Along with this, the use of extravagant resources such as Water and Electricity has also reduced. (Malavade, V. N., & Akulwar, P. K., 2016)

- **Climate Conditions:** Climate plays a very critical role for farming. And having improper knowledge about climate heavily deteriorates the quantity and quality of the crop production. But IoT solutions enable you to know the real-time weather conditions. Sensors are placed inside and outside of the agriculture fields. They collect data from the environment which is used to choose the right crops which can grow and sustain in the particular climatic conditions. The whole IoT ecosystem is made up of sensors that can detect real-time weather conditions like humidity, rainfall, temperature and more very accurately. There are numerous no. of sensors available to detect all these parameters and configure accordingly to suit your smart farming requirements. These sensors monitor the condition of the crops and the weather surrounding them. If any disturbing weather conditions are found, then an alert is send. What gets eliminated is the need of the physical presence during disturbing climatic conditions which eventually increases the productivity and help farmers to reap more agriculture benefits.
- **Precision Farming:** Precision Agriculture/Precision Farming is one of the most famous applications of IoT in Agriculture. It makes the farming practice more precise and controlled by realizing smart farming applications such as livestock monitoring, vehicle tracking, field observation, and inventory monitoring. The goal of precision farming is to analyze the data, generated via sensors, to react accordingly. Precision Farming helps farmers to generate data with the help of sensors and analyze that information to take intelligent and quick decisions. There are numerous precision farming techniques like irrigation management, livestock management, vehicle tracking and many more which play a vital role in increasing the efficiency and effectiveness. With the help of Precision farming, you can analyze soil conditions and other related parameters to increase the operational efficiency. Not only has this you can also detect the real-time working conditioned of the connected devices to detect water and nutrient level.
- **Smart Greenhouse:** To make our greenhouses smart, IoT has enabled weather stations to automatically adjust the climate conditions according to a particular set of instructions. Adoption of IoT in Greenhouses has eliminated the human intervention, thus making entire process cost-effective and increasing accuracy at the same time. For example, using solar-powered IoT sensors builds modern and inexpensive greenhouses. These sensors collect and transmit the real-time data which helps in monitoring the greenhouse state very precisely in real-time. With the help of the sensors, the water consumption and greenhouse state can be monitored via emails or SMS alerts. Automatic and smart irrigation is carried out with the help of IoT. These sensors help to provide information on the pressure, humidity, temperature and light levels.
- **Data Analytics:** The conventional database system does not have enough storage for the data collected from the IoT sensors. Cloud based data storage and an end-to-end IoT Platform plays an important role in the smart agriculture system. These systems are estimated to play an important role such that better activities can be performed. In the IoT world, sensors are the primary source of collecting data on a large scale. The data is analyzed and transformed to meaningful information using analytics tools. The data analytics helps in the analysis of weather conditions, livestock conditions, and crop conditions. The data collected leverages the technological innovations and thus making better decisions. With the help of the IoT devices, you can know the real-time status of the crops by capturing the data from sensors. Using predictive analytics, you can get an insight

to make better decisions related to harvesting. The trend analysis helps the farmers to know upcoming weather conditions and harvesting of crops. IoT in the Agriculture Industry has helped the farmers to maintain the quality of crops and fertility of the land, thus enhancing the product volume and quality (Kaur, G., Tomar, P., & Singh, P. 2018), (Parasher, Y., Kedia, D., & Singh, P. 2018)

- **Agricultural Drones:** Technological advancements has almost revolutionized the agricultural operations and the introduction of agricultural drones is the trending disruption. The Ground and Aerial drones are used for assessment of crop health, crop monitoring, planting, crop spraying, and field analysis. With proper strategy and planning based on real-time data, drone technology has given a high rise and makeover to the agriculture industry. Drones with thermal or multispectral sensors identify the areas that require changes in irrigation. Once the crops start growing, sensors indicate their health and calculate their vegetation index. Eventually smart drones have reduced the environmental impact. The results have been such that there has been a massive reduction and much lower chemical reaching the groundwater.
- **Livestock Monitoring:** 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. Such as, finding animals that are sick so, that they can separate from the herd, preventing the spread of the disease to the entire cattle. The feasibility of ranchers to locate their cattle with the help of IoT based sensors helps in bringing down labor costs by a substantial amount. One example of an IoT system in use by a company is JMB North America. Which is an organization that provides cow monitoring solutions to cattle producers. Out of the many solutions provided, one of the solutions is to help the cattle owners observe their cows that are pregnant and about to give birth. From them, a battery that is sensor powered is expelled when its water breaks. An information is then sent to the herd manager or the rancher. The sensor thus enables farmers will more focus.

The above mentioned use of IoT has empowered the agriculture with modern technology. Which has filled the gap between production, quality and quantity. The multiple sensors connected through IoT gathers real time information which can be used to take fast action and reduces the crop damage. IoT has improved the business model of agriculture also by faster processing of goods and they reach supermarkets in shortest possible time. (Prathibha S. R., Hongal A., & Jyothi, M. P., 2017).

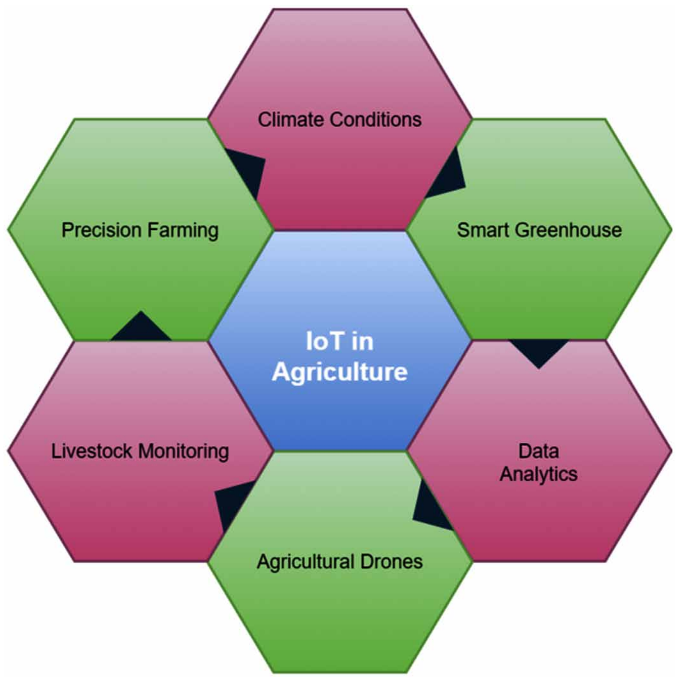
4. ARTIFICIAL INTELLIGENCE (AI) IN AGRICULTURE

Agriculture sector has welcomed the AI into their practice to improve their efficiency with reduced environmental hostile impacts. AI is shifting the way our food is produced where the agricultural sector's emissions have decreased by 20%. With the help of AI farmers are able to manage any uninvited natural condition. At present, majority of agricultural based startups are focusing on AI based production technologies to enhance the efficiency. The Market study report stated that the global Artificial Intelligence (AI) in Agriculture market size is expected to reach 1550 million US$ by the end of 2025. Implementing AI-empowered approaches could detect diseases or climate changes sooner and respond smartly (McKinion J. M., & Lemmon H. E.,1985).

4.1 Advantage of Implementing AI in Agriculture

With the help of AI farmers are able to understand the insights of data like solar radiation, temperature, precipitation and wind speed. The best thing about the use of AI in agriculture is it will help the farmers in improving their progress inspite of eliminating the jobs. AI provides more efficient ways to produce, harvest and sell essential crops with highest accuracy as shown in Figure 2.

Figure 2. IoT in Agriculture



Forecasted Weather Data

AI in a pretty technologically advanced method used by farmers to remain updated about the weather so they can minimize the risk for crops. The analysis of the data generated helps the farmer to take the precaution by understanding and learning with AI. By implementing such practice helps to make a smart decision on time.

Monitoring Crop and Soil Health

Farmers can detect possible defects and nutrient deficiencies in the soil through image recognition process of AI. Through deep learning aspect of Al many application have been developed for analyzing the flora patterns in agriculture. Such AI-enabled applications are supportive in understanding soil defects, plant pests, and diseases.

Decrease Pesticide Usage

With the help of the AI, data are gathered to keep a check on the weed which helps the farmers to spray chemicals only where the weeds are. This directly reduced the usage of the chemical spraying an entire field. As a result, AI reduces herbicide usage in the field comparatively the volume of chemicals normally sprayed.

AI Agriculture Bots

AI-enabled agriculture bots has helped farmers in more accurate way to protect their crops from weeds also helps them in managing the labor challenge. AI bots good enough to harvest crops at a higher volume and faster pace than human laborers. By leveraging computer vision helps to monitor the weed and spray them.

5. ROLE OF MACHINE LEARNING IN AGRICULTURE

Machine learning is about making machines learn like humans. And like any toddler, that means they have to learn by experience. With machine learning, programs analyze thousands of examples to build an algorithm. It then tweaks the algorithm based on if it achieves its goal. Over time, the program actually gets smarter. That's how machines like IBM's Watson can diagnose cancer, compose classical symphonies or crush Ken Jennings at Jeopardy. Some programs even mimic the way the human brain is structured, complete with neural networks that help humans and now machines, to solve problems (Liakos K. G., Busato P., Moshou D., Pearson S. & Bochtis D., 2018).

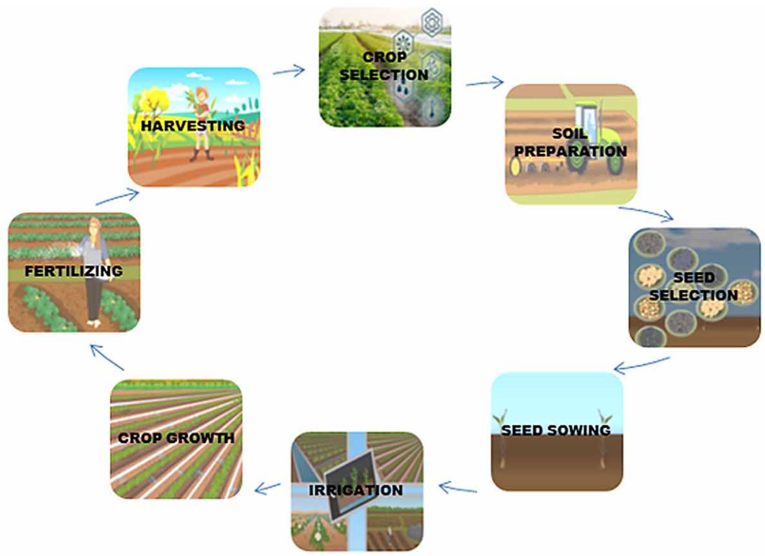
Before moving ahead it is necessary for us to have a look on the processes followed for farming. The eight major actions performed by a farmer are as follows and are shown in Figure 3.

1. Crop Selection
2. Soil Preparation
3. Seed Selection
4. Seed Sowing
5. Irrigation
6. Crop Growth
7. Fertilizing
8. Harvesting

Soil Preparation

Soil is required to be prepared for crop production. Soil is usually found solidified into hard chunks of soil mass. This soil needs to be softened and loosened. Loosening of soil is mandatory before cultivation because loose soil will allow more air to pass to the roots of the plants this will in turn aid the growth of the plant leading to good crop production. Another advantage of loosening of the soil is that it helps the soil to retain water it then leads to the growth of favorable microbes that help to produce humus in the soil. These microbes help in the process of decomposition of all living things in the soil and this de-

Figure 3. Digital Technologies in Farming Steps



composed matter is rich in nutrients and is known as humus. This is what plants depend on for nutrition. Also loosening up the soil helps to turn up the lower soil by plowing and makes it accessible to the plant.

Now it is obvious to understand the importance of moisture, fertility nature, nitrogen and phosphorus levels and softness of soil; but significance of pH value is yet not clear. The pH is a way to determine whether a substance is acidic or basic in nature. It is gauged on basis of positive numbers ranging from 0 to 14 where the number 7 indicates a matter is neutral, i.e., neither acidic nor basic. While the pH value of below 7, denotes acidic nature and above 7 denotes basic nature of a substance. The soil with pH value 7 ± 0.5 is considered to be ideal for agriculture. The pH value depicts the level of toxic substances, minerals, bacterial growth etc.

The BoniRob takes a soil samples and then analyze its pH, phosphorous and nitrogen levels by liquidizing it on real time basis. In conjunction to it multiple sensors positioned in the field will check for moisture content of the soil and provide data with respect to softness of the soil. All these data are collected and made available to the farmer on his smart phone through a compatible application.

Seed Selection

Seed selection is very important step in cultivation; quality of seeds should always be good so as to get better production of crops. For sowing, seed selection depends upon the following factors:

1. One should select whole seeds and broken or crushed seeds should be avoided.
2. The sowing quality of seeds should be high.
3. They should have high germinating capacity.
4. Seeds should be free from infection.
5. The seeds should not be mixed with seeds of weeds or with other seeds.
6. Seeds should be disease-resistant.

7. The seeds should be supplied by good seed agency (certified seeds).

The NK Seed Selection Tool from Syngenta is a seed analyzer which allows the farmer to place products that are best for a field, not just based on the soil type but also the weather and considers the effects on productivity out of the annual change. By obtaining the forecast about weather for upcoming years, it makes sure that only those seed hybrids and varieties are picked, that are going to do well for next few years, in that local environment.

Seed Sowing

There are two methods in sowing the seeds.

Broadcasting.

Wheat, maize and paddy are sown by this method. In this method, seeds are sprinkled or thrown in a random manner in the cultivated field. This method is common in agriculturally backward areas.

Seed-drilling.

Sowing of seeds is done in lines by seed-drill, it is called drilling. There are two kinds of seed-drills—automatic and hand-operated. A seed drill is long metal tube with fingers and a funnel at the top where the seeds are fed. The drill is attached to the plough, as the plough makes furrows in the soil, the seeds are dropped fairly and equally by the drill.

Irrigation

Irrigation is a method used to fetch water to the land. It can be as simple as using a garden-hose to water plants in the garden or as complicated as a system of canals, log channeled ditches and pipelines designed to transport water to a dry area. Irrigation is used wherever rainfall is either incongruous or is unable to endow with an adequate amount of natural water to facilitate growth of crops. The three most common types of irrigation are

Flood Or Furrow Irrigation. When the water is allowed to flow on the earth surface after pumping it from a water source it may be underground water, canal, river or lake.

Drip Irrigation. In this case water is supplied through hoses to having holes in them. Due to reduced exposure of water to external environment lesser water is wasted due to evaporation and about 25 percent lesser water is required as compared to flood irrigation.

Spray Irrigation. In this water is pumped at high pressure through hoses and is sprayed through nozzles connected to them. It is losing popularity because electricity is required to pump the water and a large amount of water is wasted.

Though irrigation is an essential process of agriculture, but it has got its own associated cons too. It takes a major share in total water consumption of a country and is a major expense for farmers. Now the excessive water which flows over the fields i.e runoff from irrigation pollutes the local water bodies by carrying dissolved fertilizers and pesticides residues into them.

Today frequent use of AI technology has acted as a boon and has played a significant role in elimination of water wastage, cost of training the labour and has prevented undesired harm to environment.

Now let us consider an example of artificial intelligence in irrigation system in a green house, this system can be expanded to an open field with minor modifications. In a closed greenhouse different sensors deployed are as follows:

Temperature Sensors

Temperature sensors are used to switch on or off the fans to blow the hot air out of the greenhouse so that optimum temperature and moisture in air, for plant growth is maintained.

Soil Moisture Sensor

Soil moisture sensors are used to switch on or off the water pumps to irrigate and also to switch on or off the misting system to maintain adequate moisture in the soil and atmosphere to facilitate growth of plants.

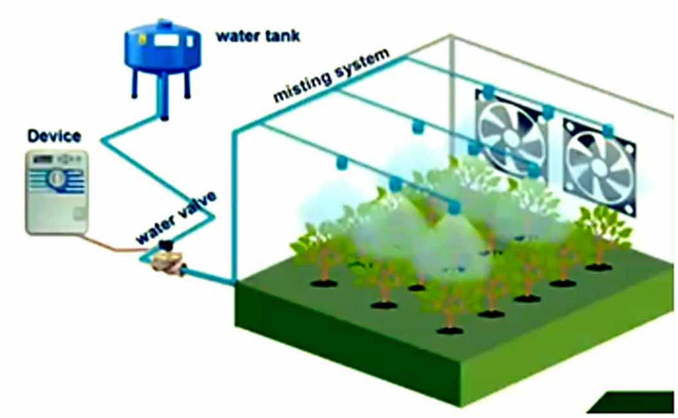
Light Detector

Light detectors are used to sense the level of daylight available inside the greenhouse in case it is not sufficient the artificial lights placed in the greenhouse are switched on.

About 5 to 8 sensors deployed in one acre of land will suffice the requirement and cost of each of these sensors is somewhere between 20 to 60 rupees which makes it cost effective.

All the sensors are controlled by a microcontroller and the values of temperature moisture and light are selected manually as per crop and soil type. Rest all will be done by the IoT and farmer will keep on getting updates of his green house farm as shown in Figure 4. Farmer is also provided with an option to overrule the preferred mechanism and control moisture and temperature manually.

Figure 4. Light Detectors in Agriculture

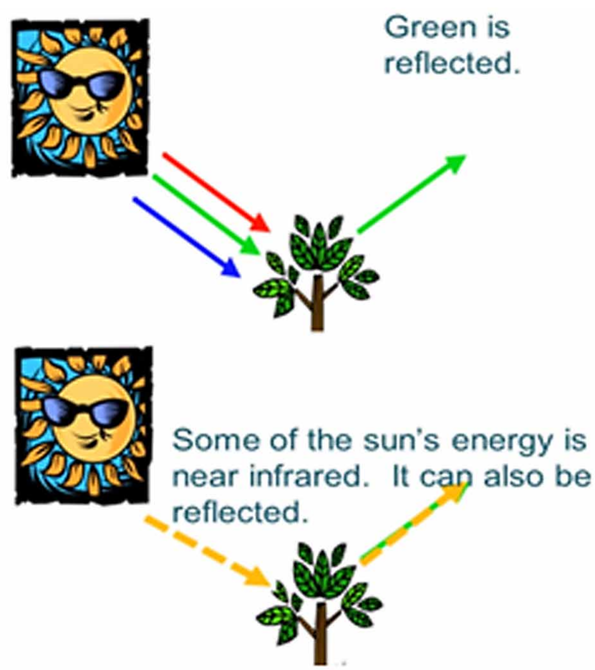


Crop Growth

Monitoring crop growth and taking preventive measures to avoid loss or decrease of crop yield is an integral part of the agricultural processes.

Now the question arises is "How can one can determine the vegetative greenness plants using remote sensing" The sun's energy is absorbed, reflected or re-emitted by vegetation depending on the amount of chlorophyll in the plant. Satellites collect the reflected or emitted energy from the vegetation as described in Figure 5.

Figure 5. Stages of Crop Growth



NDVI- Normalized Difference Vegetation Index NDVI is a remote sensing method that allows one to display greenness of vegetation, i.e. its relative biomass. NDVI compares reflectivity of NIR and Red wavelength bands. NDVI enables a farmer to have a close view of his crop and monitor its growth on day to day basis, using remote sensing. NDVI determine issues that are affecting the health of the plant prior to harvest. Some of these problems may be irreversible for the current year, but changes can be made for the next crop cycle or year. For this high correlation yield maps are used.

1. At Higher resolution NDVI may be used to check the following:
2. Nutrient Deficiencies (tissue tests/soil samples)
3. Equipment Problems (compaction, depth control, etc)
4. Locate Tiles (tiles can be visible as the soil starts to drain for a brief period after a spring shower)

Insects and Disease Pressure

Following satellite imagery may be referred for better understanding of how remote sensing takes pictures and how collation of these pictures helps to monitor the crop growth and related problems to aid the farmers to take appropriate preventive measures. Different Satellite Options available to observe crop growth are:

- Advanced Very High Resolution Radiometer (AVHRR)
- Spatial: large portions of the Earth
- Temporal: regular basis (frequent) to identify seasonal and annual changes
- Resolution: 1 km
- Landsat 8
- NDVI (Near IR - Red) / (NIR + Red)
- Spatial: Less Area
- Temporal: 8 days if the sky is clear
- Resolution: 30 m

Fertilizing

Farmers apply nutrients on their fields in the form of chemical fertilizers and animal manure, which provide crops with the nitrogen and phosphorus necessary to grow and produce the food we eat. However, unutilised residues of nitrogen and phosphorus from the crops, can over flow from the farm fields and contaminate the air and water quality of local water bodies, by flowing with rainwater and reach ground water by leaching through the layers of soil excessive irrigated water. Contamination of water bodies may entail to hypoxia ("dead zones"), leading to death of fish in them and reduction of aquatic life. These excessive nutrients when get into freshwater systems lead to increased growth of Harmful Algal Blooms (HABs), which besides disturbing the eco-cycle, produce toxins harmful to humans.

To deal with such hazardous activities which put serious threat to environment AI and IoT have proven a boon. Blue River Technology of USA is building the next generation of smart agriculture equipment. They have developed "See & Spray technology", enabling a world in which every plant counts. This technology makes use of large number of cameras to take pictures of the plants growing in the field and identifies the unwanted weeds and wanted crop. Different sprayers available in the equipment itself will spray the herbicides on the unwanted weeds or lasers may be fitted to burn the weeds. Meanwhile the unhealthy or weak wanted crop plants are identified using imagery of colour, size and texture of their leaves and fertilizers are sprayed around 20 plants only. This technology makes use of 90% lesser herbicides and pesticides by spraying them only where needed and with exactly what is needed.

Harvesting

Performing the agricultural processes using artificial Intelligence and internet of things the last process of agricultural practices that is harvesting is not confined to harvesting only but has covered wide range of processes which are as follows:

Harvesting. The process of cutting & gathering mature crops with sickle.

Winnowing. The process of separating chaff from grains.

Threshing. Process of separating grain from hay.

In case of small fruits, vegetables and flowers farms the robotic pickers depending upon size and color of fruits and vegetables, will decide whether the fruit or flower has riped enough to be plucked or not and will pick and collect them at right time. Few such robotic pickers are small-scale capsicum and potato harvester, robotic lettuce harvester, cotton harvester etc.

While in case of large crop fields, the pictorial data is gathered from remote sensing with the help of drones and satellites will provide farmer with information about right time to harvest the crop. Few equipments used in large crop fields are carrot harvester and separator, corn harvester, sugar cane harvester, combine (grain) harvester etc (Sujjaviriyasup T., & Pitiruek K. 2013).

CONCLUSION

In last two decades many companies have joined hands and started working for rising agricultural industry. To evaluate completely autonomous agricultural technology, research and development department of Harper Adams in the UK is working towards growing and harvesting Barley in one hectare farm with zero human physical intervention. Machine learning is a continuous process of improving ability of a system to differentiate between diverse range of crops and the weeds which are threat for them. For example Agribotix of USA has developed a commercial software that scrutinizes the infrared images captured by drones and identify unhealthy crop and undesired weed growth. A US based company Mavrx makes use of light-aircraft fitted with multispectral cameras for gathering data over huge farm fields spread over the country.

PlanetLabs operates a fleet of CubeSats which take images of large pieces of land from space on weekly basis to have a wider view of landscape to aid crop monitoring.

Many companies over the globe are developing farm-management system software and associated hardware, allowing growers of all scales to excel in their business. The Agricultural Network merges data from countless farms into a giant pool, to provide its users with a macro and micro-level insights for most efficient farming with least efforts.

REFERENCES

Creating a Sustainable Food Future. (n.d.). World Resources Report 2013–14: Interim Findings.

Deeksha Jain, Krishna, & Saritha. (2012). *A Study on Internet of Things based Applications*. Academic Press.

Kaur, G., Tomar, P., & Singh, P. (2018). Design of cloud-based green IoT architecture for smart cities. In *Internet of Things and Big Data Analytics Toward Next-Generation Intelligence* (pp. 315–333). Springer. doi:10.1007/978-3-319-60435-0_13

Liakos, K. G., Busato, P., Moshou, D., Pearson, S., & Bochtis, D. (2018). Machine learning in agriculture: A review. *Sensors (Basel)*, *18*(8), 2674. doi:10.339018082674 PMID:30110960

Malavade, V. N., & Akulwar, P. K. (2016). Role of IoT in agriculture. In *National Conference on Changing Technology and Rural Development CTRD* (pp. 56-57). Academic Press.

McKinion, J. M., & Lemmon, H. E. (1985). Expert systems for agriculture. *Computers and Electronics in Agriculture*, *1*(1), 31–40. doi:10.1016/0168-1699(85)90004-3

Parasher, Y., Kedia, D., & Singh, P. (2018). Examining Current Standards for Cloud Computing and IoT. In *Examining Cloud Computing Technologies through the Internet of Things* (pp. 116–124). IGI Global.

Parasher, Y., Singh, P., & Kaur, G. (2019). Green Smart Town Planning. *Green and Smart Technologies for Smart Cities*, 19-41. doi:10.1201/9780429454837-5

Prathibha, S. R., Hongal, A., & Jyothi, M. P. (2017, March). IOT Based monitoring system in smart agriculture. In *2017 International Conference on Recent Advances in Electronics and Communication Technology (ICRAECT)* (pp. 81-84). IEEE. 10.1109/ICRAECT.2017.52

Singh, P., Dixit, V., & Kaur, J. (2019). Green Healthcare for Smart Cities. *Green and Smart Technologies for Smart Cities*, 91-130.

Sujjaviriyasup, T., & Pitiruek, K. (2013). Agricultural Product Fore-casting Using Machine Learning Approach. *Int. Journal of Math. Analysis*, *7*(38), 1869–1875. doi:10.12988/ijma.2013.35113

Wang & Liu. (2014). The application of internet of things in agricultural means of production supply chain management. *Journal of Chemical and Pharmaceutical Research, 6*(7), 2304-2310.

Chapter 5
Farming Automation

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ABSTRACT

Farming automation requires a whole lot of new skills and use of technology for achieving a substantial increase in the crop yield. Smart farming enables the use of technology in tracking, monitoring, and analyzing various farming operations. Internet of things (IoT) platform is formed with sensors and actuators, cameras and drones, telecommunication technologies, edge devices, cloud servers, and specialized hardware and software. This chapter will discuss the available hardware and software technology elements that can be used in farm automation. The chapter is comprised of four sections. The first section provides an overview of precision agriculture and smart farming. The second section provides the literature review of existing research. The third section describes IoT techniques, sensors, and cloud and edge computing solutions for the implementation of smart farming. The fourth section provides a few case studies of the application of IoT in smart farming. Specifically, the chapter will describe the IoT platform solution for complete farm automation.

INTRODUCTION

Farming Automation makes use of the technology, Internet of Things (IoT) and robotics to automate the crop production and livestock management in order to make farms more efficient and productive.

Over the years the amount of food consumption is increasing because of the growth in population as well as people are increasingly got concerned about the quality of food. Moreover the impact of environmental changes also have forced scientist to think about finding the innovative ways to meet the new challenges faced in agriculture sector. All these developments have lead to emergence of a new paradigm called precision agriculture.

Precision Agriculture has gained lots of attention recently. Basically precision agriculture employs information technology in farming. Use of information technology in farming has tremendous potential for better and informed decision making. It leads to the creation of smart farms that will be sustainable and environment friendly and also leads to the increased production. The scope of precision agriculture also includes the crop management, livestock management as well as the management of other agricul-

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ture products. The precision Agriculture can improve overall efficiency, productivity and profitability of the agriculture.

The quality of soil is a major contributor in sustainable farming. The soil must have the required organic matter and other nutrients. As compared to chemical based fertilizers, the compost method is proved to be better in preserving the desired minerals and nutrients in the soil. Internet of Things (IoT) has potential to improve composting and thereby to improve the overall quality of soil. This chapter focuses on a number of solutions for smart farming and smart composting system. In the next section the research work conducted in smart farming in recent years is highlighted.

LITERATURE REVIEW

The literature review presents research work conducted on Smart Farming in recent years. Araby et al. (2019) has proposed a smart IoT monitoring system. The system offers a predictive analysis. As mentioned in the paper, a wireless sensor network can be deployed that collects the data about certain crops. In this study the crops of potato and tomato have been utilized. The data obtained is provided to the machine learning algorithms which generate a warning message.

The use of machine learning algorithms in cultivation of potato crops can detect the signs of infection early so that appropriate measures can be applied to prevent further spread of the disease. This paper suggested a system to detect the occurrence of Late Blight disease in crops such as potato using regression analysis and gives appropriate advice to the farmer using a Graphical User Interface. The proposed system also has the advantage of reducing the unnecessary use of pesticides.

Jo et al. (2019) proposed an IoT enabled Compost Monitoring System. The system performs the monitoring of essential parameters of soil in real time. In this study an IoT based technique has been used to properly performing all processes of composting. The processor used in the system is Raspberry Pi and communication module is LoRa based. DHT11 sensor has been used to monitor temperature and relative humidity. The proposed approach will help the farmers to identify the most suitable time to turn the compost.

Abbasi et al. (2019) has presented a survey on the application of Internet of Things (IoT) on agriculture. This survey explored the IoT hardware platforms for agriculture like Arduino, Raspberry and Intel based models. The survey also explored various software platforms related to the agriculture. These software platforms are mostly cloud based platforms including Amazon Web Services (AWS) IoT Platform, Salesforce IoT platform, SAP IoT platform, Google Cloud Platform, Oracle IoT Platform IBM Watson IoT Platform and Microsoft Azure IoT hub. The IoT applications listed in the survey are environmental and ecological monitoring and irrigation. Several mobile apps on agriculture related tasks are also discussed. The challenges on the use of IoT in agriculture are identified as standardization of IoT devices, sensors and communication protocols, security and privacy and data storage and analysis on which more work is required.

Dewi et al. (2019) proposed an approach on decision making with IoT data collecting on Precision Agriculture. The data can be collected using various sources. For instance, it can be climate related data, crop and soil related data as well as agriculture machinery related data. Data collection requires the selection of appropriate sensors. Common sensors are temperature and humidity sensors like DHT11, LM35 and SHT 3x-DIS. Then a decision model is required for decision making. In this paper, a decision tree based implementation is provided.

Agrawal et al. (2019) proposed another method for IoT based precision agriculture which they claimed as an energy efficient system. It is a Wireless Sensor Network (WSN) based system. In a WSN system, there are thousands of inexpensive sensor nodes. However, these sensor nodes are often battery powered. Therefore, the nodes may die eventually when battery of the nodes is consumed. An energy harvesting approach is presented in this paper. Energy is harvested using a solar panel. Energy efficient routing using clustering algorithms is also applied on the system. Use of data aggregation algorithm like LEACH is also discussed in this paper. The experiment was conducted using NS2 (Network Simulator). The proposed model was proved to be more efficient than the existing solutions.

Keswani et al. (2019) proposed a smart irrigation technique. In the proposed scheme they have made use of IoT in measuring environmental temperature, humidity, soil moisture, CO2 level, and daylight intensity. The measuring sensor nodes are employed on multiple points. In this study an optimum usage of irrigation is presented which is achieved by precise measurements. Soil water requirement can be predicted with the help of neural networks and this can be used to control the water valves. Also it can be used to locate the regions of farms which have water deficiency and uniform water requirement can be computed for the entire farm. This paper suggested the use of fuzzy logic and Artificial Neural Networks (ANN) for making predictions.

Bacco et al. (2019) presented a survey on research activities related to smart farming. It is stated in this study that most research activities are inclined towards the use of agricultural robots, Unmanned Aerial Vehicles (UAV) for aerial imagery for detecting the spread of a disease and use of Wireless Sensor Networks (WSN) for collection of data. The most prominent challenge in employing smart farming in rural areas is the lack of connectivity and unavailability of electricity. The data collection requires the use of cloud storage which requires uninterrupted connectivity. Other major barriers in the implementation of smart farming is lack of education and digital skills among farmers as well as the high cost of deploying sensors, robots and UAVs.

Hossam et al. (2018) proposed an IoT based predictive platform called PLANTAE for enabling Precision Agriculture. The purpose of this platform is to control the plantation environment by predicting plant diseases. The leaves images are collected and machine learning algorithms are applied on the collected images for disease classification. Similar to other systems, the proposed platform also collects data and uploads on a web server. Then the classification is performed using a machine learning model. The proposed system uses a soil moisture sensor, a pH sensor and a temperature and humidity sensor. The collected sensor data is used to turn on a water pump when soil moisture drops below 30% and turns on a fan when temperature exceeds 37°C. The images are captured by using mobile camera and uploaded on the web server. Plant diseases are predicted using deep learning.

Ahmad et al. (2018) proposed IoT based smart farming solution for rural areas. The proposed system reduces the network latency substantially by making use of the fog computing. The fog and cloud computation is done on WSN gateways.

Andrew et al. (2018) proposed an IoT solution for Precision Agriculture. Apart from using sensors for climate monitoring, this paper also indicated the use of wearable sensors for livestock health monitoring.

Islam et al. (2018) proposed an IoT based smart farming system for agriculture control and irrigation monitoring. The system is energy efficient. In this study, a web application and an Android application is developed for users. The RF (Radio Frequency) communication and LoRa protocol is used for larger coverage of area.

Math et al. (2018) proposed a weather station and monitoring system for Precision Agriculture. This study is focused on the need of having a local weather station so that the environmental conditions can be known precisely. In the proposed system DHT22 sensor is used which measures Temperature, Humidity, Dew Point, Absolute Pressure, Light Intensity and the amount of rain fall. The data has been visualized by MATLAB.

Rao et al. (2018) proposed an IoT based system for crop field monitoring. The proposed system aims to satisfy the watering needs of the field automatically thereby making the automatic system more efficient than the existing manual system. The system monitors temperature and humidity in the soil and daylight intensity. The temperature sensor LM35 and soil moisture sensor has been used. The data is collected on a cloud server.

Biradar et al. (2017) presented a review on IoT based multidisciplinary models on smart farming. The study indicated the models on Big data, Wireless Sensor Networks, Cyber Physical Systems and Cloud Computing.

Pratibha et al. (2017) proposed a monitoring system for smart agriculture. In the proposed approach temperature and humidity of the field is monitored using sensors and CC3200 Single Chip. The chip also has camera interfaced to it for capturing the images.

Rekha et al. (2017) proposed an IoT based Precision Agriculture system for Groundnut cultivation. This study aims to increase the crop yield by incorporating IoT based techniques. The IoT based techniques enable farmers to know the characteristics of their crop and allow them to take necessary actions in a timely manner. In this study, Wireless Sensor Network has been used. The sensor nodes in the network collect data about agriculture parameters. The farmers can be notified with the help of Android app. However, only soil moisture data has been collected and analyzed in this study.

Sreekantha et al. (2017) presented agriculture crop monitoring using IoT. Several research papers have been reviewed in this study indicating the use of leaf wetness sensor, soil moisture sensor, soil pH sensor and atmospheric pressure sensor along with the temperature and humidity sensor.

Ghadage et al. (2017) proposed an IoT based system for garbage management. This study indicates the importance of wet and dry wastes so that both types of waste can be appropriately handled. First of all earlier garbage management techniques are reviewed. The earlier systems employed large number of sensors to collect the data. Some of them indicated the use of sensors for determining the level of dustbins so that waste can be prevented to overflow. Weight sensors and height sensors have been employed to check the level of dustbins. In this study the use of ultrasonic sensor, moisture sensor and flame sensor is indicated. Hence the proposed system enables user to detect whether the dustbin is full using the ultrasonic sensor or whether the waste is wet using the moisture sensor or whether there is fire in dustbin using the flame sensor. Notification about any of these events is indicated on the web page as well as an SMS is also sent on user's mobile phone.

Cambra et al. (2017) proposed an agriculture monitoring system which is IoT service-based. The system makes use of a Wireless Sensor Network. The proposed system is for large and smart farming systems. It indicates the combined use of IoT, aerial images and Service Oriented Architecture. The system utilizes IoT sensors, aerial sensors and the irrigation controllers. It has Network Administration Middleware for collecting and storing the data. The system also has a MySQL database storage. The system has a rule engine container and rule engine core. The system utilizes Rete Pattern Matching Algorithm. The parameter rules of irrigation functionality are stored in rule container. These rules also contain the weather rules. Each rule contains the condition section and the action section. Rules are declared with the rule keyword and followed by the name of rule. The output of the system can be observed on a multimedia browser.

Mat et al. (2016) presented an IoT based system for detecting soil moisture level. Here a Wireless Sensor Network is used which acts as Wireless Moisture Sensor Network. The sensors used in this network measure temperature, humidity and soil moisture. The system efficiency has been compared with and without the use of sensor network. It has been observed that there is an average saving of 1500 ml. water per day per tree. The proposed system is helpful in determining the optimum water and fertilizer requirement.

Casas et al. (2014) also proposed an IoT based system for smart composting monitoring and control. This study indicates that there are several kinds of organic wastes in the form of plant leaves, food leftovers and food waste which can be utilized to make the organic manure. These biodegradable materials can be transformed into a stable compost which can increase the quality of soil. The biodegradable material can be decomposed and during this process the temperature is substantially increased. After that the temperature is reduced. Hence a temperature sensor can determine that the decomposition process is going on. A moisture sensor is also required during decomposition process, since the amount of moisture should be 60% at this stage. So there are several parameters to be monitored during the composting process. These parameters include temperature, moisture level, oxygen, pH, Carbon-to-Nitrogen ratio etc.

Ye et al. (2013) proposed a Precision Agriculture method based on IoT and WebGIS. The Precision Agriculture Management System (PAMS) used in this study has several modules. The information infrastructure module comprises of communication systems, sensor networks and image transmission systems. The Database module maintains databases to store images and sensor data. The WebGIS module collects, analyzes and displays the spatial data of farm land. The local system module collects and analyzes the sensor data. The Mobile client module enables the monitoring of the data by user.

Next section contains different ways to implement Smart Farming solutions using IoT Platforms.

IMPLEMENTATION OF SMART FARMING

IoT Platforms for Smart Farming

(i) IoT Platforms for Weather Monitoring

The micro-climate analysis is done for detecting extreme weather vulnerabilities and climate risk in crop production. The crop management from the weather conditions such as heat and cold waves, hailstorms, cyclones, floods and draughts is required. The use of IoT in agriculture helps in microclimatic modification so that loss of crop yields can be reduced. Microclimatic modification can be obtained in various ways as listed below.

1. Temperature and humidity measurement
2. Availability of proper sunlight
3. Rainfall detection
4. Soil Moisture detection

An IoT platform for micro-climate analysis will contain the appropriate sensors and a mechanism for data analysis.

(ii) IoT Platforms for Crop Management

The crop management can be done by soil analysis, assessing watering requirement, monitoring of crops during growth for any disease and fertilizers and pesticide spray. The IoT platform provides the sensors for measuring various parameters, analyzing and initiating appropriate action.

Robotics also play significant role in farming automation. Fruits and vegetable picking robots are common. Autonomous seeding and planting machines can cover much wider area in less time. These machines make use of sensor data to determine soil quality, nutrition level, soil moisture and density.

(iii) IoT Platforms for LiveStock Management

Health of farm animals can be monitored using various sensors such as temperature sensor and various biosensors. These are wearable sensors that help in monitoring health of animals remotely.

The health of farm animals can be monitored using the robotic pills. The production of milk in cows is effected by their health. Robotic pills can be ingested by cows and placed correctly using AI. The pills send data indicating its health conditions as well as location data. The location data helps in isolating the sick cows so that they can be treated independely from other cows in the herd.

(iv) IoT Platforms for Logistics Management

Automation of tractors and farming vehicles makes the harvesting process efficient. Self-driving tractors can be pre-programmed or can be made autonomous by incorporating AI. Autonomous tractors can be equipped with sensors to keep track of harvesting process. These autonomous vehicles can be monitored from remote. Also they allow us to collect the data remotely for further analysis along with their primary task.

The autonomous self-driving tractors make harvesting of large segment of land possible without procuring farming labors and makes the overall farming process efficient.

Sensors Used in Smart Farming

Precision Agriculture is enabled by the use of a number of sensors. The sensors provide information to farmers which help them understand lots of things about crops and climate. With the help of sensors the farmers can achieve increase in crop yield with limited resources such as water, fertilizers and the seeds.

Agriculture sensors play very important role in smart farming. Sensors enable farmers to optimize the crop yield by adapting to the environmental conditions. Basically, the sensors can be attached on weather stations, Unmanned Aerial Vehicles (UAV) or drones and Unmanned Ground Vehicles (UGV) or the robots. The sensors can be controlled using mobile apps. The optical sensors are mostly attached on drones or robots since they can examine the whole field and take necessary pictures.

The sensors which find their place in Precision Agriculture are listed below:

1. NJR NJG1157PCD-TE1 is an example of location sensor. Location sensors help locate the field with the help of satellites. These sensors indicate the longitude, latitude and altitude.

2. Soil properties are very much significant in precision agriculture. Soil properties can be measured by the optical sensors. These sensors can monitor soil moisture, plant disease, clay and organic matter. These sensors can be fitted in drones which can be used to monitor the entire field.
3. Soil chemical data is also a useful factor in determining the quality of soil. It indicates the pH level and nutrients in the soil. The electrochemical sensors are used to find the chemical properties of soil. These sensors detect the presence of specific ions in the soil.
4. The pulling requirement in soil can be determined by fitting the mechanical sensors in tractors. For example, Honeywell FSG15N1A is a Tensiometer is very useful in irrigation.
5. Dielectric constant assesses the soil moisture by using dielectric soil moisture sensor.
6. Soil air permeability can be measured by Airflow sensors. These sensors help in determining very important properties of soil.

Crop yields can also be increased with the use of sensors. These sensors have several applications like yield monitoring, yield mapping, variable rate fertilizers, weed mapping, variable spraying, boundary control, salinity mapping and guidance systems.

The sensors can monitor the health and behavior of livestock. For instance, the sensors monitor cow's activity level, behavior and health.

Apart from sensors, there are a number of Smartphone tools available which help in smart farming. These tools include phone camera for taking pictures of plants and disease for the purpose of identifying a potential disease, GPS for determining the location of weeds, solar radiations and need of fertilizing and paste location. Microphones can be used in maintenance of agriculture machinery. Other Smartphone tools are accelerometer and gyroscope.

There are lots of Smartphone apps that help in performing smart farming. Some examples of these smart apps are listed below.

1. Disease detection apps. These apps makes use of plant and leaf images and determines the occurrence of a disease by using machine learning techniques.
2. Fertilizer Requirement Calculator. These apps receive input data from a number of soil sensors and compute the requirement of fertilizers on specific area.
3. Soil Study apps. These apps also accept data from soil sensors and climate sensors and determine the quality of soil.
4. Water Requirement Prediction apps. These apps accept the image data from parts of the fields and also accept data from soil moisture sensor and computes the requirement of water in the specific area.

Hence the sensors provide a number of benefits to farmers. These enable the reduced requirement of fuel and energy. Therefore less carbon dioxide emission is achieved. Less use of fertilizers reduces the nitrous oxide release. Pest control can be done precisely. Therefore reduced chemical spraying is achieved. Also the water requirement can also be minimized.

Hence we can summarize that for Precision Agriculture we can measure leaf wetness and fruit diameter. We can also measure trunk diameter and stem diameter. For irrigation purpose we can measure soil moisture. For greenhouses we can measure solar radiation, humidity and temperature. We also need to have weather stations in irrigation systems. So we need to measure temperature and humidity. Therefore, we can have Anemometer, wind vane and pluviometer.

Sensors have numerous benefits in smart agriculture. However they have certain drawbacks. The first drawback of using sensors is the requirement of internet connectivity all the time. In rural areas the internet connectivity and electricity may not be available all the time. This situation limits the use of smart farming. Also, the smart farming also requires the availability of basic infrastructure like cellular towers and smart grids which may not be possible in rural areas in developing countries. Another drawback is that most of the time farmers are not literate enough to adopt the IoT technology.

The use of sensors in smart farming also generates very large volume of data per day. Hence there is also the requirement of cloud storage in smart farming. Again the cloud storage needs Internet connectivity all the time. The requirement of cloud storage can be overcome by the use of edge computing. Edge computing allows the data collected by sensors to store locally at the network edge and also data to be analyzed there only. Only the processed data that need to be saved for future analysis and use need to be saved on the centralized cloud storage. The edge computing permits the use of distributed computing as opposed to the centralized computing with cloud server.

The sensor technology in smart farming also enables the predictions possible with the use of AI and Machine Learning. The data collected over a period of time can be used to explore the profitability of crops which are being cultivated currently as well as the scope of newer crops can be explored. The sensor technology allows farmers to perform their irrigation tasks efficiently so that both resources and time can be saved.

Cloud and Edge Computing Solutions

With the emergence of IoT in several tasks of Precision Agriculture, the sensor nodes have been used in large numbers. As mentioned earlier, the IoT can benefit irrigation systems, compost making, environment monitoring, soil inspection, plant disease detection, livestock health monitoring, irrigation machinery and logistic control. Each application of IoT in smart farming requires several sensor nodes connected with each other, thus forming a Wireless Sensor Network (WSN). These networks working for specific applications collect data at regular intervals. The data collected by sensor networks in each application is transferred to a cloud server for further processing. It indicates the need of both a cloud server storage as well as the 24×7 Internet connectivity. Therefore large volume of data is collected by sensor networks each day which is often irrelevant to be stored on the cloud server.

For instance, suppose a robot is taking pictures of plant leaves for the purpose of detecting a disease. It may happen that large numbers of images captured indicate normal leaf texture. Only few images need to be further analyzed. In such situation there is no need of transferring all images to the cloud server. The images need to be filtered before sending to the cloud server.

Similarly, in environment monitoring application, if there is sudden surge in temperature or there is rainfall, only then there is a need of action and data storage for future use. For normal weather condition, the summary data can be saved. In similar way the data collected by all sensors must be analyzed locally at the network edge and filtered before sending to the centralized cloud server. It will eliminate the need of Internet connectivity all the time as well as the requirement of large storage. Moreover, as the volume of data transferred is reduced it will also result in reduction of bandwidth consumption and makes the data transfer faster and substantial reduction in cost.

Therefore, edge computing will become major trend in Smart Farming. Use of Edge Computing has several advantages over the centralized cloud computing which are discussed below:

1. If only cloud computing is available, then all data first required to be transferred to the cloud server, where further processing is performed. The outcome of processing is sent back to the device at the field in order to take appropriate action. There is a challenge of securely transferring raw data to the cloud server and prevent the data theft. The raw data transfer will make the system vulnerable to potential cyber-attacks. This can be prevented by sending only the summary data to the cloud server. For example, suppose the day's temperature doesn't vary widely, then only the average temperature of that period can be sent to the cloud server. Since the traffic to and from the cloud server is reduced much so is the chances of cyber-attacks. Also, the attackers will not get complete information even if the data is leaked somehow. Hence the edge computing solutions make the system more secure.
2. Imagine there are thousands of sensor nodes in a Wireless Sensor Network (WSN) performing a specific task of irrigation. Each sensor nodes in the network collects data at regular interval and sends to the cloud server. It will cause a delay in analyzing and sending response. If the agriculture devices are being monitored and controlled remotely, then the delay in getting the insight of a situation such as health of an animal or a fire outbreak will make the system ineffective since the corrective action can't be taken on timely manner. Since, the use of edge computing makes data transfer fast, the quick response from the cloud server can be obtained.
3. The reduced cost is another advantages achieved by using edge computing since it will reduce the need of expensive cloud storage. Also the processing time is reduced and therefore the cloud server cost is also reduced.

The next section contains a few use cases of Smart Farming.

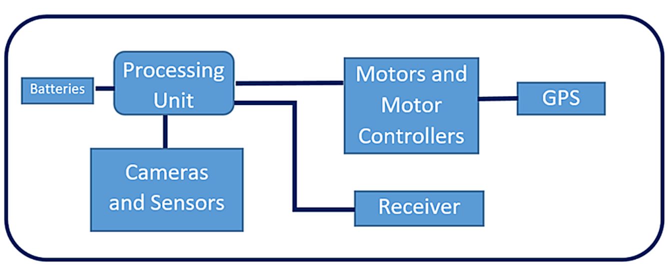
IoT Use Cases of Smart Farming

(i) Unmanned Ground Vehicle (UGV) or Agriculture Robots

Autonomous Unmanned Ground Vehicles (UGV) can be used as sensor carriers in a farm. The UGV can be equipped with cameras to capture images of the soil as well as plants and leaves for detecting the spread of a disease.

The major building blocks of a UGV are processing unit, batteries, motors, GPS, motor controllers, remote control receivers, Laser scanners, Ultrasonic scanners and cameras.

Figure 1. Block Diagram of Unmanned Ground Vehicle



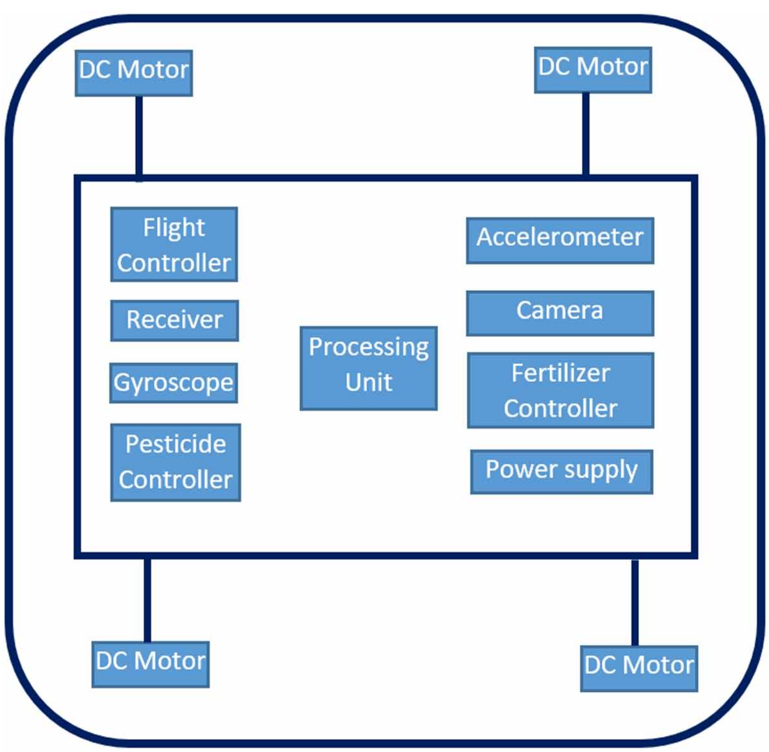
The processing unit controls the localization sensor for locating objects. Cameras take complete view of surrounding areas. Laser scanner detects the obstacles in the path. Ultrasonic sensors are used to avoid collisions. Accelerometer, gyrometer and magnetometer produce three dimensional pose estimate. The remote control receiver enables direct communication with human operator.

(ii) Unmanned Aerial Vehicle (UAV) or Drones

Unlike unmanned ground vehicles (UGV), the Unmanned Aerial Vehicles (UAV) have much more applications in Smart Farming. UAVs can be used for surveillance over the entire field fitted with cameras and capture images to monitor the condition of field and the crop. The UAVs can also be used to spray fertilizers and pesticides. The doses of sprays can be varied according to the need.

UAV is also used to provide geolocation of crops and vehicles and helps in understanding soil variability. The processing unit in a UAV may be a microcontroller like ATMega328.

Figure 2. Block Diagram of Unmanned Aerial Vehicle



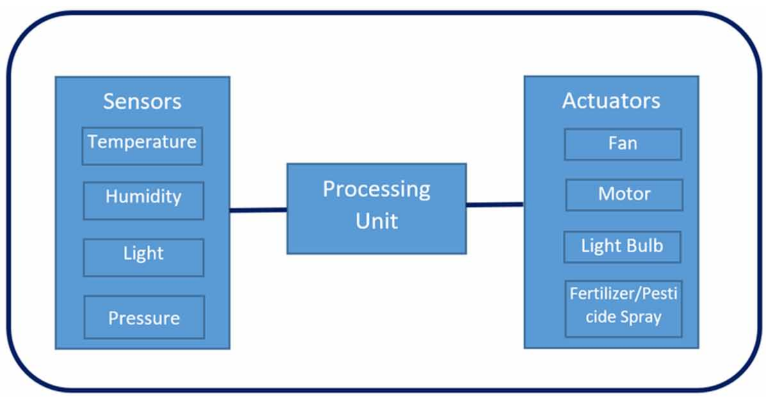
(iii) Smart Greenhouse

Greenhouse farming has been used to increase the yield of vegetables, fruits and other crops. A smart greenhouse is one that makes use of sensor technology to monitor the growth of plants. Several climate parameters are monitored and controlled in a smart greenhouse. Commonly used sensors in the smart greenhouse are light sensors, pressure sensors and temperature and humidity sensors. The data collected by sensors is sent to the cloud server for more processing. The response obtained by processing the data may result in turning the heater or fan on, opening window or any other action with the help of actuators. The use of IoT can help in increasing the production by 100%.

ADVANTAGES OF SMART FARMING

Consumer Benefits

Figure 3. Block Diagram of Smart Greenhouse



The technology used in Smart Farming enable farmer to monitor their crop in more detailed manner. Therefore, they can reduce the wastage of different resources like water, pesticides and fertilizers by their selective application. So, the overall expenditure on farming can be reduced. By closely monitoring crops for diseases, the farmers can also reduce damage to crops. Hence, more farm yield can be achieved with less cost. Since the crop yield increases with the use of automation, consumers will get the farm produce at lower cost. Also they will get them fresh with faster delivery.

Efficient Farming Labors

Farmers can devote more time on analyzing crop data and find innovative ways for harvesting crops rather than doing tedious tasks of watering and spraying fertilizers and pesticides. The smart equipment and vehicles used in farming make their work lot easier. Also the less people are required in farms at a time. Hence, the labor shortage can be alleviated with the use of automation.

Environmental Friendly Farming

With reduced use of pesticides and fertilizers there will be reduction in the emission of greenhouse gases. Minimal chemical usage will make the environment clean. The smart farming technique also allow us to prepare compost efficiently that will make the crop healthier.

CHALLENGES IN SMART FARMING

There are several challenges in carrying out smart farming.

First of all, it is costly. Smart farming requires setting up several sensors throughout the field. These sensors need to be monitored and maintained. The batteries need to be replaced. All of this adds the cost of farming. Smart farming also requires various autonomous systems like robots, drones, self-driving vehicles and so on. Hence it requires substantial capital initially.

The second challenge in performing smart farming is that it requires manpower with different skill set. The people employed in smart farming must be well trained to work with technology, IT and agriculture. They should have knowledge of web-based systems as well as mobile applications. It is not easy to find out lots of workers with the required skills to perform smart farming.

The third challenge is that smart farming applications are data-intensive. They collect large volume of data that need to be stored and analyzed. It requires cloud based solutions. However, it will cause delay in sending the data to cloud server for computation and getting the response which makes the application ineffective.

The smart farming also requires 24×7 Internet connectivity and electricity. In many areas it is also a major challenge that needs to be addressed.

CONCLUSION

As the population of the world keeps on growing each year we need a solution to the problem of making food available to everyone. The traditional way of agriculture is not sufficient to fulfill the growing demand of food. With the use of technology, the smart farming can provide the solution by increasing the crop yield.

The smart farming is possible with the use of sensor technology, autonomous systems and robots, cloud and edge computing solutions as well as web applications and mobile apps.

REFERENCES

Abbasi, M., Yaghmaee, M. H., & Rahnama, F. (2019, April). Internet of Things in agriculture: A survey. In *2019 3rd International Conference on Internet of Things and Applications (IoT)* (pp. 1-12). IEEE. doi:10.1016/j.comnet.2020.107148

Agrawal, H., Dhall, R., Iyer, K. S. S., & Chetlapalli, V. (2019). An improved energy efficient system for IoT enabled precision agriculture. *Journal of Ambient Intelligence and Humanized Computing*, 1–12. doi:10.100712652-019-01359-2

Ahmed, N., De, D., & Hussain, I. (2018). Internet of Things (IoT) for smart precision agriculture and farming in rural areas. *IEEE Internet of Things Journal*, *5*(6), 4890–4899. doi:10.1109/JIOT.2018.2879579

Andrew, R. C., Malekian, R., & Bogatinoska, D. C. (2018, May). IoT solutions for precision agriculture. In *2018 41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)* (pp. 0345-0349). IEEE. 10.23919/MIPRO.2018.8400066

Araby, A. A., Elhameed, M. M. A., Magdy, N. M., Abdelaal, N., Allah, Y. T. A., Darweesh, M. S., . . . Mostafa, H. (2019, May). Smart IoT Monitoring System for Agriculture with Predictive Analysis. In *2019 8th International Conference on Modern Circuits and Systems Technologies (MOCAST)* (pp. 1-4). IEEE.

Bacco, M., Barsocchi, P., Ferro, E., Gotta, A., & Ruggeri, M. (2019). The Digitisation of Agriculture: A Survey of Research Activities on Smart Farming. *Array*, *3*, 100009. doi:10.1016/j.array.2019.100009

Biradar, H. B., & Shabadi, L. (2017, May). Review on IOT based multidisciplinary models for smart farming. In *2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)* (pp. 1923-1926). IEEE. 10.1109/RTEICT.2017.8256932

Cambra, C., Sendra, S., Lloret, J., & Garcia, L. (2017, May). An IoT service-oriented system for agriculture monitoring. In *2017 IEEE International Conference on Communications (ICC)* (pp. 1-6). IEEE. 10.1109/ICC.2017.7996640

Casas, O., López, M., Quílez, M., Martinez-Farre, X., Hornero, G., Rovira, C., Pinilla, M. R., Ramos, P. M., Borges, B., Marques, H., & Girão, P. S. (2014). Wireless sensor network for smart composting monitoring and control. *Measurement*, *47*, 483–495. doi:10.1016/j.measurement.2013.09.026

Dewi, C., & Chen, R. C. (2019, April). Decision making based on IoT data collection for precision agriculture. In *Asian Conference on Intelligent Information and Database Systems* (pp. 31-42). Springer.

Ghadage, S. A., & Doshi, M. N. A. (2017, December). IoT based garbage management (Monitor and acknowledgment) system: A review. In *2017 International Conference on Intelligent Sustainable Systems (ICISS)* (pp. 642-644). IEEE. 10.1109/ISS1.2017.8389250

Hossam, M., Kamal, M., Moawad, M., Maher, M., Salah, M., Abady, Y., Hesham, A., & Khattab, A. (2018, December). PLANTAE: an IoT-based predictive platform for precision agriculture. In *2018 International Japan-Africa Conference on Electronics, Communications and Computations (JAC-ECC)* (pp. 87-90). IEEE. 10.1109/JEC-ECC.2018.8679571

Idbella, M., Iadaresta, M., Gagliarde, G., Mennella, A., Mazzoleni, S., & Bonanomi, G. (2020). AgriLogger: A New Wireless Sensor for Monitoring Agrometeorological Data in Areas Lacking Communication Networks. *Sensors (Basel)*, *20*(6).

Islam, A., Akter, K., Nipu, N. J., Das, A., Rahman, M. M., & Rahman, M. (2018, October). IoT Based Power Efficient Agro Field Monitoring and Irrigation Control System: An Empirical Implementation in Precision Agriculture. In *2018 International Conference on Innovations in Science, Engineering and Technology (ICISET)* (pp. 372-377). IEEE. 10.1109/ICISET.2018.8745605

Jo, R. S., Lu, M., Raman, V., & Then, P. H. (2019, April). Design and Implementation of IoT-enabled Compost Monitoring System. In *2019 IEEE 9th Symposium on Computer Applications & Industrial Electronics (ISCAIE)* (pp. 23-28). IEEE.

Katsigiannis, P., Misopolinos, L., Liakopoulos, V., Alexandridis, T. K., & Zalidis, G. (2016, June). An autonomous multi-sensor UAV system for reduced-input precision agriculture applications. In *2016 24th Mediterranean Conference on Control and Automation (MED)* (pp. 60-64). IEEE. 10.1109/MED.2016.7535938

Keswani, B., Mohapatra, A. G., Mohanty, A., Khanna, A., Rodrigues, J. J., Gupta, D., & de Albuquerque, V. H. C. (2019). Adapting weather conditions based IoT enabled smart irrigation technique in precision agriculture mechanisms. *Neural Computing & Applications*, *31*(1), 277–292. doi:10.100700521-018-3737-1

Kingra, P. & Kaur, H. (2017). Microclimatic Modifications to Manage Extreme Weather Vulnerability and Climatic Risks in Crop Production. *Journal of Agricultural Physics*, *17*(1), 1–15.

Mat, I., Kassim, M. R. M., Harun, A. N., & Yusoff, I. M. (2016, October). IoT in precision agriculture applications using wireless moisture sensor network. In *2016 IEEE Conference on Open Systems (ICOS)* (pp. 24-29). IEEE. 10.1109/ICOS.2016.7881983

Math, R. K. M., & Dharwadkar, N. V. (2018, August). IoT Based low-cost weather station and monitoring system for precision agriculture in India. In *2018 2nd International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC) I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), 2018 2nd International Conference on* (pp. 81-86). IEEE. 10.1109/I-SMAC.2018.8653749

Mkrttchian, V., & Belyanina, L. (Eds.). (2018). *Handbook of Research on Students' Research Competence in Modern Educational Contexts*. IGI Global. doi:10.4018/978-1-5225-3485-3

Prathibha, S. R., Hongal, A., & Jyothi, M. P. (2017, March). IoT based monitoring system in smart agriculture. In *2017 International Conference on Recent Advances in Electronics and Communication Technology (ICRAECT)* (pp. 81-84). IEEE. 10.1109/ICRAECT.2017.52

Radoglou-Grammatikis, P., Sarigiannidis, P., Lagkas, T., & Moscholios, I. (2020). A compilation of UAV applications for precision agriculture. *Computer Networks*, ▪▪▪, 172.

Rao, R. N., & Sridhar, B. (2018, January). IoT based smart crop-field monitoring and automation irrigation system. In *2018 2nd International Conference on Inventive Systems and Control (ICISC)* (pp. 478-483). IEEE. 10.1109/ICISC.2018.8399118

Rekha, P., Rangan, V. P., Ramesh, M. V., & Nibi, K. V. (2017, October). High yield groundnut agronomy: An IoT based precision farming framework. In *2017 IEEE Global Humanitarian Technology Conference (GHTC)* (pp. 1-5). IEEE. 10.1109/GHTC.2017.8239287

Sreekantha, D. K., & Kavya, A. M. (2017, January). Agricultural crop monitoring using IOT-a study. In *2017 11th International Conference on Intelligent Systems and Control (ISCO)* (pp. 134-139). IEEE.

Tokekar, P., Vander Hook, J., Mulla, D., & Isler, V. (2016). Sensor planning for a symbiotic UAV and UGV system for precision agriculture. *IEEE Transactions on Robotics*, *32*(6), 1498–1511. doi:10.1109/TRO.2016.2603528

Ye, J., Chen, B., Liu, Q., & Fang, Y. (2013, June). A precision agriculture management system based on Internet of Things and WebGIS. In *2013 21st International Conference on Geoinformatics* (pp. 1-5). IEEE. 10.1109/Geoinformatics.2013.6626173

KEY TERMS AND DEFINITIONS

Agriculture Robot: Is a robot mainly used for different agriculture related tasks such as plucking the fruits and vegetables, harvesting crops, planting seeds, climate monitoring, and soil monitoring.

Precision Agriculture: Is a technique of agriculture that aims to enable farmers to provide the crops those resources which they need precisely with great accuracy. The resources may be sunlight, water, fertilizers, or pesticides.

Smart Farming: Is the use of technology in agriculture with the aim of increasing the crop yields. Basically, the focus of Smart Farming is on making informed decisions using information technology and data science.

Smart Greenhouse: Is a breakthrough in farming technology that creates a microclimate for consistent plant growth with the help of sensor technology. It optimizes the plant growth by adjusting the growing conditions automatically.

Chapter 6
Food 4.0:
An Introduction

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ABSTRACT

The fourth industrial revolution is a prospective innovation path for human life to possibly replace human intelligence and manual labour with artificial intelligence and robotics. The concept of 4IR is being embraced and applied in all sectors of human life. The academics are researching intensely into the revolution, while industry captain braces up to the inevitable and fast implementation in energy, automobile, telecommunication, services, security, medicine, and other industrial sectors. Agriculture and food sector, which is termed Food 4.0, being the highest employer of human resources, is a major sector that is expected to benefit tremendously from the concept and application of 4IR in driving the sector into the new era of development.

INTRODUCTION

The First-To-Fourth Industrial Revolutions

Industrial revolution involves the replacement of one or more previous technologies by new inventions whose use and diffusion will cause a sudden change in human development within a short technological progress period (Sung, 2018). Various literatures have highlighted three previous industrial revolu-

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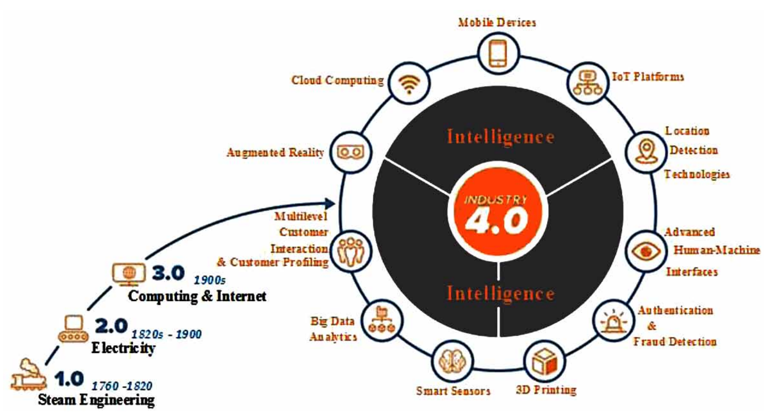
tions, with the fourth already in operation. The first industrial revolution (Industry 1.0) arose towards the windup of the 18th century with the overview of mechanisation through steam and waterpower. The production capacity of various industrial sectors was enhanced through the aid of the mechanised steam engine systems. The second industrial revolution (Industrial 2.0) occurred between the twilight of the 19th century and early 20th century. This phase brought about mass production through electrical energy, the use of conveyor belts, the introduction of telegraph and others. The third industrial revolution, also known as Industry 3.0 brought about automation, the use of electronic devices, computer and information technology. It was consummated in the 1970s from the events of the middle of the 20th century. During this phase, digital advancement was steep. Automation and information technology were the crucial drivers of the economy in the extracting, manufacturing, processing and engineering services (Sung, 2018). The industrial progression from the start of the first industrial revolution through the third industrial revolution spanned over about twenty-five decades. Today, the era of cyber-physical systems known as the fourth industrial revolution otherwise called industry 4.0 or 4IR is in place. It is the era of integrating the real physical to the virtual worlds through technology. The industrial revolution transit from industry 1.0 to Industry 4.0 and the features of each era are as illustrated in Figure 1(ICT works, 2019).

Figure 1. First – Fourth Industrial Revolutions and the Features



The fourth industrial revolution (4IR) is an emerging concept that effect rapid changes in how people live and transact, through disruptive demand-driven business models and supply-driven technological inventions. Germany federal government introduced a high-tech strategy termed 'Industry 4.0' in 2011, which later led to the theme 'Fourth industrial revolution (4IR)' in Davos, Switzerland in 2016. At the World Economic Forum (WEF) annual meeting in 2016, 4IR was argued by its founder and chairman Klaus Schwab, to have arrived as a revolution with entirely different scope and influence, from the previous industrial revolutions. The presentation of the term 'Fourth Industrial Revolution' in his paper has earned him the entitlement of introducing the 4IR. However, the University of Stellenburg Business School (2017) has noted that the term can actually be traced to Rostow (1983), an essay paper presented by W. W. Rostow in 1983.

The scope of coverage of 4IR is far bigger than just the application of technology in the various aspects of our societal development. It is a key component of our immediate future. The concept and the defining terms are still relatively new, and not clearly defined yet. As also reported about other industrial revolutions at the early stage, the concept of 4IR is still evolving; while individual, industries and policymakers are already exploring the economic opportunities within (Sung, 2018). Despite the description by the British House of Commons that the 4IR is a vaguely defined term with potentially vivid effects on the society and its economy (House of Commons Library, 2019), the 4IR has distinct features separating it from the earlier revolutions. The concurrent, real-time and trending breakthrough in the technological revolution in various sectors is an affirmation of the workings of 4IR. Nanotechnology is replacing gene sequencing. Quantum computing is substituting renewable. 4IR has evolved from the integration of these technologies over diverse and multi-related fields. The potential of 4IR technologies is capable of interconnecting vast population together through the internet, to drastically cause improvement in environment, business efficiency, asset management, organizational uptime and others. 4IR is orbiting the world away from the basic system automation, use of electronic devices, computer and information technology, to a merge of the virtual and the physical worlds. The fusion in the 4IR era will be facilitated by interoperability, autonomy, and advanced artificial intelligence (Schwab, 2016; Hwang, 2016). The distinct features of 4IR are summarized to incorporate digital, physical and biological technology advances, integrate the advances through the internet for rapid technological revolution globally at low cost, and create a very broad spectrum of influence on human life (Li, Hou, & Wu, 2017).

Within the next decade, the technologies to remodel human development and transform the society are still emerging, and are mostly experimental archetypes. The convergence of these technologies is the enabling instrument of development in the 4IR. These technologies include, but not limited to the machine learning, internet of things (IoT), advanced artificial intelligence (AI), nanotechnology, smart materials, 3-D printing, transport technology, bio-informatics and bio-fabrication, robotics, rapid prototyping technologies, and Block chain (University of Stellenburg Business school, 2017; Schwab, 2016). 4IR has presently introduced practical changes to the economic and social aspect of human lives through technological transformation. Cyber-physical systems have brought about the integration of the people to utilise the hardware and software, and the virtual technologies in getting all production and servicing done (Brynjolfsson & McAfee, 2014; Kuruczzleki, Pelle, Laczi & Fekete, 2016). Klaus Schwab had categorised the enabling technologies under the distinct features of 4IR. Physical technologies include robotics, 3-D printing, autonomous vehicles, new materials and others. Digital technologies are, but not limited to Block chain, IoT, Bitcoin, and others. Biological technologies include embedded devices, genetic sequencing, 3D printing, synthetic biology, genetic modification.4IR will open plenty of opportunities, but with the inevitable challenges of strategic complexity, occasioned by the uncertainty that always comes with new technological innovations. In observing the opportunities and the challenges in the 4IR, three broad categories have been identified. First, digital technological advancement has defined humanity. Second, digital technological advancement has brought immense benefits to humanity. Third, digital technological advancement has embedded challenges and downsides to its benefits to humanity (Schwab, 2016; Baldassari & Roux, 2017).

The fourth industrial revolution is a prospective innovation path for human life to possibly replace human intelligence and manual labor with artificial intelligence and robotics. The concept of 4IR is being embraced and applied in all sectors of human life. The academics are researching intensely into the revolution, while industry captain braces up to the inevitable and fast implementation in energy, automobile, telecommunication, services, security, medicine, and other industrial sectors (Sung, 2018). Agriculture and food sector, which is termed food 4.0, being the highest employer of human resources, is a major sector that is expected to benefit tremendously from the concept and application of 4IR in driving the sector into the new era of development.

Industrial Revolutions and Food

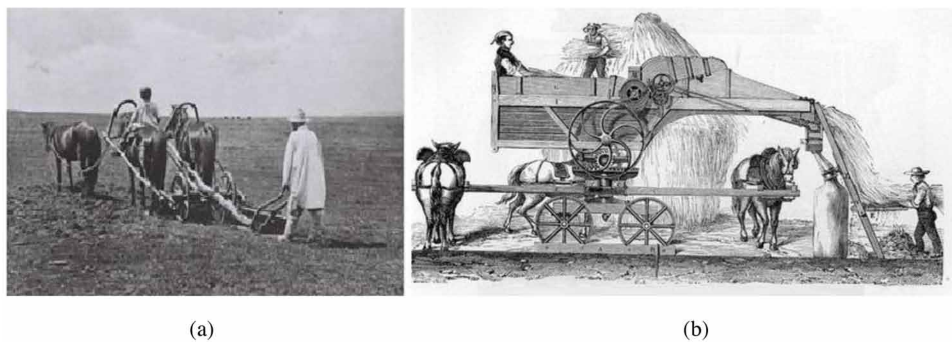
Over the industrial revolution years, the food sector is arguably the most critical industry for the global economic development and live support of the people. The continuous increase in the world population leads to a corresponding concern on the food production. The past half-century has experienced significant food growth, but not without a critical challenge of producing food for about nine billion people in the mid-21st century. A recent report indicated an estimation of 75% to 100% increase in food production will be needed for the demand increase without a significant price surge. In most countries, the percentage of the manufacturing value-added and the gross domestic product (GDP) depending on this food sector is very high (Miranda, Ponce, Molina & Wright, 2019; FAO, 2017; Burwood – Taylor, 2017). The level of importance of the sector has therefore made the challenges faced by it, a global and critical issue.

The challenges are mostly related to increased food demand, environmental protection, food security, climate change, government policies, market and trading issues among others (Retief, Bond, Pope, Morrison - Saunders & King, 2016; OECD, 2016). The food industries are constantly implementing new approaches to combating these challenges to remain afloat and market competitive. These approaches have been consistently about improving technological expertise in line with the industrial revolution at the time. However, a major resulting task in the sector is the necessary high cost in adopting the novel technologies by the small-scale and medium-scale farmers in the developing countries. The components of the revolutions in the food sector can be described from the formative of the success of the early man in transforming from the hunted to the hunter, through food fabrication instinct (Miranda, *et al.,* 2019; Skolnik, 1968). Across the industrialisation eras, there have always been three cardinal functions being provided by agriculture and food sector: increasing the production and productivity in order to feed the teeming non-agricultural population, making the potential workers necessary for industries and towns available in surplus, and providing capital accumulation to be applied in the other modern sectors of the economy.

Food in Industry 1.0

In the course of history, the manufacturing industry has always been the enabler of the evolution in the food industry through its technological development. Industry 1.0, which is sometimes collectively referred to as the 'Agricultural Revolution' was the period of advances in the food processing industrialisation, occasioned specifically through system mechanisation and steam engine applications. In the early period, horsepower as illustrated in Figure 2 enabled food cultivation and processing. The substantial changes in the agriculture sector from the mid-1600s within Great Britain paved the way for the revolution. During the period, changes through technology and capital investment were modest until the mid-1840s when maturity was attained in agricultural science and engineering. Earlier in the mid-1750s, Britain had a lower than two-third of agricultural share through the working population in farming, relative to other European countries. Enclosure Acts were enacted by the British parliament, which transferred the ownership and tenancy of farmlands by the small-scale farmers to wealthy landowners. The singular event resulted in the mass migration of some previous farmers to the cities and abroad, thereby creating a drastic reduction in the farming workforce and food production in the rural ends, but increased the industrial operational class in the cities. Consequently, the period profited from the new commercial methods of farming through improved crop management, also known as the four-field system. Crops are rotated on the farmland each passing season in order not to leave any field fallow but maintaining a high deposit of minerals and nutrients in an approach.

Figure 2. Food revolution by horsepower during Industry 1.0, (a) Cultivation, (b) Processing (Johnson, et al., 1941; Kamminga, 1995).



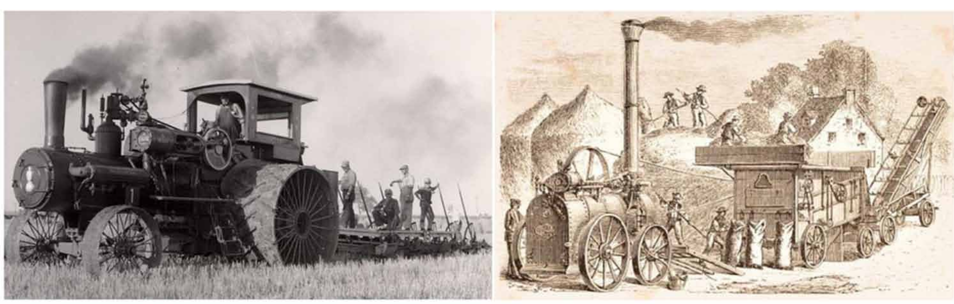
In addition, between 1800 and 1850, there was an aggressive introduction of farming machinery for more efficient and profitable farming. The machinery cut across all the aspects of food production, including mechanical seed planters, reapers and harvesters, grain threshers, and others. Besides, the use of fertilizers was introduced to raise the productivity of farmland, which further increased the space of land for food production. Contemporarily within the period, animal food production also experienced a steady rise. New breeds and better approach of rearing livestock were introduced. This led to the production of a stronger, larger and better quality of livestock (University of Stellenburg Business School, 2017; Easton, *et al.,* 2014).

Food in Industry 2.0

In the period of Industry 2.0, the food sector experienced mass production through the electricity-enabled systems. The introduction of the new systems consequently involved the application of new farming methods, which are based on stall-fed animal and fodder crops production. In addition, the use of new tools and implements were necessitated, with the usual challenge of the cost of adopting the new entities. The technological innovations during industry 2.0 were application-specific, mostly dependent on the crop type and environment. Chemically produced fertilizers in commercial proportion improved food crop production during this period. In addition to fertilizer supplements, fungicide and pesticides were introduced through a breakthrough in science and technology. In 1885, Pierre-MarrieMillardet, a French botanist invented a Bordeaux mixture of fungicide to help combat an outbreak of dreadful potato disease in Ireland. However, there was a challenge of a negative effect on food supply due to external influence from other sectors. The adverse effect was grave at the early stage, but food productivity and supply gradually improved within the period (Estadisticas, 2018; Mokyr, 1998).

During Industry 2.0, agriculture and food revolution were slower than most other sectors. Other sectors like manufacturing and engineering experienced localization advantage over the agriculture and food industry. Despite the invention of electricity and steam engine, the types of machinery introduced for food production were still largely dependent on animals for a power source. The benefits of the technological innovation of the steam engine were relatively lost on the agriculture and food sector due to the need for the power sources being situated at the production site. Few sections of the food production slowly enjoyed mechanisation at the early stage. It was reported that in 1977 and 1984 respectively, James Sharp in London built the winnowing machine while Andrew Meikle in Scotland built the threshing machine. Meanwhile, the first tractors with complete internal combustion engines were built and deployed around the Atlantic in 1892 (University of Stellenburg Business school, 2017; Easton *et al.,* 2014; Estadisticas, 2018; and Mokyr, 1998). A mechanized food production system aided by the steam engine is as illustrated in Figure 3.

Figure 3. Food revolution based on steam engine systems, (a) Cultivation, (b) Processing (Baker, 2014).



(a) (b)

Food in Industry 3.0

The revolution in agriculture and food industry during Industry 3.0 happened at the twilight of the 20th century. It was the agricultural revolution, otherwise known as the Green revolution. The period was an era of digital or computer, electronics, semiconductors, robotics and automation revolution, in which specialised pieces of machinery were introduced into the various operational field of agriculture and food production. Tremendous progress and increased productivity were documented in crop techniques, storage processes and livestock production (Miranda, *et al.,* 2019; Estadisticas, 2018). The Western nations were the first to experience technological revolution in agriculture and food, leading to drastic yield increase through mechanised farming and very large livestock production through indoor methods of animal rearing, with a relatively low and hidden cost. The governments supported farmers with the provision of new seedlings, irrigation and chemical inputs, soft loans and increased extension services. There was a deliberate international effort at eradicating hunger and improving food index among nations to meet the food need of the increasing population. The efforts yielded some good results. The United States had the 1966 highest sales in the food industry with a total sum of $77.85 billion in the year (Skolnik, 1968).

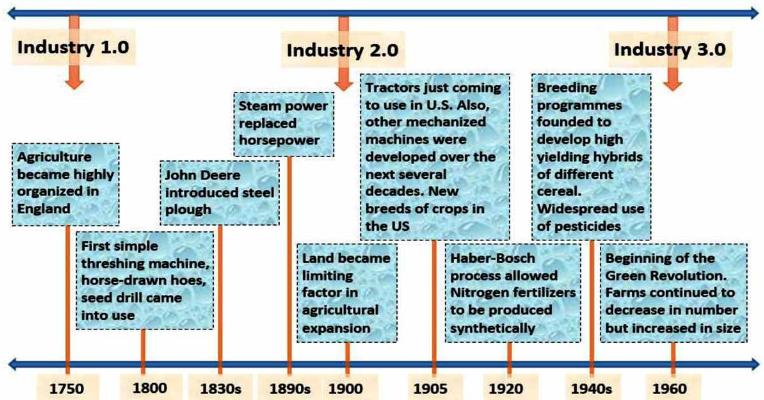
Across the period of Industry 3.0, agriculture and food undertook rapid technological advancement. The famous genetically modification of crop and plant cell was introduced in 1982 by Monsanto Company. The first experimental specimen was the tomato crop that was resistant species to insects and herbicides. In addition, the advent of software, information technology and mobile devices had a great impact on the food sector during this period. In 2004, mobile devices began the tools being used by farmers and extension workers to keep colleague in a loop of communication. Food storage, transport and marketing also enjoyed the usage of mobile devices in their enabling systems. The devices help workers to stay connected in and out of the field, with adequate real-time access to information on the seedlings and chemical inputs. These helped farmers to boost their harvest and increase food yields. Also, advancement in information and communication technology (ICT) and the use of mobile devices enhanced newer varieties of crops that are resistant to pests, innovative irrigation technology and improved channels of communication (Baker, 2014). Big data analytics occurred in 2015 and have since been revolutionising the food sector. Data is king, data is a beautiful bride. Farmers and food workers could now apply data in making informed decisions and avert losses through sustainable use of resources. A typical example is a digital platform by Climate Field-View, which incorporates a collection of data, agronomic modelling, monitoring of local weather, and a better field knowledge by the farmers. The platform is an enabler of environmental-friendly decisions and a planner for a good harvest by the farmer (FAO, 2014). Summarily, the food industry experienced a bridged gap in its knowledge and information deficit through linkage of knowledge and innovation by ICT infrastructures. In the same year of big data introduction, mobile phone applications greatly aided information exchange for pest tracking and disease surveillance (Piper, 2017; FAO, 2015).

The success of the food sector during Industry 3.0 was not absolute, as there was also a plethora of challenges during the period. The first setback was the uneven distribution of the feats achieved from one place to the other. Increased food production in some places was rapid and high, while other places experienced a slow increase. The increase in incentivized reduction in hunger, but famine was still present. In addition, the increased food production involved a higher cost of production and increased environmental degradation leading to climate change. Another challenge in the farming communities was the diminishing arable lands, coupled with the evolution of resistant pests and diseases, arising rather more difficult farming practices. In effect, technological advancement in the sector was not the haven guarantee for food supply, food security, even distribution of wealth and sustainable ecosystem. Therefore, the nexus of the challenges within the successes inevitably drew out the birth of the next food revolution called Food 4.0. The timeline of the food revolutions across the period of Industry 1.0 to industry 3.0 is as shown in Figure 4.

Food in Industry 4.0

The agriculture and food sector is currently motivated by the techniques, methods, technologies, and strategies within the Industry 4.0. Presently, the food sector takes advantage of modern machinery, tools and emerging ICTs that consider the Internet of Things (IoT) capabilities. The relevance of the fourth industrial revolution (4IR) to the development of the agriculture and food industry, the implementations have given way to a new era of food production called Food 4.0, where automation, connectivity, digitalisation, the use of renewable energies and the efficient use of resources are predominant (Miranda, *et al.,* 2019).

Figure 4. Timeline for First – Third Food Revolution

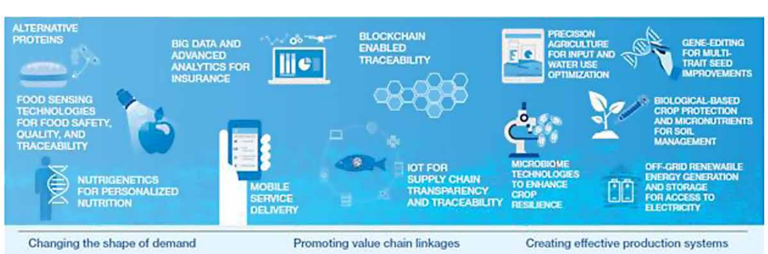


The era of 4IR is for cyber-physical systems. The benefits of 4IR by the precision and food production systems are enormous, with beneficial technologies including smart sensors, robots, intelligent greenhouses, drones, vertical farms, wireless sensor networks and others. Digitisation and modern devices are other upbeats of the 4IR, with crucial emphasis on the economic, social and environmental issues in the food production sector. The targets within the sector focus on optimizing water, fuel and chemical usage, cost, and renewable energies application (Yahya, 2018).

Before the advent of 4IR, development in agriculture and food had been largely influenced by chance. The sector development had been a case of art based on generation and civilisation shifts. The technological advancement in the sector had been relatively slow, but adequately delineated and progressively evolved on a successor basis. The 4IR is unique, both in concept and in applications. Food 4.0 is therefore already situated to enjoy the tremendous benefit from the components of the revolution. The focuses of the food industry in the 4IR are the components related to planning, direction, emphasis on effort and money. Food 4.0 is consequent upon the need to curb hunger and famine and make affordable food available to the projected booming world population (Skolnik, 1968).

The food industry is projected to advance into a high-tech sector in which all the sections are integrated with the technologies like artificial intelligence (AI), IoT, robotics, big data and others. Agricultural systems will be merged into a singular unit with farm machinery; farm management, irrigation, and production forecasting are converged together. The evolution will perfuse the multifaceted social, economic, and

Figure 5. The combinations of 4IR technologies to enable innovations in the food sector (World Economic Forum, 2018).



ethical values alongside the different industries, and is expressed as business models. The combinations of 4IR technologies will create three major impacts in the food sector as illustrated in Figure 5.

Precise optimization will enhance solutions to many challenges, especially in the area of food waste. The representative nature of the agriculture industry indicates inconsistency in the inputs and outputs. The FAO white paper shows that the actual volume of food produced globally is enough to feed the world population. However, many people still die of hunger due to the level of waste in food production. Approximately, 80% of the total produced water is applied to farming, about 20% of the viable crop is cultivated, and the remaining water and about 35 – 50% of the produced food is wasted. In addition, rural production elements and human resources reversion will be another impactful factor in agriculture and food production. During the previous industrial revolutions (especially Industry 2.0), there was massive rural to urban migration of the workforce. During 4IR, the workforce in the cities would prefer rural labour due to space for relaxation. So, labour, capital and technological resources that abandoned farming villages previously would make a return during the current revolution (World Economic Forum, 2018). Besides, our environment will enjoy a better friendly relationship with the processes of Food 4.0. The technologies of the 4IR will allow the food production process to benefit from definite and accurate prediction and control of the weather. The food systems will not be subjected to chance of nature and human wisdom, as the innovations in 4IR will enable a greater level of decision-making and applications. The challenges of resistant pest and diseases due to climate change, as well as the high cost of livestock processing and production experienced in the immediate previous revolution, will be eliminated in the current era. Summarily, the 4IR, an eco-friendly and agro-friendly industrial revolution is here (Sung, 2018; Skolnik, 1968). The revolution in the food systems as depicted in this book is very relevant to all the sustainable development goals as illustrated in Table II.

The Need and Adaptation of Food 4.0

The key message of Food 4.0 is that 4IR creates a good opportunity for the food industry to advance into a 'Food Renaissance' desired state. This is a state whereby the role players adopt the technologies, which among others include precision agriculture, smart farming, robotics, artificial intelligence, genetics and big data analytics. The technologies enable increased information access by the customers in regards of farming practices, help to create conducive and commercially sustainable working conditions for small-scale farmers, and bring about the repositioning of the food and agricultural brands in the current industrial revolution. The entire food value chain has information available to the consumers, whereby they can even change the demand for a particular product based on nutrition and quality concerns, chemical use, origin traceability and antibiotics in livestock processing. The requirement for the demands is an investment in the new technologies. The impetus for the smallholder farmers deals with a gestation period to focus on productive mindset creation and new entrants' development; family practices and technology, skill development through mentoring, business expertise development, and creation of funding alternatives for the role holders. Also, agriculture and the food industry need strategic branding to attract young talents to have a career path in the field (World Economic Forum, 2018).

In the present era, humanity perceptions are expected to shift due to increasing augmented intelligence, personality embedded machines, renewed and regrown tissue, augmented musculoskeletal systems and responsive brains to artificial stimuli. The simple observation is that disruptive models of businesses can be proliferated when enabled by disruptive technologies. The new models cause the required novel rapid change in nature, work value and location. However, the different regions and countries are not

Table 1. Relevance of food systems to the sustainable development goals

	SDG Goals	Description
1	No poverty	About 80% of the global poor people live in remote areas and are employed in agriculture
2	Zero hunger	The volume of food production can sufficiently feed the world population, but about 800 million are in critical starvation
3	Good health and well being	Malnutrition is the main contributor to the global disease in which about 4 billion people can be categorized as overweight or micronutrient deficient
4	Quality education	Malnutrition affects 25% of the world children under 5 years of age, which consequently impair brain development and reduce school performance
5	Gender equality	Women cater to about 43% of the agricultural workforce, yet there is unequal access to technology, land, markets and other resources
6	Clean water and sanitation	Presently, food systems cover 72% of freshwater extractions (Hwang, 2016).
7	Affordable and clean energy	Modern food production heavily depends on fossil fuel and consumes about 30% of global available energy (Li, Hou, & Wu, 2017).
8	Decent economic and work growth	Agriculture has the largest global workforce. It employs about 60% of workers in developing countries (Brynjolfsson & McAFee, 2014).
9	Industry, Innovation and Infrastructure	Majority of about 900 million people in the rural communities work in agriculture and don't access to electricity (Kuruczzleki *et al.,* 2016).
10	Reduced Inequalities	70% of people are living in countries with little or no regard for equality in the last 30 years. Accessibility to healthy food is a product of equality
11	Sustainable cities and communities	In the year 2030, almost 60% of the global population will reside in the urban cities, with attendant changes in consumer demand and increased pressure on resources
12	Liable consumption and production	About 35% of the world food production, amounting to 1.3 billion tons is discarded or wasted.
13	Climate action	20 – 30% of global emissions which contribute to climate change is caused by food systems. Climate change is projected to cause a reduction in food yields by 25%
14	Life below water	17% of global protein intake on animals comes from fish, with 30% of fish stocks already wrecked.
15	Life on land	Agriculture contributes significantly to deforestation accounting for 51% as from 2015
16	Peace, Justice and Strong Institutions, Peace and Justice	The consequence of conflict can be observed on food security as the number of undernourished people increased from 777 million to 815 million in 2015 and 2016 respectively
17	Partnerships for the goals	Through partnerships, food systems can be transformed by unlocking annual opportunities worth $2.3 trillion in the private sector in the year 2030

(Pereira, Feddes & Gilley, 1996)

concurrently adapting and responding to the new revolution as quickly as needed. North America and Europe are far ahead of the regions in Australia. The Australia food-manufacturing sector has a relatively low awareness concerning the impact of 4IR on their various businesses. The operations middle level of the businesses has generally low level of digitalization, thereby raising the concern of sluggishness in the food industry. Mostly, the focus has been built around the existing industry 3.0 initiatives in digitalization for labor savings, waste reduction, improved instant visibility, data warehousing and quality management. Most manufacturers of food ingredients acquire large process data from SCADA systems, with little or no capacity to analyze them. Therefore, there was a loss in opportunities for machine learning and process analysis in characterizing process behavior and improving the drive process (Corallo, Latino & Menegoh, 2018).

To create the needed environment for Food 4.0, there should be simultaneous maturity for the people, technology, process and the structure. The requirements for maturity level lifting should include a board-level commitment, establishing a business strategy for innovation, agility, and adaptability to the swiftly changing market dynamics and new models, which can leverage on to emerging technologies. The hard work in the operations management should be inclusive of establishing digitalized planning as well as control systems that include fixed capacity scheduling. Also, it ensures that production processes are driven by customer demand and there is optimal availability of the production resources. The food manufacturing process should be standardized for repeatability and able to capture the workflows instruction to eliminate dependence on implicit knowledge, which subsequently opposes a well-controlled market-responsive invention formulation, handling and configuration. Therefore, the processes and recipes of the success of Food 4.0 cannot be subjected to the cultured operator practice.

The Food 4.0 has, therefore, indicated the necessity for tertiary institutions to rework their curricula towards adding technologies, theory and skills of 4IR, and engage in food training, education and technologies. This is with a clear objective of creating competitive advantages in the window of first adopters. According to Cyril Ramaphosa, President of South Africa, the prosperity of any nation depends on its ability to advance technological change, and develop the need and capabilities in science, innovation and technology. Leadership is needed to create the future desired (University of Stellenburg Business School, 2017). This book aims at providing a general and strategic outlook of the future and prospect of the food system (Food 4.0) in 4IR (Industry 4.0). It does not focus on developing any new theory, but galvanizing the research focus around the opportunities for the food industry in the era of cyber-physical systems. The overview of the food revolution is depicted in information and process transparency, data management, and food safety.

Information and Process Transparency

A major required effort in the area of food revolution is the management of information and process transparency. Lately, consumers have been greatly conscious of the impact of the various levels of the food chain on their health. Consumers now increasingly demand information about the safety, origin, with the sustainability and traceability of the process that produces and delivers their food. They now most often build food quality, environmental conformity and safety within their purchasing decisions. Meanwhile, researches are rife to determine the willingness of consumers to pay a higher cost for sustainable food products. The changing demand of the consumers is now a factor within the food industry to ensure transparency and sustainability of food information and processes (Miranda, *et al.,* 2019; Wognum, Bremmers, Trienekens, Vander Vorst & Bloemhof, 2011).

Sharing of product information is a very crucial and integral task in the food industry. Food organizations and manufacturers are required by global compliance to make the key information about products available to all parties. Food 4.0, therefore, allows cyber-physical systems and technologies to be integrated with making the manufacturers able to effectively share the needed data of their products. A major trademark of Food 4.0 is intersection and collaboration of technologies and systems. Stakeholders within the food chain will be able to access all data about a product on various virtual platforms, starting at raw material specification stage to the last finished product. Information is acquired through big and high-quality data using analytics, form the baseline performance consistently and transparently.

Decision making through the data allows the digital baseline to be used for establishing continuous improvement exercise and predicting future performance (FAO, 2015; Wognum, *et al.,* 2011 and World Economic Forum, 2019a).

a. Traceability-induced Transparency

Transparency of the food chain refers to the shared understanding of information and the access to it about products as requested by the stakeholders, without any attendant delay, noise, or distortion. Traceability is the process of making visible, the 'invisible' in the food systems. Traceability initiatives are, therefore, a crucial differentiator among food industry players by aggregating the volume of information consumers are availed. Intending to meet the transparency demand of the consumers, traceability helps to facilitate a wide-ranging tracking on the health, economic, social and environmental consequences of various food production processes and calculating the actual food cost. Traceability-based transparency allows food producers to connect potential efficiencies, which could include fresh value sources and cost savings. Transparency in the food chain can be increased through the effect of traceability in meeting consumer demand on the food information and processes; enhancing the possibility of identifying, responding and preventing safety issues in the food system; supporting food chain optimization and reduction of food losses, and validating claims in support of the sustainability goals. For instance, the cost of production and the volume of water expended in growing a crop could be provided to consumers. In addition, companies could market the products and label to verifiable quality and taste. Customer satisfaction is therefore increased and brand loyalty guaranteed through traceability. Traceability builds on the various transformative technologies to provide a foundation for addressing the current challenges in food systems and contribute immensely to advancing sustainable development goals (World Economic Forum, 2019).

b. Transparency for Sustainability

Transparency on data implies that the latter should be accurate, relevant, available and timely in the necessary quantity. In addition, quality information should be readable, and the exchange of information must be properly arranged and reasonable. However, transparency has placed a strict requirement on the communication channels and systems of food supply chain towards stakeholders and consumers. Meanwhile, sustainability in the food industry explains the meeting the present generation needs without hampering the satisfaction of future generations. Sustainability covers the 'planet' (environmental issues), 'people' (social issues of human safety and health), and 'profit' (expected returns). The decision-making and buying behaviour of consumers should be based on the full knowledge of the sustainability of the food chain components: product, companies and processes. So, it implies that there should be adequate transparency in the entire food supply chains (Wognum, *et al.,* 2011).

However, sustainability is a major challenge for large businesses with complex food supply chains. For example, Unilever Plc aimed at sustainability in its production by adopting a 'triple-bottom-line method' in locating its raw materials – an approach to cater to people, environment and its business profits. Though consumer demand preference is a vital factor in sustainability, it is not the only influential issue. Government and other stakeholders like academic researchers and supply chain actors also affect sustainable practices, as government play a key role in environmental matters and policies. Literature works have therefore categorized transparency for sustainability into vertical and horizontal dimensional concerns. While the horizontal dimension refers to the legislation and requirements applicable to the respective businesses in the different food supply chain stages, the vertical dimension concerns the legislation and requirements for companies within a specific food supply chain. Transparency provision is therefore certain in food industries for a sustainable future of food (Wognum, *et al.,* 2011; World Economic Forum, 2019a).

Data Management

Data is a decision component of Food 4.0. The various aspects of human endeavours rely on data to make the decision and evolve development. In the area of agriculture and food, data collection often require the use of smart and autonomous devices. The processing, transmission, storage and interchange of the data outcomes depend largely on inexpensive computational platforms and internet. The food revolution in the present era depends on the data totality and operations at maintaining the required product information at all the sections of the utilization and production chain.

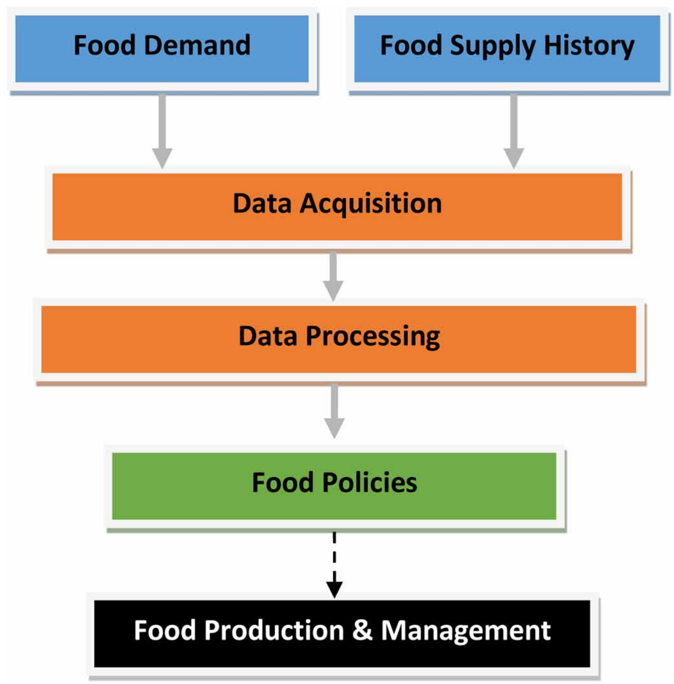
The present industrialization in the food sector will rely heavily on the analytics management and insights implementation of the food business. The integration of the technologies of 4IR and the cyber-physical systems will give huge data access for the revolution and development required in the food sector. Future demand and supply projections of food can be effectively made through the integration of the present data on demand requirements and supply history of food. Data sharing can be facilitated by the incorporation of interconnected systems, which are capable of creating compound touch-points. The increased information accessibility will, therefore, enable the streamlining of the business insights generation and data analysis.

However, the challenges of effectively managing data in the digital space are potent and relevant. The 4IR and Food 4.0 are just starting, and being confronted with strategic and operational challenges within the component organizations. Data security is the major challenge being presently researched within the implementation of Food 4.0. The challenge lies in the capacity to make proprietary operative knowledge secured. There are great risks, but there are greater rewards. Data will be more secured by restricting the accessibility of personnel to specific data (FAO, 2014; SpecPage, 2019). The typical data flow management in the food sector is as shown in Figure 6.

Food Safety

A critical issue in Food 4.0 is how to ensure the safety of food, even as the accelerating leap of technological change in 4IR is also introducing different complexities and challenges. The estimation by the World Health Organization (WHO) has put about 1 in 10 people falling sick and 420,000 die each year as a result of contaminated foods. The severity and prevalence of death due to food safety risks are relatively higher in the developing markets, with about 1 in 3 of global cases occurring in Africa. This has therefore made food safety a global critical concern. For instance, it is estimated that about 48 million people fall ill each year in the US due to food-borne diseases, and the trade restrictions by the International Trade Commission for "mad-cow disease" cost US beef companies about $1.5 billion to $2.7 between the year 2004 and 2007. The economic implication of the major food-borne diseases in the US has been estimated at $15.5 billion, a comparatively lower challenge to the overall food industry contribution size of $992 billion to the US GDP. However, the safety risk it still portends to the economy and public health is critical (World Economic Forum, 2019a).

Figure 6. Data Flow Management in a Food Sector



Technology is no exception to the possibility of problems associated with whatever brings opportunities. In the present food era, the food industry has to cope with many changes in its operational strata. For instance, the methods of mixing of ingredients will experience a precipitate change. Cyber-physical systems and technologies have created limelight for synthetic foods with its enabling the production of edible and safe synthetic materials. In enjoying the benefits of Food 4.0, the way foods are farmed, sourced, manufactured, and safely delivered to the consumers cannot be guaranteed through technology only. Sustainable production methods can support technology to ensure food safety. Effective preventative procedures will serve a crucial role in reducing food contaminants prevalence. The efficient tracking system will ensure the good and easy charting of the incoming materials and a recall of faulty products. Also, companies and organizations will meet their compliance requirements easier, by reflecting on the value of the customers through the aid of the sustainable practices (World Economic Forum, 2019a; World Economic Forum 2019b).

a. Traceability for Food Safety

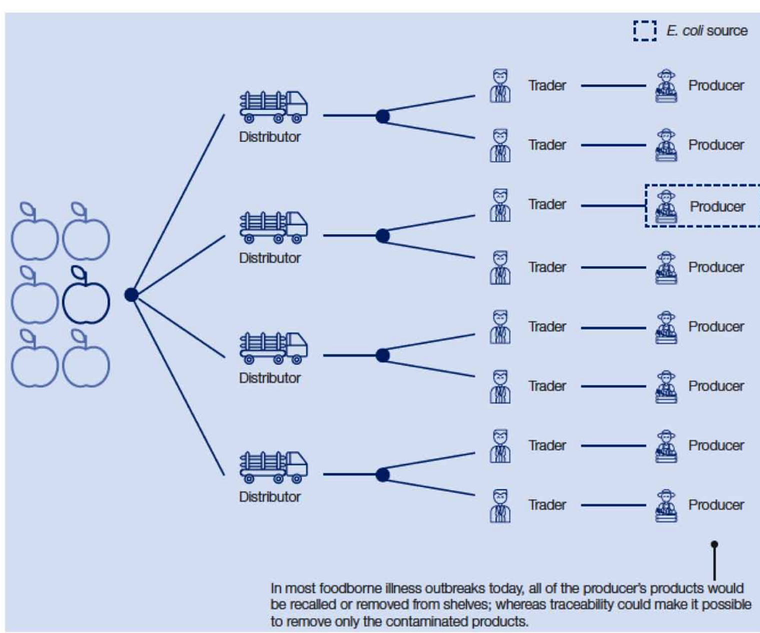
Traceability is vital to efficient identifying, isolating and source sorting for food safety cases. The method becomes very beneficial, as it gives better inspection output, prevalence reduction and minimizing cost for product recalls. The food-borne diseases will not be eradicated by the aid of traceability alone, but traceability will help the industry and governments to address food safety issues precisely. Product recall due to food safety issues is not common but it has a huge impact on the capital implication of the food industry. A recent survey showed that financial risks arising from product recalls are 81% "significant to disastrous", 58% people had been affected in the past 5 years by a product recall, and 23% of people incurred an estimated cost of $30 million in both sales losses and direct recall (Grocery Manufacturers Association, 2011).

The application of traceability will ensure more efficient, faster, and more realistic source sorting for food contamination, thereby affecting positively on the reduction of food safety risks. Lately, the processes are costly and time-consuming. The record of *E coli*disease outbreak from romaine lettuce in Yuma region for the year 2018 spanned three months of the resolution, with 210 sick persons, 96 hospitalized, and 5 deaths. The 4IR technologies like distributed ledger and IoT will help in improving the safety of consumers across the food value chains and reduce the financial risk, as only the adulterated product is expunged instead of the recall for the entire same products The traceability for food safety is illustrated in Figure 7 (World Economic Forum, 2019a; US Food and Drug, 2018).

b. Predictive Analytics for Food Safety

Artificial intelligence is a technology in the 4IR that has enabled tremendous grown in the way data are measured, stored and manipulated, even beyond human skills. With available and sufficient data, future outcomes of a process can be confidently and accurately predicted. It has previously been stated that the food sector lagged in adopting technologies being embraced in other sectors during industrial revolutions. Predictive analytics is already a common use in sectors like public policy, fleet management and insurance; with food industry just being introduced to it like other wearable technologies. Across developed economies, and even in the developing ones, the food business is fast growing with relatively proportionate increased in customer complaints and a remarkable drop in the food hygiene regulators. The feasible approach is by adopting predictive analytics. Authorities in Chicago, United States have demonstrated the efficacy of the predictive analytics to accurately forecast major risk in a food business

Figure 7. Traceability-Enabled Identification of a Contaminated Source
(World Economic Forum, 2019a)



that is failing safety audit, and offer the needed pre-emptive action (World Economic Forum, 2019a; Chester, 2017).

REFERENCES

Baker, A. (2019). *How were Steam Engines used in agriculture?* Available: https://www.bressingham.co.uk/blog/posts/2014/how-were-steam-engines-used-in-agriculture.aspx

Baldassari, P., & Roux, J. D. (2017). Industry 4.0: Preparing for the future of work. *People Strateg.*, *40*(3), 20–23.

Brynjolfsson, A., & McAfee, E. (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*. W.W. Norton & Company.

Burwood-Taylor, L. (2017). *What is AgriFood Tech?* Academic Press.

Chester, R. (2017). *The future of food safety: the revolution is on our doorsteps*. Available: https://www.newfoodmagazine.com/article/41390/future-food-safety-revolution-doorsteps/

Corallo, A., Latino, M. E., & Menegoli, M. (2018). From Industry 4.0 to Agriculture 4.0: A Framework to Manage Product Data in Agri-Food Supply Chain for Voluntary Traceability. *Int. J. Nutr. Food Eng.*, *12*(5), 146–150.

Easton, K. M., Carrodus, G., Delaney, T., Howitt, B., Smith, R., Butler, H., & McArthur. (2014). Oxford big ideas geography. Oxford University Press.

Estadísticas del agua en. (2018). *Statistics of water in Mexico*. Available: http://sina.conagua.gob.mx/publicaciones/EAM_2018.pdf

FAO. (2014). *Information and communication technologies for sustainable agriculture: Indicators from Asia and the Pacific*. FAO.

FAO. (2015). *Success stories on information and communication technologies for agriculture and rural development.* Available: http://www.fao.org/3/a-i4622e.pdf

FAO. (2017). *The State of Food and Agriculture, Leveraging Food Systems for Inclusive Rural Transformation.* Available: https://www.fao.org/3/a-i7658e.pdf

US Food and Drug. (2018). *FDA Investigated Multistate Outbreak of E. coli O157: H7 Infections Linked to Romaine Lettuce from Yuma Growing Region*. Author.

Grocery Manufacturers Association. (2011). *Capturing Recall Costs: Measuring and Recovering the Losses.* Available: https://www.gmaonline.org/file-manager/ images/gmapublications/Capturing_Recall_Costs_GMA_Whitepaper_FINAL.pdf

House of Commons Library. (2019). *Fourth industrial revolution*. Available: https://researchbriefings.files.parliament.uk/documents/CDP-2016-0153/CDP-2016-0153.pdf

Hwang, J. S. (2016). *The fourth industrial revolution (industry 4.0): intelligent manufacturing*. SMT.

Johnson, E. A. J. (1941). Economic History Association. *The Journal of Economic History*, 1941.

Kamminga, H. (1995). The Science and Culture of Nutrition. Rodopi.

Kuruczleki, E., Pelle, A., Laczi, R., & Fekete, B. (2016). The Readiness of the European Union to Embrace the Fourth Industrial Revolution. *Manag.*, *11*(4), 2016.

Li, G., Hou, Y., & Wu, A. (2017). Fourth Industrial Revolution: Technological drivers, impacts and coping methods. *Chinese Geographical Science*, *27*(4), 626–637. doi:10.100711769-017-0890-x

Miranda, J., Ponce, P., Molina, A., & Wright, P. (2019). Sensing, smart and sustainable technologies for Agri-Food 4.0. *Computers in Industry*, *108*, 21–36. doi:10.1016/j.compind.2019.02.002

Mokyr, J. (1998). The second industrial revolution, 1870-1914. Stor. Dell economia Mond., 219–245.

OECD. (2016). OECD Science, Technology and Innovation Outlook 2016: Megatrends affecting Science. *Technology and Innovation*.

Pereira, Feddes, & Gilley. (1996). *Sustainability of irrigated agriculture*. Academic Press.

Piper, B. (2019). *How technology has changed farming*. Available: monsanto.com/innovations/data-science/articles/agricultural-technology-innovations

Retief, F., Bond, A., Pope, J., Morrison-Saunders, A., & King, N. (2016). Global megatrends and their implications for environmental assessment practice. *Environmental Impact Assessment Review*, *61*, 52–60. doi:10.1016/j.eiar.2016.07.002

Rostow, W. W. (1983). Technology and unemployment in the Western world. *The Challenge (Karachi)*, *26*(1), 6–17. doi:10.1080/05775132.1983.11470821

Schwab, K. (2016). The fourth industrial revolution. Geneva, Switzerland. *World Economic Forum*.

Skolnik, H. (1968). History, Evolution, and Status of Agriculture and Food Science and Technology. *Journal of Chemical Documentation*, *8*(2), 95–98. doi:10.1021/c160029a011

SpecPage. (2019). *Food Industry 4.0 – Revolution or Evolution?* Available: https://www.specpage.com/food-industry-4-0-revolution-evolution/

Sung, J. (2018). The Fourth Industrial Revolution and Precision Agriculture. *Autom. Agric. Secur. Food Supplies Futur. Gener.*, 1.

University of Stellenburg Business School. (2017a). The Future Of The Western Cape Agricultural Sector In The Context Of The 4th Industrial Revolution, Review. *The Fourth Industrial Revolution (4IR),* 1–21.

University of Stellenburg Business School. (2017b). The Future of the Western Cape Agricultural Sector in the Context Of The 4th Industrial Revolution, Review. In *Agriculture in 4IR & its drivers – A global perspective*. Author.

Wognum, P. M. N., Bremmers, H., Trienekens, J. H., van der Vorst, J. G. A. J., & Bloemhof, J. M. (2011). Systems for sustainability and transparency of food supply chains—Current status and challenges. *Advanced Engineering Informatics*, *25*(1), 65–76. doi:10.1016/j.aei.2010.06.001

Works, I. C. T. (2019). *5 Problems with 4th Industrial Revolution – Your Weekend Long Reads*. Available: https://www.ictworks.org/problems-fourth-industrial-revolution

World Economic Forum. (2018). System Initiative on Shaping the Future of Food Security and Agriculture: Innovation with a purpose, the role of technology innovation in accelerating food systems transformation. Author.

World Economic Forum. (2019a). *System Initiative on Shaping the Future of Food, Innovation with a purpose, Improving Traceability in Food Value Chains through Technology Innovations*. Author.

World Economic Forum. (2019b). *The fourth industrial revolution food systems are ripe for technology disruption*. Available: https://www.fodnavigator.com/article/2019/01/23/

Yahya, N., (2018). Agricultural 4.0: Its implementation toward future sustainability. In *Green Urea*. Springer.

Chapter 7
Emerging Technological Model to Sustainable Agriculture

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ABSTRACT

The agricultural sector has witnessed significant technological transformations over the last few decades. The state-of-the-art technologies are transforming the traditional agriculture models into digital agriculture. From these technologies, conventional agriculture has evolved and shifted towards a smart agriculture system. In a smart agriculture system, farmers can collect and analyze the collected data to fertilize and tend their crops. The smart agriculture system provides economical and more accurate ways to predict and protect crop growth. The incorporation of these technologies digitalizes the agricultural industry by increasing profits, reducing waste, improving efficiency, and becoming sustainable. This chapter aims to study the state-of-the-art technologies used in the agriculture sector and proposes a smart agriculture model using these technologies.

1. INTRODUCTION

Agriculture is the oldest industry in civilization in the world. Recently, it is disrupted by digitization and modern technologies. With current technologies, formers can increase the chances of facing diseases, unpredictable weather, and pandemics. Growing and providing food for an increasing global population is a new challenge today.This issue needs to increase food supply to the growing community and ensure food security. With the rising population worldwide, food production and farming need to get

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increasingly productive and capable of high yields in a limited time. To meet these demands, farmers and agricultural organizations have to push their current practices' innovation limits.

There is a need for a resource with an efficient food production system that takes into consideration the aspect of *sustainability*. For example, efficient water use reduces soil erosion, ensures minimum degradation, and minimizes energy input. According to Melanie McMullen, 2017 the most significant challenges in today agriculture include

- Farmers have inadequate training and the use of modern technologies.
- Most agricultural companies are small, with fewer employees.
- The fields are located far away from farmers' homes.
- Global warming makes temperature, weather, and climate conditions less predictable.
- The growers have fewer budgets to carry out the technologies on their annual profit.
- The pests can ruin an entire crop.

A low level of digital knowledge and skills can create a significant gap benefitting from the modern agriculture revolution in the existing infrastructure. These conditions allowintroducing different models in incorporating digital technologies into agriculture. Every farmer hopes to achieve all his or hergoals at the minimum cost and period. However, such purposes post some of the requirements, which cannot be fulfilled through traditional agricultural methods.

Motivation

For example, in the agriculture system, sowing seeds is a laborious manual task. This task often uses a scattered method by a human. This method can be inaccurate and wasteful when seeds fall outside the optimal locality. Hence, it requires an effective seeding method of planting seeds to allow optimal plant growth.

Modern agriculture replaces the scatter method with seeding machines, covering more space faster than a human can. Precision seeding equipment is designed with various factors (i.e., combineGeomapping, sensor data, soil quality, density, moisture, and nutrient levels) that takes a ton of the cultivating cycle's mystery. Seeds get the opportunity to grow and develop, and the general yield may have a superior reap.

As traditional cultivating moves into the future, existing exactness seeders may accompany self-ruling work vehicles and innovation empowered frameworks. A whole field might be planted with single human observing the cycle over a computerized control while numerous machines move over the region.

Innovation in Agriculture

With the expansion in food requests and the requirement for supportability in agribusiness, the ranchers and the partners need to put a ton in information and more mechanized farming machines and gadgets. In the modern world, "*how to increase the quantity and quality of agricultural products*"meets the increasing populations worldwide with less cost and time. The answer is using state-of-the-art technologies in agriculture or smart agriculture. The emerging technologies can identify the technologies expected to affect the agriculture sector significantly. The purpose is to examine state-of-the-art technologies in agriculture and assess them against selection criteria. The other research questions are:

- What is the impact of the emerging technologies on agriculture?
- What are the barriers to the adoption of these emerging technologies to agriculture?

Solution

Emerging technologies have opened so many opportunities for the agriculture sector. These technologies transform from traditional agriculture to technology-oriented agriculture (also called AgriTech), which is now imperativewhile avoiding more time and labor requirements. Recent advances and technologies have allowed the development of 'sensing solutions' that automatically collect data from the fields. Such data can help the decision-making process, enable early detection of animals' health, and applyappropriate corrective husbandry practices.Online agricultural services can reduce the cost for farmers, develop supply chains, and create a farmers' network for marketing.By using technology innovations, farmers have gained better control over growing crops and maintaining their livestock. Innovative agriculture solutions meet high standards of smart, sustainability, and profitability.

Integrating smart technologies in agriculture is known as an intelligent (or a smart) agriculture system. A smart agriculture system combines new Information and Communication Technologies (ICT) with traditional farming practices to enhance agricultural products' quality and quantity. Some of the technologies are currently used for digitizing the farming processes are sensors & actuators, robotics, GPS, big data & analytics, drone, etc. By adopting these technologies, farmers can reduce costs and labor costs, increase crop yield, and improve crop production with less time.

The digital transformation process in agriculture may affect other organizations (e.g., governments, public sector companies, and local agripreneurs) and other challenges such as rural livelihood, labor, and youth unemployment. Besides, this process generates many challenges in taking these technologies that may disturb the social, economic, and environmental areas.

Contribution

Our contribution in this chapter is to introduce various state-of-art technologies to the modern agriculture system. They aremobile technology (Global Positioning System or GPS), data science, data analytics, data management, drones, robotics, Internet of Things (IoT), machine learning (ML), sensors, etc.Besides, a technology model is proposed for a smart agriculture system. This proposed model can reduce the costs, improve production with lessen labor in the modern agriculture sector.

The chapter's organization is planned as follows: *Section 2* presents the state-of-the-art technologies have been applied to modern agriculture. Literature review and methodology have been done in *Section 3*. *Section 4*discusses various emerging technologies used for smart agriculture that promotessustainable agriculture. Finally, *Section 5* concludes this chapter with some future enhancements.

2. SMART AGRICULTURE - STATE-OF-THE-ART TECHNOLOGIES

The agrifood sector has been challenged as never before due to digitalization, globalization, technology, and innovation. Shifting the Agrifood sector to digitalization is set to be a major challenge. Major transformations of traditional agricultural systems, rural markets, societies, and natural source management will be required for digital agriculture as a universal paradigm to achieve its full potential.

Innovation remains the cornerstone of the existing agriculture system. Agriculture is the first principal human technological breakthrough globally. The early men learnt how to plant and harvest food; they stopped traveling around to gather food. The agriculture processes led to the creation of shelters, languages, leaders, towns, and trade. Farmers have produced food according to the early seasonal patterns and predictable knowledge to warn of droughts, cyclones, and floods that could threaten crops and livelihoods. With the increasing population worldwide, food production and farming need to get increasingly productive and capable of high yields in a limited time. To meet these demands, farmers and agricultural organizations have to push their current practices with innovation.

Innovation in Agriculture

State-of-the-art technologies in agriculture have always been intertwined as smart agriculture, which-makes headway across industries. The latest technologies, such as microcontroller, cloud, Web, cameras, sensors, and devices, are deployed to better understand the land conditions.

The adoption of ICT technologies continues to spread rapidly into agriculture. Today, ICT roles and responsibilities have become essential. For example, automatic identification and data capture techniques (RFID tags) used in retail and supply chain management—biometrics, and personal identification, for accessing buildings and smart devices. The scope of technology also covers Artificial Intelligence (AI), Big Data, cloud computing, coding of audio, picture, multimedia and hypermedia information, data management, Internet of Things (IoT), virtual reality, and more. These advances can enhance all zones of cultivating, from developing yields to ranger service. The huge territories of horticulture that innovation can change are exactness cultivating and cultivating computerization/robotization.

- Precision Farming. Exactness cultivating (or exactness horticulture) can make cultivating more controlled and precise. Plants, yields, and cows can get accurately the treatment with more exactness. The ranchers can support the adequacy of pesticides and manures on ranches.
- Agricultural Drones. Robots can be utilized for crop wellbeing appraisal, water system, crop observing, crop splashing, planting, soil, field investigation, and so on
- Internet of Food (or Farm 2020). It investigates the capability of IoT innovation for horticulture. IoT brings robotized dynamics to horticulture and development.
- Smart Greenhouses. Innovation-driven savvy nurseries can cleverly screen, control the atmosphere, and take out manual intercession (Aprajita Srivastava, 2018).
- Third Green Revolution (TGR). Smart cultivating, IoT, and sensor-driven farming are preparing for what can be known as a TGR. The TGR consolidates the utilization of information examination with accuracy cultivating.Modern technologies in agriculture also enable better food traceability that leads to food safety. These technologies are beneficial for the environment with efficient water use and effective delivery of agriculture products. They make the sustainable form of agricultural productionmore precise and resource-efficient.

Digital Agriculture

Digital technology can highlight the different challenges to unpredictable degrees. It can also help in working towards digital agriculture and avoid possible threats (e.g., Digital Divide) to the global Agrifood system. This digital divide has been no longer associated with poverty and rural zones. Digitization in agriculture has broadened the gap between different sectors and economies.

Agriculture with digital technologies offers opportunities through the availability of interconnected devices and computational technologies (Nikola, 2019). Digital agriculture transforms fundamentally every part of the Agrifood value chain. Digital agriculture affects farmers' behavior and input providers, tasks or processes, retail companies market, price, and sell products. Digital agriculture can be applied to all aspects of agriculture systems, including managing resources towards optimized, individualized, intelligent governance, in real-time, web-based, and driven by data. The results will be higher productivity, safe, ready, and adapted for the weather change to offer food security, profitability, and sustainability.

The profits of digital agriculture are considerable, and the challenges should be presented in the digitalization transformational.

Smart Agriculture

Smart agriculture usesmodern and innovative technologies into agriculture to yield better crop management, efficient soil analysis, and deploynew techniques for crop cultivation and harvesting. The other related terms to smart agriculture are precision and green agriculture. Smart Agriculture helps monitor all the details about crop production, collection, weed management, and soil analysis. These details help yield more effective and cost reducing results in smart agriculture. The quality of the plants can be increased drastically with the help of an alert management system.

Smart agriculture engages many advanced technologies such as Big Data, data analytics, GPS, IoT, and interconnected devices. A smart agriculture system helps to collect information from the field and farming automation. The field data can be managed with IoT sensors, cameras, drones, and actuators. The collected data are then transferred via the Internet to the farmer for decision-making.The collected information is then analyzed for making accurate decisions to grow high-quality plants and crops.

Precision agriculture comprises remote sensors that capture the images of crops using drones and UAVs. Smart agriculture help pursue greenhouse farming.

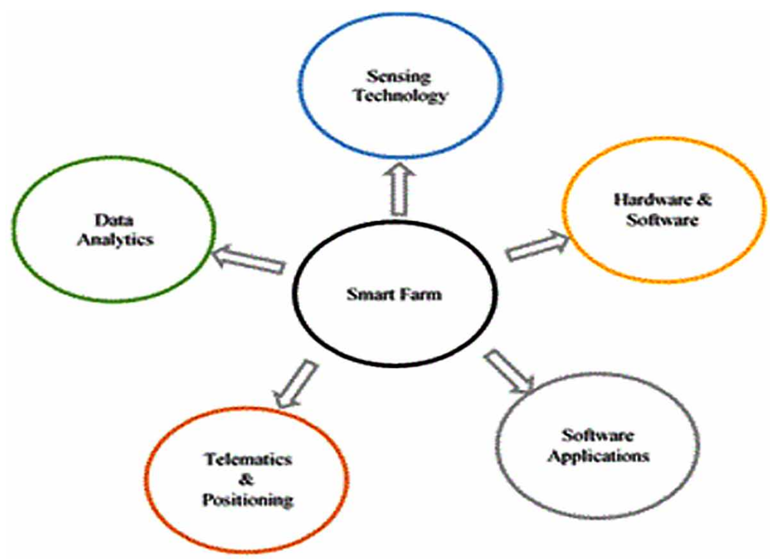
Green agriculture is the application of sustainable development to modern agriculture.

Smart Farming

Smart farming is a software management system focused on providing the agricultural industry with the infrastructure to leverage modern technology. Smart farming can be software-managed and sensor-monitored. Smart farming can be used to track, monitor, automate, and analyze farming operations. It is grown due to the need to efficiently use natural resources, the increasing use of ICT, and the growing demand for climate conditions.Thetechnologies that are considered factors of smart farmingare sensors, location, robotics, and software. The available technologies are *connectivity* (examples cellular, LoRa, *etc*.), *location*(examples GPS, satellite, *etc*.), *robotics* (autonomous tractors, processing, *etc*.), *Sensors* (examples soil, water, light, humidity, temperature management, etc.), *software*and *data analytics*.

Smart farming is related to various technologies: *management information systems (MIS), precision agriculture, agricultural automation, and robotics.*Using smart farming, farmers can monitor individual animals' needs and adjust their nutrition correspondingly. It helps to preventdisease and enhance herd health. Smart farming uses modern technology to increase agricultural products. Fig. 1 shows the tech-

Figure 1. Technologies used in Smart Farming



nologies used in intelligent agriculture.Smart farming drives connecting smart machines and sensors to make farming processes data-driven and data-enabled.

Besides, smart farming facilitates machine-to-machine (M2M) derived data. This derived data can be fed into a decision-support system. This data helps farmers to know what is happening at a granular level than in the past. The issues in traditional farming are pesticides, natural disasters, pests, and other hazards. They cause challenges for the food that comes from farms and those living animals in agriculture. Smart farming gives farmers better data and better resources for managing crops, equipment, and data. Table I shows the differences between traditional and smart farming.

Table 1. Differences between Traditional and Smart Farming

Traditional Farming	Smart Farming
Application of fertilizers and pesticides throughout the field	Field and finance data available in the same place.
Geo-tagging and zone detection not possible	It can detect the zones in farms with the help of satellites.
Manual maintenance, separate finance data, and leading to errors.	Early detection and application in the affected region.
Weather prediction not possible	Weather analysis and prediction can be made.
The same set of practices for cultivation of a crop throughout the region	A different set of practices for cultivation of crops and optimized water requirements.

Smart farming allows farmers and agriculturists to significantly increase pesticides and fertilizers and selectively use them. Smart farming helps with soil scanning, data management, equipment management, etc.According to Sciforce, 2019, smart farming can increase the quantity and quality of agriculture products while optimizing production’s human labor.

Smart Farming Life Cycle

The devices and sensors installed on smart farming can repetitively collect and process data to optimize the farming process. They allow farmers to react to the issues and changes in environmental conditions. Smart farming follows a cycle with observation, diagnostics, decisions, and action.

- *Observation*. Rural sensors and gadgets can record the watched information from the yields, domesticated animals, soil, and climate.
- *Diagnostics*. The recorded information is taken care of to a brilliant cultivating stage with predefined choice guidelines and models that can be utilized to look at an article's condition and recognize the insufficiencies.
- *Decisions*. After issues are uncovered, the stage's client and AI approaches can decide the area's explicit treatment.
- *Action*. After the end-client assessment and step, the ranch cycle rehashes from the earliest starting point.

Smart cultivating assist ranchers with bettering screen the necessities of individual animals and change their sustenance to forestall ailment and upgrade crowd wellbeing.

Benefits

Automation and decision-support systems in agriculture boost efficiency. Automated agriculture services enhance product quality and volume by better production processes. They lead to better cost and waste reduction in farming processes. They make farming more connected and smart. Smart agriculturereduces the overall costs, improves quality, and increases the number of products, sustainability, and consumers' experience. The benefits of technologies in smart and precision agriculture are listed below:

- *Accurate Forecasting.* Accurate forecasting help farmers to maintain and guarantee a desired quantity of yields all year round.
- *Efficiency*. Automating processes in farming can reduce human labor, errors, and overall cost.
- *Increase in Production*. Monitoring plants' needs can prevent disease, enhance drove, and crop health.
- *Real-time Data.* Real-time data can facilitate the decision-making process with less time.
- *Remote Monitoring*. Remote monitoring of multiple fields can enable farmers to make real-time decisions from anywhere.
- *Sustainable Agriculture.* With control overproduction, waste levels and costs can be effectively managed.

A smart cultivating framework can empower cautious administration of the interest figure and conveyance of merchandise to the market to lessen squander. This framework can control the cultivating framework, oversees sensors info, and conveys distant information for speedy choices.

Sustainable Agriculture

Supportable horticulture and shrewd cultivating depend on the accessibility of cultivating information. Savvy cultivating upholds economical agribusiness through the mix of satellite information, and land perception information can be considered by ranchers during cultivating.

Advancement in cultivating is viewed as a branch of information investigation. There are assorted information investigation strategies that can be utilized by ranchers. Maintainability in agribusiness can be accomplished through the correct utilization of information in the dynamic framework. Ranchers can encounter a progression of factors going from soil creation to environmental change. Such varieties need a helpful audit for the cultivating practice. Savvy cultivating underscores large information innovation in dynamic and accomplishes set creation objectives. For instance, through enormous information innovation,

- Farmers can set up the fruitfulness of their farmland by investigating ranch information and looking at satellite pictures.
- Smart cultivating approaches have guaranteed the assortment of value satellite information and earth perception information.
- Smart cultivating can be seen with GPS innovation in work vehicles. With GPS, ranchers can send information on the farm truck's position and develop land consistently and spare fuel.
- Sensors can assist ranchers with choosing how, where, and when to distribute explicit assets to improve biological and monetary yield.

Sustainable agriculture minimizes the use of pesticides that can harm the health of farme and consumers. The fundamental principles are linked to sustainable agriculture:

- It develops efficient, self-sufficient, and economical agricultural production systems.
- It increases efficiency in food production and distribution to the market.
- It manages the quality of air, water, and soil for better production.
- It optimizes the use of natural resources for production.
- It preserves, protects biodiversity and territories

Related Terms

The modernization of agribusiness and computerized innovation has made new ideas develop, for example, advanced cultivating, shrewd cultivating, exactness cultivating, and savvy cultivating. Shrewd cultivating is the use of ICT and information innovations for streamlining cultivating frameworks. Ranchers can utilize shrewd gadgets to get to constant information about the state of soil and plants, territory, atmosphere, climate, asset utilization, labor force, financing, and so forth Notwithstanding, a portion of the connected terms to shrewd cultivating are introduced beneath.

*Digital Farming.*Digital farming is integrating both concepts of precision farming and smart farming. It usesWeb-based data platforms with big data analytics.

*Intelligent farming*or iFarming. Intelligent farming (MdAshifuddinMondal, 2018) has 100% insight and control of a smart farm 24/7. It has placed at the forefront of developments that improve the processes in agriculture.

*Precision Farming.*It isalso calledPrecision agriculture. According to Michell Christopher, 2018, modern farming management uses digital techniques to monitor and optimize agricultural production processes. Precision farming measures the field soil variations and fertilizer strategy that leads to optimizedfertilizer use, saving costs, and environmental impact.

Agricultural Technologies

As indicated by Meghan Brown, 2018, keen cultivating can profit by innovative progressions, i.e., from planting, watering, treatment, and gathering. It needs to address populace development, environmental change, soil disintegration, and work issues brought to rising innovation. Most agrarian advancements fall into three classifications: self-sufficient robots, robots or UAVs, and sensors or IoT. These advancements are relied upon to turn into the mainstays of the savvy ranch.

- Automatic Watering and Irrigation. The water system technique permits ranchers to control when and how much water their harvests get. The complex IoT-empowered sensors can empower the cultivating framework to work self-governingly, depending on information from sensors in the fields to perform water system varying.
- Driverless Tractors. Ranchers for various farming undertakings use work vehicles. Self-governing farm trucks become more proficient and independent after some time, particularly with the advances (i.e., cameras and machine vision frameworks, GPS, IoT, and LiDAR). These innovations essentially lessen the requirement for people to control these machines effectively.
- Drones. Robots outfitted with cameras can be utilized to create ethereal photos at a small amount of time. With these photos, ranchers can enhance each part of their property and harvest the board.
- Harvesting. The complex innovation with sensors, IoT gadgets, and the mechanized machines can consequently start the reap when conditions are ideal and free the rancher for different undertakings. For instance, Panasonic's tomato-picking robot and Abundant's apple-picking robot. These robots can constantly watch fields with an IoT framework, keep an eye on plants with their sensors, and gather ready yields as proper.
- Monitoring and Analysis. Robots can take on far off checking, examination of fields, and harvest information. Ranchers can gather and audit the information to evade individual excursions as opposed to sitting around and exertion by keeping an eye on sound plants.
- Planting. Model robots (for instance, DroneSeed and BioCarbon) are being tried to supplant difficult work in cultivating and planting. They can utilize packed air to fire cases containing seedpods with manure and supplements straightforwardly into the ground. Robots are likewise offering the occasion to mechanize the work serious errand. They can perform crop splashing errands all the more productively and with more prominent exactness and less waste.
- Reducing Labor and Increasing Yield. Consolidating self-governing mechanical technology into farming remains the objective of lessening physical work, expanding item yield and quality. They lead the ranchers to perform different assignments, for example, fixing, troubleshooting robots, breaking down information, and arranging ranch activities.
- Robotic Labor. Agrarian robots (or AgBots) replaces human work with computerization. It shows up on ranches and performing errands going from planting, watering, reaping, and arranging. It makes ranchers produce more and better food with less HR.

- Sensors and the IoT. Sensors can be inserted all through each phase of the cultivating cycle. Sensors set up over the fields gather information on lighting levels, soil conditions, water system, air quality, contamination, and climate. These information will help make higher yield creation, diminish expenses, and increment food accessibility and quality.
- Weeding and Crop Maintenance. Weeding and irritation control are basic parts of plant support and ideal for self-sufficient robots. These robots can explore self-rulingly through a field utilizing video, LiDAR, satellite, and GPS advancements. These robots can likewise be utilized to distinguish nuisances and application bug sprays. It utilizes the AI (ML) way to deal with recognize weeds before eliminating them.

Notwithstanding the abovementioned, the Business Intelligence (BI) arrangements anticipate that IoT gadgets introduced in agribusiness are required to more information. This tremendous information and other data produced by cultivating technologywill be the future savvy homestead's spine. Ranchers can have the option to see and survey all parts of their activity and settle on educated choices.

3. LITERATURE REVIEW AND METHODOLOGY

The adoption of ICT technologies continues to spread rapidly into the agriculture sector. The role and responsibilities of ICT have become more critical in this sector. The ICTs for agricultural business and consumer applications with automatic identification and RFID tags can be used for accessing smart farms with smart devices.

The Fourth Industrial Revolution is driving digital innovations and disruptive digital technologies, including the food and agriculture sector. According to USAID, 2018, it was difficult to get information about smallholder farmers, their basic needs, and problems such as access to inputs, prices, markets, and microfinance. The next wave of mobile technologies is expected to come from rural communities for engaging agriculture activities daily. The mobile technologies (3G/4G/5G) and the remote sensing services are opened new opportunities to integrate smallholder farmers in new digital Agrifood systems.

Technological innovationshave been described as the most recent 'revolution' todisturbthe agricultural sector. Recent investigations (AgTech, 2018.) have highlighted the importance of capitalizing and the productivity gains that modern technologies can deliver.Smart technologies play an essential role in achieving enhanced productivity and greater eco-efficiency (David Christian Rose, 2019).

Precision agriculture (Michell Christopher, 2018) increases the yield with precision planting, precision fertilization, and precision spraying. These technologies allow farmers to monitor their lands in real-time and reply to changes in advance.Smart farming (MdAshifuddinMondal, 2018) is based on IoT to offer high precision crop control, data collection, and automated farming technique. An intelligent agriculture field monitoring system can monitor soil humidity and temperature.

With the help of smart farm applications (Seung Keon Kim, 2015), farmers can open/close the ventilation system, sprinklers, control watering, and apply manures. Thus, farmers increase their efficiency, increase crop production, save time, and expenditures through increased labor productivity. The smart farm can help to prevent incidents such as cold climate damage.

IoT technology is designed and implemented as a new automatic aeroponics system using IoT devices. A connected farm with IoT (MinwooRyu, et al. 2015) aimed to provide smart farming systems for end-users. Aeroponics farming (Stephen C. Kerns 2017) is awell-organized and effective process for growing plants without using soil.

Cloud computing technology (Jithin Das, et al. 2019) can help determine the adoption behavior barrier and enhance the present agriculture system. The cloud computing adoption among young farmers is greater than the old farmers in Ireland.

According to Charush Nair, 2020, Robotic Process Automation (RPA) allows both farmers and dealers to automate the repeated actions to focus their energy and efforts on performing other main tasks requiring special attention and skill.The e-commerce platform's intentionis to be an e-commerce giant in the agriculture sector. This platformwill be of great value to Agri products' farmers and retailers (*Kisan Market, farMart*, and *Agroman*).

In the future, computer vision technology may be combined with intelligent technology such as machine and deep learning approaches. Deep Learning can be applied to the agricultural management system's massive data sets (Hongkun Tian, et al., 2020). This management system promotes the agricultural automation equipment and techniques in a more intelligent direction.

Data processing systems in agriculture can collect data from drones and satellites and stores in the management system. These data will help farmers adopt better production and harvest plans, enabling them to increase their yield.

4. METHODS: EMERGING TECHNOLOGIES

Smart farming, digital agriculture, and precision agriculture play a crucial part in sustainable agriculture, using emerging technologies. They ease the formers from harvesting as many products as possible while consuming less energy and inputs (e.g., fertilizers, phytosanitary products, water). Sustainable farming methods are crop rotation and diversity, cover crops, no-till farming, integrated pest management, agroforestry, natural animal raising, renewable energy use, etc.

Factors Considered

Smart devices and technologies can help farmers to increase intelligent farm performance and revenue. Therefore, certain factors have to be considered while providing an intelligent farming solution. They are hardware, brain, maintenance, mobility, and infrastructure.

- *Hardware.* To build a technological solution, the agriculture sector needs to choose sensors and smart devices. It may depend on the types of information and the purpose of the farming solution. The solution may rely on the accuracy of reliable data from the lands. The quality of the sensors is also crucial to the success of the product.
- *Infrastructure.* To ensure the smart farming application, it needs robust internal support and infrastructure.
- *Maintenance.* The sensors are used in the land can be easily damaged due to many reasons. Thus, the hardware is durable, easy to care for, and replacement. Usually, maintenance of the hardware is a challenge for IoT devices in agriculture.
- *Mobility.* Smart farming systems can be tailored for use in farms and fields. A farm owner can access the information either on-site or remotely via smart devices (e.g., smartphones, tablets,

or desktop computers). These devices may have enough wireless range to communicate with the other tools and send data to the centralized server.

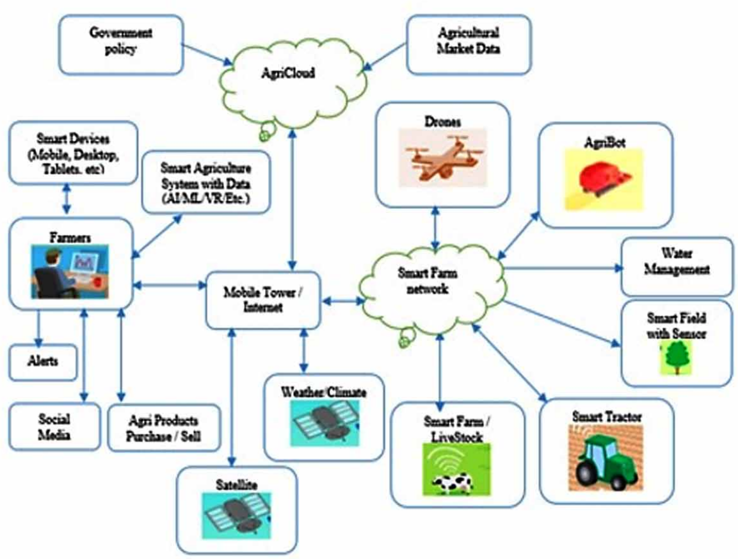
- *The Brain.* Data analytics and scientists might be at the core of every smart agriculture solution. Thus, Smart farming systems need to have robust data analytics applications, predictive algorithms, and ML &DL to obtain actionable insights based on the collected data.

Furthermore, internal agricultural systems have to be more secure. Failing to secure the farming system can increase someone's likeliness to break into it, steal the data, or even take control of the autonomous tractors.

Smart Farming

Digitization and smart technologies play an increasing role in the farming sector. The intelligent farming systems thrive on the integrated performance of sensors and devices with intelligent technologies. Fig.2 shows the smart farming solution with emerging technologies. The data from agricultural fields are collected using smart devices or IoT sensors. These data can measure sunny levels, temperature, soil sourness, moisture, CO_2 levels, water quality, etc. The data analysts and scientists then analyze the collected data and send it to the farmers for better crop production.

Figure 2. Digital Farming Solution



Hence, the collected data needs to be processed. The farm system ingests the collected data, analyze,and compare it to historical information.Agriculturists and farmers can also explore the collected data to conclude the weather pattern, soil fertility, crop quality, amount of water required, etc. Technologies are then turning the collected data into useable, providing cultivators with valuable feedback on how their crops could be better served. Depending on the operation's size, the smart systems lets dictate watering quantity, light intensity, duration, CO_2 levels, pest control, etc. The intelligent farming controller system can automate every aspect of a controlled atmosphere, from HVAC, to nutrient injection systems, to pH, heating and cooling, etc.

Smart farming solutions can be self-ruling reaping, independent farm truck, hereditary altering, domesticated animals observing, and keen water system.

- Autonomous Harvesting. Mechanization in reaping guarantees lower weight on business and higher profitability in social event crops. It shields the laborer from likely mishaps or snakebites. For instance, Saga Robotics plays out a few undertakings, including the collecting of foods grown from the ground.
- Autonomous Tractor. Computerization in driving and self-sufficient work vehicles saving time for ranchers to zero in on other horticulture highlights. For instance, Agribot, a self-ruling work vehicle, offers a few advantages for the rancher.
- Genetic Editing. Hereditary control methods are perhaps the most advancement in agribusiness. These procedures, as C4 Photosynthesis, CRISPR/Cas9, or genomic choice, can alter a yield quality. Plastomics methods can improve crops by making alterations to the plant's hereditary qualities.
- Livestock Monitoring. Cows, sheep, pigs, goats, and chicken contribute fundamentally to nourishment for people. Creature husbandrydeals with the everyday mindful, reproducing, raising, and checking of domesticated animals. Desamis, an AI-based brilliant dairy stage screen, identify and break down cows conduct with the goal that the rancher can settle on proficient choices.
- Smart Irrigation. Brilliant water system gives ideal water conveyance to crops. It guarantees insignificant wastage in water utilized for farming. For instance, One water, an IoT based canny water system frameworks, can detect soil dampness, mugginess, and temperature to consequently execute trickle water system on the ranch, sparing important assets.

The ranchers can recognize the most important shrewd cultivating arrangements dependent on their particular models and cooperation methodology.

Smart Technologies

The rising trend of business farming is expected to fuel the demand for smart agriculture. Smart technologies such as a microcontroller, cloud platform, Web-based platform, intelligent devices, sensors, and cameras are used to better know their land condition.Intelligent technologies help agriculture to pursue greenhouse farming. Smart agriculture contributes to automated farming and automated data collection from the field. The field data are collected with devices, sensors, cameras, microcontrollers, and actuators. The collected information is transferred via the Internet and then analyses it to make accurate decisions to grow a high-quality crop.

Precision agriculture utilizing shrewd advancements gives the product instruments and information for an inside and out an investigation of cultivating rehearses. In this manner, formers can settle on more intelligent choices about the homestead and what sources of info are generally proper for their dirt and harvest, boosting crop efficiency. The intelligent technologies provide holistic, smart farming solutions that include sensors, drones cooperatives, AI, big data, cooperatives, drones, sensors, IoT, LoRa, blockchain, cloud computing, dashboard, etc. These technologies have their own place and impact in the smart agriculture and Agrifood chain. Integrating technologies within the Agrifood value chain may depend on the chain's complexity and stage of maturity. Therefore, this chapter classifies digital technologies according to the structure, complexity, and dissemination of these technologies in the smart agriculture and Agrifood sector.

- Big Data, data analytics, and cloud computing.
- Coordination and integration module that includes blockchain, data management, ERP, microfinancing, and insurance systems.
- Intelligent systems include AI, ML, and DL, drones, robotics, and autonomous systems.
- Mobile technology, mobile devices, and social media networks.
- Precision agriculture and sensor technologies, including IoT, UAV, and satellite.

Above-classifiedtechnologies are presented below:

Artificial Intelligence (AI). AI technology studies varied climatic conditions to realize the crop water need. AI technology can reduce the chance of disease and pest infestation at their farms. AI system ensures sensible use of pesticides and fertilizers as well. As a result, AI technology reduces the overall farm cultivation cost and increases crop productivity.

Big Data Platform. Farmers collect a range of data about their work on the farms. These data are very massive in nature. Researchers can populate the above data in agriculture. Providing a big data platform can accelerate and enhance the impact of smart farming. There are some possibilities for data coordination and analysis on a wide scale. Farmers monitor their farms with the above data on rainfall, fertilizer use, crop varieties, and yields.

Blockchain Technology. Blockchain technology upgrades agricultural worth chains by helping ranchers improve admittance to fund and advances through improved data sharing. It incorporates ranchers' verification, their exchanges, improving food detectability, making a connection among ranchers and retailers, and dispensing with specialists' utilization. Both blockchain and IoT can possibly improve cultivating across landmasses fundamentally. For example, the Hello Tractor platform (using AI and blockchain) allows farmers to access timely and relevant data to increase their yields. This saves time, earns more and portfolio management.

Cloud Technology. Cloud innovation deals with all the farming exercises and more through a solitary gadget. Horticultural companies can use information examination and satellite symbolism to gather, break down, and deal with all the homestead exercises to fork.

- Cloud framework stores colossal volumes of information identifying with climate cycles, crop designs, soil quality, collecting, and satellite symbolism to give bits of knowledge sharp precision and speed. All the information related with the ranch is put away in the cloud and promptly available by the clients.
- Database the board permits each sort of information accessible for the homestead to empower dynamic. Meteorological information, market information, ranch information, GIS, and water accessibility information are broke down completely before giving the ideal estimation of cultivating, water, and pesticide for a homestead. The ready framework can caution at whatever point inconsistencies in crop development are recognized and illuminating ranchers with noteworthy information.

- Data stockpiling is likewise huge in the precise examination. All the put away information can be gotten to through telephone, work stations, and tablets.

Cooperatives. Cooperatives need to play in the selection of exactness agribusiness. Cooperatives can give the financial force needed to put resources into savvy cultivating and opening the advantages of clever advancements for all.

Dashboard. The dashboard represents smart farming data visualization embedded in the intelligent agriculture or smart farm solution. The dashboard demonstrates real-time data collected from sensors using application-programming interfaces (API). The smart farming dashboardhighlight the features of low-latency updates, the ability to zoom-in into the charts, and advanced tooltips and legend.

Data Analysis. Today, prediction has become more important to farmers. Data analysis allows the agricultural industry and farmers to predict the outcomes more accurately. However, predictions can be stressful and time-consuming processes. The forecasts are becoming more critical with the increasing expectations of production and severe weather experienced in some areas affecting the crops.

Drones. Drones catch the yield pictures of harvests and guarantee them to settle on all around educated choices. Drones take a gander at standardized distinction vegetation file, which recognizes whether a territory contains live green vegetation. Robot reconnaissance can give early admonition of harvest pressure and medical problems by conveying crop pictures that empower exact and solid insights. Drones with sensors can recognize weeds, conjecture yields, measure absence of or overabundance water, bother invasions, and absence of supplements. Drones with sensors lifted off in a legitimate vacuum and flying into firmly directed airspace.

Distinguishing proof Technology. The distinguishing proof innovation sensor is intensely utilized in the dairy area. The radiofrequency ID (RFID) framework encourages each lactating creature routinely to one area to be drained and takes into consideration the individualistic administration (Caja, 2016). The current RFID of dairy bovines is as yet dependent on huge high-recurrence transponders (i.e., neck collars). Nonetheless, scaled-down low-recurrence gadgets are less expensive and promptly accessible (ear labels, injectable gadgets, or rumen boluses).

Internet of Things (IoT). IoT innovation includes sensors, robots, and robots associated with the Internet, which perform tasks to build effectiveness and consistency. Mechanization in Agriculture and robots (Agribots) begin to pick up consideration among ranchers. IoT uses sensors for social event information, which is sent to expository apparatuses for investigation.The IoT with AI and ML enables agriculture industries to streamline processes, improve efficiency, and reduce costs as they become digitized.

LoRa Technology. LoRa technology provides agribusinesses with a cost-effective way to help their business grow. LoRa technology includes many services, i.e., detecting fill levels in water tanks and animal waste receptacles. It receives signals from sensors to monitor soil temperature, moisture, and salinity. It tracks livestock to monitor their health and detect their location. It monitors the site of farming equipment and machinery.

Remote Sensing Technologies. These advancements are utilized to screen crop conditions distantly. These advances depend on electromagnetic radiation collaboration with soil and plant material caught as pictures with sensors connected to different stages (e.g., satellites, airplanes, and automated airplane frameworks). Exactness farming includes recognizing and gathering photographs utilizing reflectance data from the obvious and close infrared groups from either exposed soil and yield shades. Ranchers and yield scouts may utilize automated airplane frameworks (UAS) to acquire the most elevated spatial goal explanations of plants. Sensors on satellites and UAS can enhance crop assessment. These incorporate multispectral, hyperspectral, Radar, Light Detection and Ranging (LIDAR), and warm imaging.

Robotic Process Automation (RPA). Agriculture includes many repetitive tasks that involve a high workload, and there are only very few skilled people. So it needs to free people from these repetitive tasks, and automation is the solution. RPA helps farmers and companies automate most repetitive tasks (Palanivel, 2020) to spend their valuable time on more critical tasks requiring attention and skill. These tasks can lead to increased productivity and hence more profit.

*Sensors.*Smart farming use sensors for precise data collection. These data can be sent to farm Control Centres. These Centres provide the details of fertilizer requirements and pest control. These sensors can measure how well the plants are growing. A typical farming sensor offers a range of field data and allows farmers access to specific information using Wi-Fi or mobile phone. Sensors enable crop yield projections using actual plant status and weather forecasting information.

Smart Logistics. IoT transforms the agriculture industry and enables farmers to ensure that the environmental conditions during transit were maintained within set levels. Innovative smart logistics solution addresses the issues (e.g., temperature, gas and oxygen levels, and humidity) and increasing the quality, quantity, sustainability, and cost-effectiveness of agricultural production. It monitors the temperature everywhere the material and automatically reports any deviations from set thresholds.

Wearable Devices. These devices are now used very commonly in dairy herds (Caja, 2016). Most commercially available reproductive management technologies are (e.g., oestrous mating, calving) are based on activity recording of one sort or another using accelerometers. They are offered to wear ear tags, nose halter, neck collar, or leg pedometers. Some devices provide information on feeding behavior (e.g., eating, ruminating, and drinking).

The use of the above technologies in agriculture helps farmers produce food more efficiently and improve their overall quality sustainably through emerging technology. With agriculture being the most vital industry globally, it is more important than ever to embrace emerging technology in the agriculture industry.

Sustainable Agriculture Solution

The proposed sustainable agriculture has the features of the automated sprinkler system, climate monitoring & forecasting, drone monitoring, livestock tracking, and geofencing, predictive analytics for crops and livestock, small plant and soil monitoring, remote equipment monitoring, sensor-based field and resource mapping, smart greenhouses, smart logistics and warehousing, smart pest management, stats on livestock feeding and produce, etc. These features are presented below:

Automated Sprinkler System. The automatic or controlled water dispersion helps ensure no risk of damaging crops due to overwatering. It may use IoT sensors or devices.

Climate Monitoring and Forecasting. Climate checking and climate determining can caution the rancher of the approaching changes and guarantee preventive measures. The IoT sensors can foresee and break down the climate, and the harvests can be spared from being annihilated.

Drone Monitoring. Robots can examine the development rate and the vegetation list of the harvests. IoT empowered Drones can catch information and figure crop wellbeing by means of warmth marks.

Livestock Tracking and Geofencing. In any ranch's maintainability, homegrown animals are raised as items and produce. An ongoing geofencing is an aid for ranchers.

Prescient Analytics for Crops and Livestock. Prescient investigation can foresee information for improving cultivating rehearses.

Remote Crop and Soil Monitoring. The dampness, soil richness, and harvest development rate can be observed distantly through ongoing movement and illustrations by means of cell phones. It causes the rancher to settle on educated choices for the homestead.

Remote Equipment Monitoring. Farm trucks, pickups, gathering machines, and hardware are IoT empowered with sensors. Introducing, provisioning, and overseeing IoT endpoints, safely and dependably interfacing the equivalent. Ingesting, overseeing, curating, and investigating IoT information should be possible distantly.

Sensor-based field and Resource Mapping. Ranchers can utilize sensors to guide and monitor the whole homestead. It incorporates the insights of HR, apparatuses, and institutional resources.

Smart Greenhouses. Plants develop and flourish in smart nurseries with an expansion in quality and yield. Nurseries have been industrialized in size and ability to develop foods grown from the ground.

Smart Logistics and Warehousing. Homesteads are regularly enormous creations. Reap times bring about a yield that is a coordinations bad dream. With keen farming arrangements set up, capacity and preparing in distribution centers should be possible easily.

Smart Pest Management. Pesticides help in forestalling pervasions. Notwithstanding, some unacceptable amount can bring about annihilated yields. Keen vermin the board gives nitty gritty examination that predicts swarm examples and alarms on the yields' wellbeing.

Stats on Livestock Feeding and Produce. Taking care of examples of the steers regularly anticipate if there is any disease around the corner. The quality produce of milk and protein relies upon the sum and quality utilization of the creatures.

Sustainable Agriculture Framework

The framework of a technology model (Trendov, 2019) allows users and consumers to identify the following:

1. The elements that characterize the digital transformation in modern agriculture.
2. Making advances in the structuring of a methodology that digital transformation brings in the agriculture sector.

This methodology allows structuring the elements, such as technologies, policies and incentives, agribusiness models, and the conditions that promote the adoption ofdigital transformation. The structure is simplified based on basic requirements, enablers, and the impact of technology.

1. Necessary conditionsincluding connectivity (e.g., mobile subscription, network coverage, and Internet access), educational systems, literacy and employment, and government policies for enabling digital agriculture.
2. Enablers for acceptance of digital technologies include using digital technologies, digital skills, and innovation.
3. Applying digital technologies includes advantages of technology to improve economic, social and cultural, and environmental effects with different types of resources.

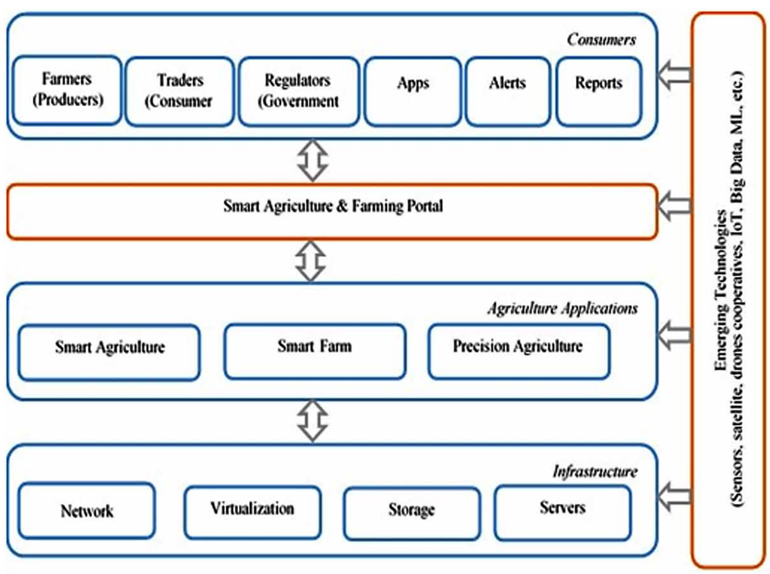
Technological Model

Fig.3 shows the proposed innovative model for supportable horticulture. Ranchers need to execute and facilitate various apparatuses to deal with the total homestead activity. The proposed model has gotten across the board device to deal with every one of these exercises and more through a solitary gadget. Ranchers and agribusiness companies can use information investigation and satellite symbolism to gather, break down, and deal with all the homestead exercises to fork.

Information assortment is the best utilization of keen farming. It gathers and stores a bigger volume of information identifying with climate cycles, crop designs, soil quality, collecting, and satellite symbolism to furnish bits of knowledge with precision and speed. All the information related with the ranch is put away in the cloud and consequently promptly available.

Information base administration concerning ranch empowers a more elevated level of dynamic. All the information from over a wide span of time are examined completely before giving the ideal estimation of cultivating, water, and pesticide necessities for a ranch.

Figure 3. Technological Model to Sustainable Agriculture



All the information is accessible constantly and can be gotten to through savvy gadgets. Information stockpiling is additionally huge in the exact investigation. The more data is accessible identifying with ranches, the more exact recognition of climate wonders, bothers, crop yield, and benefits will be.The application of modern technologies and the proposed model to agriculture promises excelled efficiency, expansion, reduced resources, cleaner procedure, agility, and enhanced product quality. As a result, the above factors can eventually lead to higher income.For example, Cattle can be accidentally get detached from their herd, and cows can get pregnant without the owner's awareness. IoT devices can be used for the above issues. The farmer must know this, as cows require special consideration to stay healthy and bring a healthy calf.

A farm management system brings IoT devices and sensors together. It can be installed on-premises as a dashboard, having analytics proficiencies and built-in accounting and reporting features. With a farm management system, maximizing existing strengths can happen at less cost and a short time.The businesses, farmers, and landowners can holdthe potential of technology for better income and productivity. With the ever-increasing population, the demand for more food is increasing. Smart technologies can strengthen affordability and sustainability in the making in modern agriculture.

Agricultural technology opens up new ways through which farmers' common issues can be put to an end. There are some difficulties in monitoring climate conditions, managing crops better, cattle monitoring, and farm management system.Sensors or IoT deviceslocated across fields collect meaningful data from the atmosphere and send it to the Agri Cloud for further reference. This may be a challenging task when the technology or device fails.Crop management sensors or IoT devices gain many insights from real-time data. This data understand crop health. These data can vary from one location to another. Monitoring cattle health is crucial. IoT devices can monitor body temperature, nutrition intake, activity, and more. It is complicated to watch in case the device fails.

Real-Time Applications and Uses Cases

The enumerated benefits can find a specific application in real-life. These applications crop monitoring, drones, greenhouse automation, livestock monitoring, and monitoring climate conditions.

Crop Monitoring. Crop monitoring can collect information on humidity, temperature, crop health, precipitation, etc. If there are any abnormalities in the collected data, farmers may identify them before and make suitablechoices. IoT technology can help farmers to decide when the best instant to plant crops and harvest them. For example, Semios monitors crops that provide farmers with remote control of climate, insect, and disease monitoring.

Drones. Drones can give farmers with time and area explicit information with respect to parasitic contaminations, crop well-being, development bottlenecks, and so forth Robots can recognize drier districts in a field, and measures would then be able to be taken to branch such territories with better strategies. For instance, an eBeeSQ farming robot can cover several sections of land in a solitary trip for extremely productive harvest observing and investigation.

Nursery Automation. Climate stations can naturally change the dirt conditions to coordinate the given impediments and give the most appropriate nursery condition. For instance, GreenIQ, a savvy sprinkler regulator, deals with the lighting frameworks and water system distantly.

Animals observing. Sensors and IoT gadgets assist ranchers with gathering information in regards to their domesticated animals' area, prosperity, and wellbeing. This checking information encourages them in distinguishing the state of their animals. For instance, discovering debilitated creatures to isolate from the group forestalls the spread of the malady to the whole cows. ML conveys significant information, for example, movement, temperature, rumination and conduct for any wellbeing admonitions, infection pointers, estrus identification and feed advancement.

Screen atmosphere conditions. Climate stations can gather climate information and direct valuable data to a rancher. Climate observing programming examines this information and sends it to the rancher to keep away from crop harms. For instance, allMETEO screens climate conditions and cautions the early admonition of ice, energizing temperatures, and stormy climate on the homestead fields.

5. RESULTS AND DISCUSSION

This section presents detailed information about the modules of the proposed model. It elaborates on the technological model and the components. Yet, it highlights the security component that might be occurring in the model. It was also drawn the challenges, limitations, and opportunities.

Many technological factors disturbing creativity are revealed in this chapter. These technical factors create technological self-efficacy, cooperativity, and interactivity, resource enriched, and interactivity.

Benefits and Limitations

Some of the advantages of sustainable agriculture are ecological protection, public health improvement, and economic and social equity. Sustainable agriculture protects the environment, reduces corrosion, natural resource deprivation, improves air, water quality, increases biodiversity, and decreases carbon releases. Sustainable agriculture does not use dangerous pesticides and fertilizers. As a result, farmers can produce inoffensive and healthier food for consumers and neighboring communities.

However, some of the challenges are *food security, food productivity*, and *natural resource availability*. With the growing population, the high-levels of hunger, and malnourishment, sustainable agriculture yields a need to address food security by producing more food in less time and fewer expected resources. The green agriculture is facing is undoubtedly the rapid degradation and reduction of natural resources.

Challenges in Smart Agriculture

A smart agriculture system using modern technologies can be the savior of the entire agricultural industry. However, incorporating the technology to traditional farm methods faces some problems, including connectivity, design and durability, and limited resources and time.

- *Connectivity-* The connectivity should be reliable irrespective of severe weather and open space conditions.
- *Design.* Any IoT framework utilized in agribusiness ought to have the option to deal with the states of open air spaces. Robots, sensors, IoT gadgets, and climate checking stations ought to have a simple practical plan and a specific degree of vigor to work.
- *Limited Resources.* The rural organizations who plan and create IoT for farming need to consider quick environmental change, developing climate boundaries, work with insufficient land accessibility, and horrible components like passing on pollinators.
- *Cost.* The cost of a smart farm is a significant barrier due to compatibility between sensors and devices. However, this can be increased by reducing the device's complexity, improving data transfer between devices, and transforming collected data into useable and accessible information.

Digital technologies in agricultureidentify the possible zones for improvement andacceleration. In particular, these zones correspond to economic, social, and environmental.

1. *Economic*. Technologies can increase productivity, reduce logistic costs, reduce wastages, increase market occasions, bring sustainability, value chains, etc.

2. *Social and Cultural*. Technologies can create a participating effect at a social and cultural level through the devices.
3. *Environmental*. Smart, precision, or digital agricultureallows monitoring, optimizing agricultural processes, value chains, and delivered products. The use of digital technologies provides prevention, adaptation, and the best use of natural resources.

6. CONCLUSION AND FUTURE ENHANCEMENTS

Traditional agriculture has seen many revolutions, including the systematic use of crop rotations, farming developments, the green process, and the everyday use of human-made fertilizers and pesticides. Agriculture can go another revolution with the increasing use of ICT in agriculture. ICT transforms agriculture to feed a growing population. Farmers can increase their agricultural products' value by taking advantage of related data, providing nutritional content, and sustainability. Therefore, using modern technologies in agriculture has a big promising future as a driving strength of efficiency, durability, and scalability.

This chapter conducted a review of emerging technologies for smart agriculture. Based on this paper's findings, several conclusions can be drawn on the state-of-the-art technological applications in smart agriculture. Still, several hurdles must be overcome. Agriculture business models and technical architecture guarantees high-quality agriculture data that trust all actors involved in modern agriculture. A security mechanism is required to avoid the misuse of data in the field of agriculture. This will be the future work of this chapter.

REFERENCES

AgTech. (2018). *Emerging Technologies in Agriculture: Regulatory & other challenges*. ACIL Allen Consulting, AgriFutures Australia.

Bacco, Berton, & Ferro. (2018). *Smart Farming: Opportunities, Challenges, and Technology Enablers*. IEEE Explore.

Caja, C., Castro-Costa, A., & Knight, C. H. (2016). Engineering to support the well-being of dairy animals. *The Journal of Dairy Research*, *83*(2), 136–147. doi:10.1017/S0022029916000261 PMID:27210489

Datta. (2019). *Smart Farming is the Future of Agriculture*. Academic Press.

Jithin, D. V., Sharma, S., & Kaushik, A. (2019). Views of Irish Farmers on Smart Farming Technologies: An Observational Study. *AgriEngineering*, *1*(2), 164–187. doi:10.3390/agriengineering1020013

Kerns, S. C., & Lee, J.-L. (2017). Automated Aeroponics System Using IoT for Smart Farming. *Proceedings of 8th International Scientific Forum, ISF 2017*, 104-110.

Kim & Jeong. (2015). *Experiences and Emerging Trends Related to ICT, Innovation, and Productivity in Korea, Knowledge Sharing Forum on Development Experiences: Comparative Experiences of Korea and Latin America and the Caribbean*. Academic Press.

McMullen. (2017). *Smart Ag IoT Optimizes Growth in Plant Nursery*. Academic Press.

Meola. (2020). *Smart farming in 2020: How IoT sensors are creating a more efficient precision agriculture industry*. Academic Press.

Mondal & Rehena. (2018). *IoT Based Intelligent Agriculture Field Monitoring System*. IEEE.

Nair, C. (2020). *An Inside Look at How Robotic Process Automation in Agribusiness is more Productive & Profitable*. https://blog.accubits.com/robotic-process-automation-in-agribusiness/

Palanivel, K., & Suresh Joseph, K. (2020). Robotic Process Automation to Smart Education. *International Journal of Creative Research Thoughts*, *8*(6), 3775–3784.

Robinson, A. (2019). Smart Farming Uses Driverless Tractors, and Weed-Killing Robots. Academic Press.

Rose, D. C., & Chilvers, J. (2019). *Agriculture 4.0: Broadening Responsible Innovation in an Era of Smart Farming, Science, Society, and Sustainability (3S) Research Group*. School of Environmental Sciences, University of East Anglia.

Ryu & Yun. (2015). Design & implementation of a Connected Farm for Smart Farming System. IEEE.

Sciforce. (2019). *Smart Farming: The Future of Agriculture*. Academic Press.

Srivastava, A. (2018). *Technology-Assisted Knowledge Agriculture for Sustainable Development Goals Advances in Crop Science and Technology*. doi:10.4172/2329-8863.1000391

Tian, H., Wang, T., Liu, Y., Qiao, X., & Li, Y. (2020). Computer vision technology in agricultural automation, A review. *Information Processing in Agriculture*, *7*(1), 1–19. doi:10.1016/j.inpa.2019.09.006

Trendov, N. M., Varas, S., & Zeng, M. (2019). *Digital Technologies in Agriculture & Rural Areas Status Report*. Food and Agriculture Organization of the United Nations Rome.

Trendov, N.M., Varas, S., & Zeng, M. (2019). *Digital Technologies in Agriculture and Rural Areas – Status Report*. Academic Press.

USAID. (2018). *Digital Farmer Profile: Reimagining Smallholder Agriculture*. USAID.

Walter, A., Finger, R., Huber, R., & Buchmann, N. (2017). Smart farming is key to Developing Sustainable Agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, *114*(24), 6148–6150. doi:10.1073/pnas.1707462114 PMID:28611194

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M.-J. (2017). Big Data in Smart Farming – A review. *Agricultural Systems*, *153*, 69–80. doi:10.1016/j.agsy.2017.01.023

Chapter 8
Synergistic Technologies for Precision Agriculture

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ABSTRACT

Precision agriculture (PA) as a concept allows input optimization by farmers and food producers in order to improve productivity and enhance quality yields while minimizing costs and environmental impacts. Developed countries typically identify with precision agriculture due to very large sizes of farms and the possibility of mechanized systems of crop production. The method involves the data collection, analysis, and plotting on productivity, soil quality parameters, and environmental levels at different locations within the field to decide on the amounts of the applicable inputs (such as water, nutrients, and fertilizers) to the field. In most developing countries, precision agriculture technology is still largely missing. The field sizes are smaller, and technology access, training, and financial capital are still grossly limited. Nonetheless, the farmers in the developing countries still explore the available resources and means at their disposal to increase their agricultural production and productivity.

INTRODUCTION

One of the major concepts for revolutionizing the food industry during the fourth industrial revolution (4IR) is precision agriculture (University of Stellenburg Business School, 2017). Precision agriculture (PA) as a concept, allows input optimization by farmers and food producers in order to improve productivity and enhance quality yields while minimizing costs and environmental impacts. Developed countries typically identify with precision agriculture due to very large sizes of farms and the possibility of mechanized systems of crop production. The method involves the data collection, analysis and plotting on productivity, soil quality parameters, and environmental levels at different locations within the field,

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to decide on the amounts of the applicable inputs (such as water, nutrients and fertilizers) to the field (Tran and Nguyen, 2006). In most developing countries, precision agriculture technology is still largely missing. The field sizes are smaller, technology access, training and financial capital still grossly limited. Nonetheless, the farmers in the developing countries still explore the available resources and means at their disposal to increase their agricultural production and productivity.

The world population is projected to be approximately 9.5 billion by the year 2050, while food production is estimated to be doubled to meet the consumption need of the people. Precision farming, a new technological development, supports the farmers to feed more people even from the same field size. Before the era of the agricultural revolution, almost 90% of the global population engaged in peasant farming. The trend has drastically changed, as 80% of the developed nations now engage in the service industry. As the agriculture workforce is steadily reducing, the ages of the farmers are increasing with youths not embracing it. A case study of the Republic of Korea, more than half farmlands are owned by 60 years old and more than 40% are owned by above 65 years of age. Noteworthy, 5% of the global population that works in agriculture contributes 60% of the global economy. The reality has forced many developed countries including the USA and Japan to make efforts at solving agricultural challenges through modernization, mechanization and automation in which the 4IR adequately represents (Sung, 2018; Lee, 2017).

Precision agriculture, sometimes called digital agriculture resulted from the third phase of the agricultural revolutions, after the advent of mechanization between 1900 and 1930s, and the green revolution in 1960s. The concept of PA has its first revolution in a form of weather prediction, aerial and satellite imagery, and varying fertilizer application. The second phase of PA development involved aggregation of machine data for topographical mapping, soil data, and more precise farming exercise (Kukuta, 2016). In the fourth food revolution (Food 4.0), digital agriculture will change farming, as PA and other technologies of the 4IR hold the answers to the challenges of sustainably feeding the growing global population (Dongoski, Rob & Selck, 2017). The change-agent technologies in the food sector include driverless tractors, smart robotics, sampling sensors, drones, and agricultural robots. The food industry, being a representative industry where there is any inconsistency between inputs and outputs, requires a method that will effectively construct an optimized agricultural model which strikes a balance among production, distribution and consumption. Despite that enough foods are produced globally, many people still die of famine because about 30-50% of the produced foods are wasted.The interest in PA is steadily increasing due to its balance between minimizing environmental pollution and maximizing the production of food products. Precision agriculture enables sustainable intensification of increased yields through a prudent and minimal application of inputs. Also, soil moisture and quality could be improved while reducing the environmental impact due to excessive input applications. Moreover, farmers tend to involve in more competitiveness through lower production costs and targeted inputs application (Sung, 2018). A solution for reducing the agrochemical inputs as well as the adverse environmental impacts is presented by PA. This is emphasized through three fundamental benefits: economy increased yields, and environmental benefits (Kendall, *et al.,* 2017).

Digitalization of agriculture and food means that almost every aspect of the industry is mostly reliant on the hardware, being controlled by the software. Despite the possible resistance from the traditional and analogue ways of food production, the industry is being transformed through the innovative and technological disruptions, which are synergistic with precision agriculture. PA as a concept involves drones, big data, farm management software, and sensors in the various aspects, which include environmental control, smart packaging, micro-farms, and gene manipulation. The technologies and innovative practices would in addition to being the future of farming and food, be the surviving strand for the human race. PA has various forms of application, which include precision irrigation, forecasting, yield monitoring, crop scouting, variable rate application, and others. Precision irrigation and the variable rate application are major enablers of the precision crop farming. The introduction of autonomous robots is radically augmenting the growth in both crop and animal farming. In addition, indoor farming is growing due to the expanding urbanized areas and the increasing demand for fresh food. Aquaculture is also enjoying the benefits of management software in ensuring efficient aquatic breeding of species.

The concept of PA can also be defined from the view of timely variation management, down to cropping systems implementation. It is an underpinning of crop management on a site-specific basis, whereby resource applications decisions and agronomic methods are better improved to suit soil requirements and varying crops in the field. The focus in this concept is the decision-making based on resource allocation, and not on information technologies (IT) adopted on the farmland. The interesting part of the view is that the decisions made ensure all-encompassing benefits that may not be presently measurable. The concept has expanded coverage of IT application and production experience to site-specifically optimize quality, optimize efficiency in production, minimize risk and minimize environmental bearing. The evolving trend of the site-specific crop management (SSCM) approach is as shown in Figure 1. The SSCM is continuous management strategy with decisions being formed from typical data monitoring and analysis. The effect of the decision is to be monitored and the information being fed into the next management decisions cycle. The enabling technologies of SSCM allow the approach to apply to geo-referencing, attribute mapping, decision support systems, data monitoring and differential action (Taylor and Whelan, 2016).

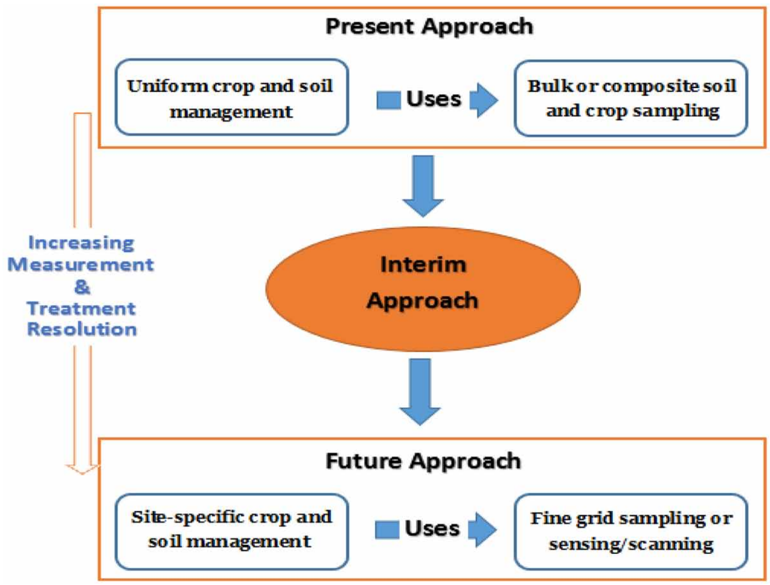
Geo-referencing activities allow for options of mapping and visually displaying farm operations. These provide an insight into variability and inefficiencies in crop production and operational activities. In monitoring the crop, soil and climate, several sensors and devices had been developed for real-time measurement of the variables. The area of trending research interest remains the adaptability of the existing sensor and developing new ones, and the need for agricultural scientists to continue the assessment of the possibility for multiple crops and measured production indicators (Taylor and Whelan, 2016; and Rains and Thomas, 2009).

Summarily, precision agriculture is an evolving management practice with the sole potential of increasing profits through information utilization on agricultural resources. In crop production, the management often involves input variables, like cultivation selections, application rates, irrigation scheduling and tillage practices. The advent of 4IR technologies is enabling the feasibility of PA management on a large-scale perspective. The PA concept has been developed to a framework in which field information can be monitored and controlled at a relatively low cost to the farmer. Selective application of pesticides is possible on pest-infested areas only, thereby reducing the quantity of usage pesticide and consequent reduction of the environmental impact. In addition, soil nutrients can be optimized through the correct choice of the plant population, while correctly selecting the plant variety can enjoy the benefits in the field conditions. The monitoring of crop yield can also result in the creation of maps for decision making on the low and high production areas on the field. Though the concept of PA management was first mainly accepted in the Midwest for corn, soybean and wheat, it can have applications to virtually all agricultural commodities (Rains & Thomas, 2009).

SUMMARY

Precision Agriculture Synergistic Technologies

Figure 1. The Progressing Timeline of Site-Specific Crop Management
(Taylor & Whelan, 2016)

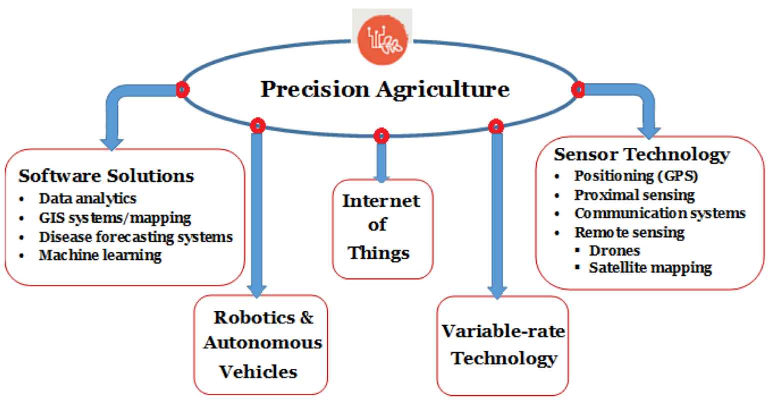


The architecture of precision agriculture comprises of software solutions, which include various technologies such as data analytics, machine learning and others. New technologies are changing today's farming practices through the concept of PA. Different expert works have shown that expanded smart farming will culminate to increased crop production and better efficiency in the production systems. In addition, PA manifests in diverse farming practices that include vertical farming, controlled environment agriculture, and livestock farming. The extent of developed lands for agriculture in urban cities has offered the opportunity of introducing urban and pre-urban agriculture practices via smart agriculture. The economics of urban agriculture may not bring massive profit initially, but has a great promise of social entrepreneurship (University of Stellburg Business School, 2017). The technology architecture of precision farming is illustrated in Figure 2. To harness the full benefits of PA, several technologies do integrate within farming practices. Therefore, good importances of technology acceleration, as well as the costs reduction are being facilitated by synergistic integration of technologies and aiding platforms for full-blown technology adoption.

a. Sensor Technology

A sensor device detects the changes in its environmental parameter(s), and sends a corresponding signal to other electronic devices. The feature is embedded in the technology of data collection for the crop, soil, animal data, and so on, through the integration of agricultural machines, drones, equipment, satellites, aircraft and others. The technology allows for real-time data detection, measurement, analysis, planning and usage for more effective farming and food production. The application of sensor technology within the precision agriculture concept in Food 4.0 is well pronounced.

Figure 2. The technology overview in precision agriculture



Precision agriculture incorporates sensors in determining among other things crop stress, pest and disease outbreak, and soil properties. The travel agents (tractors and scout) in the field, as well as aeroplane or mapping satellite during precision farming take advantage of sensor technology to measure the soil and plant properties. The yield monitoring systems presently in use have sensors primarily for real-time measurements, while real-time soil properties measurement and rate changes are possible via commercial sensors. There are other ongoing researches on the commercial applications for detection of weeds and nitrogen levels in plants. Sensors are available that are capable of spot-checking plant health, by using light reflectance on the plant leaves to measure the chlorophyll levels. Experts have established that direct proportionality between plant nitrogen levels and chlorophyll production. Also, there are kits available for determining soil pH and other elements remotely without using soil samples (Rains & Thomas, 2009).

Sensor technology helps in data planning, livestock/crop management, processing and harvesting. It synergistically combines for food security and product traceability. It has a vital integrating tendency into the entire food production, post-harvest and supply chain. In addition, it has particular relevance in the monitoring of soil, water, and climate. Presently, and shortly within the food production cycle, sensors remain the basic elements within crucial technology applications. Sensors are becoming very smart, cost-effective and increasing in integrated capacity for food applications. In 4IR, food applications will integrate sensors for remote sensing and positioning. Local and remote sensing systems in collecting large data for food production management need to be integrated with efficient big data analytics for providing finest-resolution decision-making guides. Remote sensors have the features of providing instant maps of field parameters, while optical sensors can present the changes in field colour parameters corresponding to the variations in crop development, soil type, field boundaries and others. The indices presented through satellite and aerial imagery can indicate the health of the plants.

The positioning within the sensor technology is done with global positioning satellite (GPS). This consists of 24 satellites placed at a very high altitude up the earth orbit for locating objects on the earth surface (Rains & Thomas, 2009). There are special receivers designed to decipher the continuously transmitted signals from the GPS. There is a requirement of at least four satellites for the receivers to calculate the object position on the surface of the earth. The deliberate offset by the manufacturer and atmospheric conditions reduce the accuracy of the determined position. Therefore, a raw signal from the GPS without the reference is not adequate to correctly determine the accuracy of the positioning. A differential global positioning system (DGPS) uses the reference signal to establish the correct data set on the positioning. The GPS systems eliminate the recurring site visit for a soil sample to establish the fertilizers or pesticides need on the crop and the field.

b. Robotics

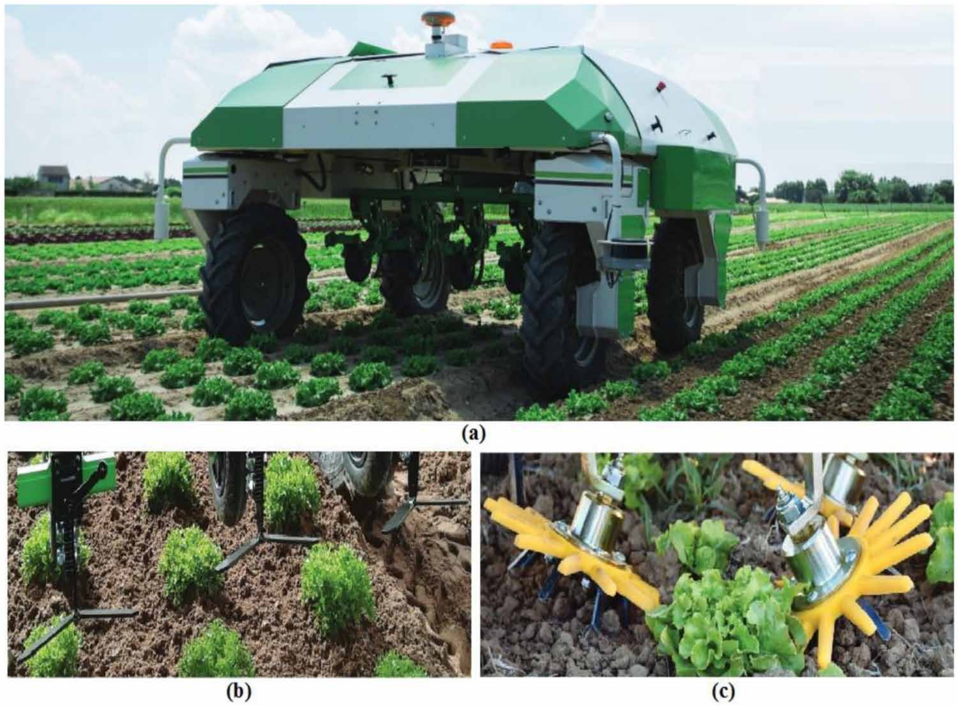
The development and operations of automated robots are the underlying concepts in robotic technology. Many technologies overlap with robotics in the synergistic integration within the precision agriculture concept. Robots specifically perform the tasks outside the ability window of humans to execute. Food productions and agricultural practices apply different forms of robots, which include industrial robots, autonomous vehicles and bionics. Robotics is becoming an innovative for boosting farm yield and food supply. Simpler and more reliable machines can be produced from specially made robots, and then reduce the number of needed systems and components. Automated systems help in planting, harvesting and food packing. A typical example is the automated high-speed identification and harvesting of ripe berries by robots without crop damage.

Robotics has a synergistic relationship with some other technologies for applications in food production and management. With advances in big data analytics and machine learning, robotics can now leverage on the use of large data. Presently, robots tend to imitate human intelligence and perform even more tasks. In effect, more machines and robots have gradually replaced humans on the previously reserved functions and tasks. The opportunity left for human to explore is gradually diminishing. As artificial intelligence begin to gain more and more prominence in Food 4.0, human interventions and involvement also begin to steep lower. Meanwhile, it is inferential that the reducing cost of robotic technology is against the possible opportunities for farm labourers. Investors and producers are gradually taking advantage of lowering cost in adopting robotics in all aspect of food production and management. An automated weeding robot for vegetative crops and its attached accessories are as shown in Figure 3. The robot weeds without human intervention, and allows for the elimination of chemical weed control as an advantage for both the environment and the crops.

c. Software Solutions

Food production through agriculture has all its aspects enabled by software solutions such as artificial intelligence, machine learning and big data analytics. Big data steadily provides insights into productive farming systems by driving real-time decisions on operations and enabling process re-designs for cutting-edge business models. The big data landscape will be dominated by a two-throng scenario: secured proprietary systems, with farmers being a crucial component of a highly integrated value-chain; and exposed collaborative systems, with farmers and other role players being flexible to choose business partners with the chain network of technological food production. Meanwhile, visualization techniques

Figure 3. Automated weeding robot for vegetable crops, (a) robot, spiked harrow tool, (rotary hoe) (Preudhomme, 2019).



allow data to be made more user-friendly with the implication of a better understanding and implementation of real-time data analysis (Heikkila, 2017).

Machine learning and artificial intelligence (AI) are continuously and rapidly developing into inevitable solutions in the food value chain. The two solutions are synergistic with precision agriculture and other technologies to revolutionize the food sector in the 4IR. However, human skills are gradually becoming redundant regardless of the huge potentials for economic growth through software solutions. Farms and business, with the understanding of the AI impact on employment, need to develop people's skills in the newly emerging areas that are a consequence of the software solutions. A typical application of software solution in precision agriculture is in the area of driverless vehicles, with AI driving them on the farm. Smart Ag Company announced the invention of "AutoCart" software in the introduction of driverless farm tractor technology (Grassi, 2018). The AI cloud-based software fully automates the grain cart tractor to provide great assistance to farmers in the peak of the harvesting season.

Geographical Information Systems (GIS) is computer software capable of providing data storage, data retrieval, and conversion of field or spatial data. This software solution has a good application in precision agriculture and farming management. The area of usage includes layering nutrient level, soil type and others, and assigning the information to the specific field location. The characteristics analysis between layers and the development of application maps are also basic functions of GIS. The software finds a useful complement of the Global Positioning System (GPS) in storing the field location by the longitude and latitude. The GIS software can be used to show variability in the soil type, nutrient levels, topography, yield, and pest incidence.

d. Internet of Things

Precision agriculture is synergistically related to internet-connected objects to execute tasks in food production and management. Internet of Things (IoT) is defined as devices (e.g sensors) being connected to the internet and can communicate with one another to execute functions without human intervention. Agricultural and food environments enjoy vast applicability of the array of networks and sensors. The internet-connected sensors and nodes produce data, which can easily be analyzed for improving the operational condition within the food systems. IoT is projected to play a crucial role in the agricultural and food supply chain, weather prediction, and others. The current limitations in the wireless connectivity within some regions still pose a major research concern for IoT to be fully explored in agriculture and food. Meanwhile, experts have predicted that soon within the 4IR, IoT will tremendously influence food production, logistics, market analysis and many other areas. A typical area of interest for IoT application in precision agriculture is in climate and greenhouse monitoring as shown in Figure 4. It involves the integration of smart farming sensors at different locations across the field. The data collected could be transmitted to the cloud, and the provided measurements are used to map the environmental conditions in the field. The system is mostly capable of adjusting the conditions to match the desired parameters (Aleksandrova, 2018).

Currently, IoT capabilities being considered by modern tools, machinery, emerging communication and information technologies, are being harnessed by the agriculture and food sector. This is the basic implementation in the new era of Food 4.0, in which automation, digitalization, connectivity, and efficient resource use are the main components (Miranda, *et al.,* 2019).

Figure 4. A typical IoT application in precision agriculture
(Aleksandrova, 2018).

e. Variable-rate Technology

Variable-rate technology (VRT) involves computer hardware and microcontrollers in varying the outputs of fertilizer, pesticides and lime. The controllers can integrate with the GPS in taking an application map to locate field positions and provide control for the variation of the application rate. The VRT is related to the precision agriculture in the application of fertilizer, as associated with the soil sampling, GIS and GPS. In such a case study, the location of the tractor in the field is relayed by the GPS. The field characteristics of the location are communicated to the controller through the link between the GPS and GIS. The predetermined yield target, however, dictates the exact quantity of the applicable fertilizer at the location. The machinery being manipulated by the controller therefore executes the application of the correct amount of fertilizer. The VRT process applies similarly to insecticides and herbicides, except that a real-time sensor will communicate with the controller about the exact location of the insects and weeds. Such sensor systems are still short in availability, thereby presently subjecting the VRT for pesticides to rely on manual field scouting for the infestation level mapping.

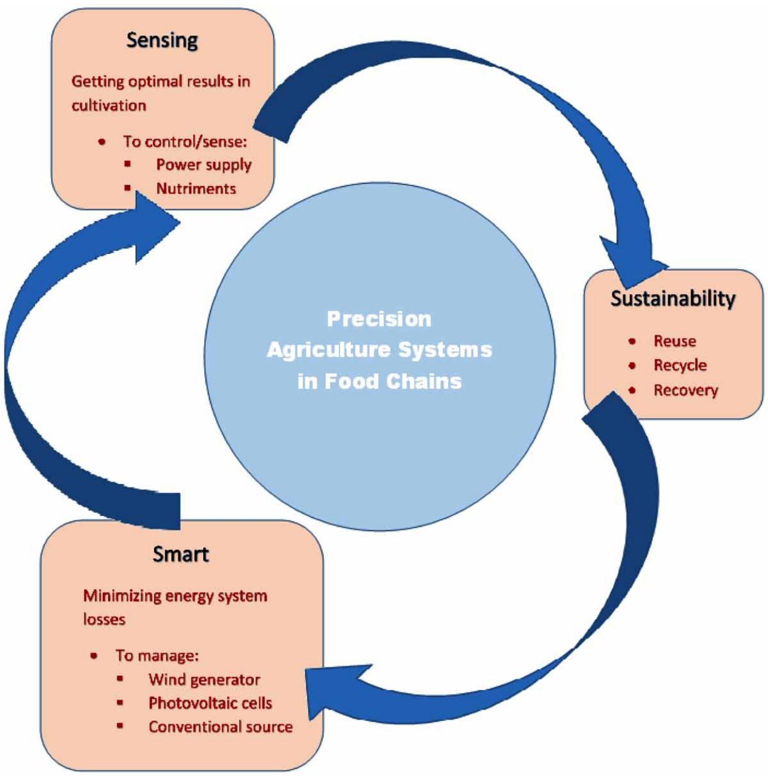
Case Study: Precision Agriculture via the Synergistic Technologies in Food Chain

Precision agriculture is a solution-enabled concept in constructing an optimized agricultural system that connects food production, distribution and consumption. The concept of PA is encompassing sensing, smart, and sustainable technologies within the food systems as being shown in Figure 5 (Miranda, Ponce, Molina & Wright, 2019). Precision agriculture can help farmers in increasing the quantity, quality, cost effectiveness and sustainability of food production. PA helps farmers to mitigate many challenges relating to water shortages, limited available useful lands, and the cost of implementing the technologies. PA allows farmers to optimize among the consisting units of the technology in which the sensors remotely monitor, manage and control connected equipment. The concept of PA is demonstrated in many case studies.

a. Libelium Networked-Sensors in Crop Monitoring

Libelium technology-enabled precision agriculture system has been deployed by the Red Tecnoparque organization of Columbia to monitor crops in the Santa Rosa region of the country. The organization selected the Libelium's Waspmote sensor platform in developing the PA project with remote networked sensors. The system was deployed to monitor plantain crops, with more scaled sensors added to the network. The system allows for the monitoring of key parameters such as temperature, humidity, trunk diameter, soil moisture, solar radiation and fruit diameter within the plantation to be monitored remotely. The resulting process can enable the producers to remotely supervise agronomic and ambient variations to investigate new varieties of banana. Also, the PA solution provides a possible record of the harvesting projection, prevention of the plagues and diseases, optimization of water usage, reduction of fertilizers consumption, and clarification of the available soil (Tomas, 2017).

Figure 5. The collaborative requirement of PA systems in the food chain



b. Smart Hydroponic Greenhouse

A smart hydroponic greenhouse (SMG) was designed as a production system by using the sensing-smart-sustainable development approach. The SMG is deployed within Tecnológiico de Monterrey, Mexico City as shown in Figure 6. The system has its application focused on the entire lifecycle of tomato production. The areas of focus in the production include the identification of the requirements, the development of the production process, and the facility development. The design process, however, was faced with the critical challenge of providing the optimum solution that describes the most appropriate physical

Figure 6. The Smart Hydroponic Greenhouse (a) exterior view, (b) interior view
(Miranda, et al., 2019)

infrastructure, and control for regulating the environmental conditions within the greenhouse (Ponce, Molina, Cepeda, Lugo & MacCleery, 2014).

The SMG system helps to evaluate the environmental conditions including wind direction, rain, humidity, wind speed, sun intensity, temperature and solar luminosity; to control and preserve the integrity of the crop within the greenhouse. The input and output data from the system can be relayed using the collaborative human and machine production technologies, and graphic user control interfaces.

c. Variable-rate Fertilizer Application in Australian Grain Farms

The process of approximating the benefits of variable-rate technology in fertilizer application involves working with some estimates of yield on each zone, relative to when either uniform management or variable rate is used. In the research of (Robertson, Carberry & Brennan, 2007) concerning the Australian grain farms, two approaches were arrived at after interfacing with the farmers in the region, depending on the environments of the case studies. There are two cases as shown in Table I and II, which show the illustration of fertilizer and assumed yield during uniform management when the management zone fertiliser rates and yields are known during variable rate management.

Table 1. Case 1 of fertilizer rates and assumed yield under uniform management when the factors in management zones within the variable rate management are known

Zone Yield Potential	Under Variable Rate Management		Under Uniform Management	
	Grain Yield (t/ha)	Fertilizer Rate (kg/ha)	Grain Yield (t/ha)	Fertilizer Rate (kg/ha)
High	3.0	75	2.75	50
Medium	2.5	50	2.5	50
Low	2.0	35	1.9	50

(Robertson, *et al.,* 2007).

In Table 1, The high zone potential yield is taken to be limited in nutrient and then increases the variable-rate yields, while the low potential zone is non-limited in nutrient and there is 5% increase in yield as a result of 'haying off'. The parameters in the medium zone remain constant.

Table 2. Case 2 of fertilizer rates and assumed yield under uniform management when the factors in management zones within the variable rate management are known

Zone Yield Potential	Under Variable Rate Management		Under Uniform Management	
	Grain Yield (t/ha)	Fertilizer Rate (kg/ha)	Grain Yield (t/ha)	Fertilizer Rate (kg/ha)
High	3.0	75	3.0	75
Medium	2.5	50	2.5	75
Low	2.0	35	1.9	75

(Robertson, *et al.,* 2007).

In Table 2, all zones are taken to be limited in nutrient within the uniform management, and then no increase in variable-rate yield, except for low potential zone with 5% increase in due as a result of less 'haying off'.

d. Multi-purpose Sun-Tracker

The use of solar panels for solar energy harvesting in recent times is a very popular development. However, other lesser clean energy sources have proved to provide reduced costs per watts. The Sun-tracker is a device herewith developed to harness maximal energy generation through solar panels and consequently provide a competitive advantage to the energy output. To solve the complex challenge of locating an optimal position, the device is developed to compose both the genetic algorithm and swarm-optimisation algorithm, which were being implemented as a digital system for positioning optimisation. The development of the genetic algorithm allows the solution to find the position of the sun tracker based on the off-line data. The solution of the off-line process can be programmed and experimentally evaluated. Computational cost is decreased through the approximation, and an effective approach for constant clime-condition areas has been developed. To develop a solution applicable to the non-constant clime-condition areas, a simplified swarm-optimisation algorithm was introduced and has been very effective in the area. An intelligent water drop algorithm was developed, adapted and validated experimentally to run an online solution. The evaluation of the algorithm showed increased sun tracker efficiency over the static solar-cell type by 40%. The Sun Tracker device as shown in Figure 7 has a very useful application in energy supply to greenhouses and provides needed automated need for smart crop field management (Miranda, *et al.,* 2019).

e. Vodafone Precision-Fertilizer Application (VPFA)

The precision farming solution is developed to enable farmers to use only the actual fertilizer quantity needed at an instance. The system is an integration of different synergistic technologies to implement a complete PA solution. A specially designed GPS device was installed on a tractor dispersing the fertilizer, and the data of the operation is relayed remotely using the Vodafone network. Each farmer could access the record of fertilizer deposit through the map created from the recorded data on the secured server. This has enabled the farmers to accurately mitigate any possible waste in the spreading of the fertilizer by easily spotting and correcting it. The VPFA system has employed the machine-to-machine and GPS technology. The operator provides the network and the special chip required for the uninterrupted data transmission from the field. The system enables the continuous tracking of both the rate and width of the applied fertilizers and gives the farmers control over the management of their farm inputs. This PA system can be modified and extended for application in other areas like effluent dispersal and spaying. The system has ensured that farmers take control of the optimal use of substances on the land (Tomas, 2017).

f. Precision Agriculture Quadrotor

The quadrotor is a drone, developed for unmanned aerial monitoring and application. The system is designed based on the fuzzy logic motion controller, to maintain a horizontal balance with separate reference to 'x' and 'y' axes, while keeping a constant motion relative to 'z' axis. The system also consists

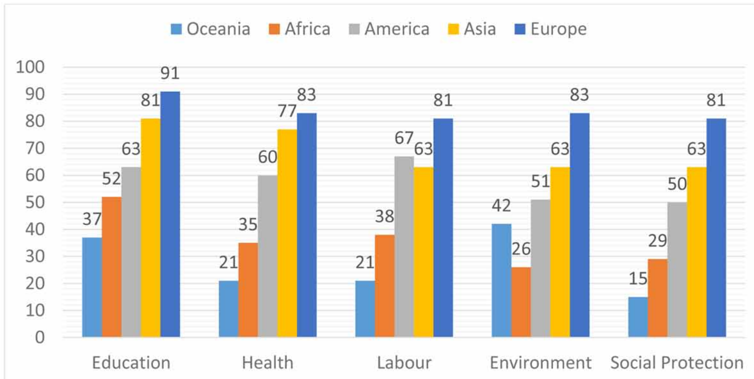
Figure 7. A Typical Prototype Sun Tracker
(Miranda, et al., 2019)

of a monitoring interface, which indicates the representative angles and their actual numerical values relative to each axis at every point in time. The interface also indicates the derivatives of the angles, the values of the actual PWM percentage in each motor, and the energy and generated torque by the motors. The values and other necessary parameters like each axis angular velocity and required information are also displayed. The quadrotor is very useful for agricultural and food applications such as UAV sprayer for pesticides, herbicides and fertilizers; monitoring of crop growth, and image capturing for 3D models.

Policy Impacts of Precision Agriculture

Policy framework from governments and producers is a critical component of the food revolution. An enabling environment is created for competitive services and digital markets. Meanwhile, a high-level administrative capacity is required for designing and managing most digital programmes, especially for the government. The skillset is inadequate in most developing countries, thereby making precision agriculture applicability to lag in the areas. In most cases, there is also a shortage of published works on government policies on digitalization of agriculture and food. Meanwhile, information is being inferred from the inference to the extent of governments' participation in e-services, data and connectivity. A typical chart of governmental services in different regions with the enablement of digital connectivity is as shown in Figure 8.

Figure 8. Government services provided through the short message (SMS), email, or Simple Syndication (% of the countries in each region)
(Trendor, Varas & Zeng, 2019).



The policymakers rely on the management optimization capacity of precision agriculture at the field-level of crop science, through the match between crop needs and farming practices, farming economics through the proficient practices of enhancing affordability, and ecology through reduction of environmental risks. Farmers are now being enriched with information on farming records, improved decision making, boosting marketing, quality improvement of yields, better traceability and upgraded leasing of lands. The decision making of the farmers is supported by PA technology in respect of fertilizer quantity based on soil type, the plant type to plant-based on soil conditions, the pesticide quantity to apply on a specific crop. The decisions made are based on assorted information sources with sophisticated requirements on analysis with reference effects on the crop quality and quantity, impact on the environment, and operational profitability (Aubert, Schroeder & Grimmaudo, 2012). Moreover, with the increase in efficiency of input use and machinery, PA enables simultaneous reduction of environmental impact, with improved productivity on the farm. Also, PA alters the economics in agricultural production. Economic incentives are used by sundry agro-environmental policies to encourage production practices adoption with lesser environmental impacts. In the event of changes by PA in constraints and incentives experienced by producers, there could be unexpected consequences in the policy measures used by production practice standards for farming (Schieffer & Dillon, 2015).

a. Decision Making

Precision agricultural practices involve plenty of multipart decision-making problems, mostly incorporating high uncertainty and actionable alternatives. In the optimization of the treatment methods for crops and farmlands, different interconnected parameters with high-complicated variability are considered. The evaluation of the field as a uniform entity, whereby parameters like water availability, crop yields, and chemical inputs are also considered, gives an impetus to a sub-optimal treatment and excessive application of pesticides which consequently leads to environmental pollution (Rains & Thomas, 2009; and Preudhomme, 2019). Meanwhile, PA technology has enabled a good turn in farming treatment practices. Farmland could now be taken as a heterogeneous entity with selective treatment approach, as against the previous homogenous consideration. The technology is contributing greatly to efficiency in farming practices and environmental sustainability issues (Heikkila, 2017; and Grassi, 2018). Policymakers would adequately enjoy a better understanding of the effects of PA on the changes in constraints that shape decisions made by producers, and the interaction of the differences with incentives resulting from the ago-environmental policy (Schieffer & Dillon, 2015).

Most recent researches are focusing on examining the application of PA concepts on various commodities such as cotton, citrus, vegetables, peanuts and livestock. The production process of the row crops requires effective operational decisions which include: application time and rate for fertilizers and pesticides, planting period, depth and population, tillage and cultivar selection (Trendor, *et al.,* 2019).

b. Economics and Environmental Impact

The food industry and policymakers encounter two major competing demands in an attempt at meeting the food demands of the surging population at a reduced rate of accompanying environmental impacts. The impacts are observed in two main areas, the running off the agricultural nutrients, which significantly weaken water quality, and the greenhouse gases generated during agricultural productions, which immensely contribute to climate change concerns. PA technology provides a very good opportunity at mitigating the environmental impact while improving productivity and profits during farming practices, through increased input use and machinery efficiency. A case study is the navigational aids, which reduce multiple passes, overlap in farm machinery and subsequently decreases the fossil fuel and other inputs being applied. Varying the pesticides and nutrients being applied can substantially reduce the application of the inputs and saving costs alongside decreasing the volume of the harmful overspill into waterways (University of Stellenburg Business School, 2017; Aleksandrova, 2018 and Miranda, *et al.,* 2019). PA increases the efficiency and however alters the economics of food production. Agro-environmental policies are as efficient and desirable as the economic incentives they produce with favourable environmental impacts alongside the production practices. Meanwhile, whenever PA alters the constraints and incentives available to producers, the policy measures adopted through standard production practices may result in unintended consequences (Schieffer & Dillon, 2015).

Recent researches have focused on the possible relationships among PA technologies, the economic condition of the farm, the environmental impacts from the decision made on-farm operations, and the efficiency of the agro-environmental policy.

REFERENCES

Aleksandrova, M. (2018). *IoT in Agriculture: Five Technology Uses for Smart Farming and Challenges to Consider*. Academic Press.

Aubert, B. A., Schroeder, A., & Grimaudo, J. (2012). IT as an enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. *Decision Support Systems*, *54*(1), 510–520. doi:10.1016/j.dss.2012.07.002

Dongoski, A. (2019). *Digital Agriculture and Big Data*. Available: https://consulting.ey.com/digital-agriculture-helping-to-feed-a-growing-world/

Grassi, M. J. (2018). *Driverless Tractor Automation*. Available: https://www.precisionag.com/in-field-technologies/smart-ag-announces-driverless-tractor-automation-platform/

Heikkila, A. (2017). *Innovative Agricultural Practices That Are Changing the World*. Available: https://www.innovationexcellence.com/blog/2018/08/06/5-innovative-agricultural-practices-that-are-changing-the-world/

Kendall, H., Naughton, P., Clark, B., Taylor, J., Li, Z., Zhao, C., Yang, G., Chen, J., & Frewer, L. J. (2017). Precision agriculture in China: Exploring awareness, understanding, attitudes and perceptions of agricultural experts and end-users in China. *Advances in Animal Biosciences*, *8*(2), 703–707. doi:10.1017/S2040470017001066

Kukuta, A. (2016). *Can Digital farming Deliver on its Promise?* Available: http://www.agnewscenter.com/archives.cfm?news=9903

Lee, J. (2017). The Fourth Industrial Revolution and Future Agriculture (2nd ed.). Science and Technology Policy Institute.

Ma, L., Feng, S., Reidsma, P., Qu, F., & Heerink, N. (2014). Identifying entry points to improve fertilizer use efficiency in Taihu Basin, China. *Land Use Policy*, *37*, 52–59. doi:10.1016/j.landusepol.2013.01.008

Miranda, J., Ponce, P., Molina, A., & Wright, P. (2019). Sensing, smart and sustainable technologies for Agri-Food 4.0. *Computers in Industry*, *108*, 21–36. doi:10.1016/j.compind.2019.02.002

Napier, T., Robinson, J., & Tucker, M. (2000). Adoption of precision farming within three Midwest watersheds. *Journal of Soil and Water Conservation*, *55*(2), 135–141.

Ponce, P., Molina, A., Cepeda, P., Lugo, E., & MacCleery, B. (2014). *Greenhouse Design and Control.* CRC Press. doi:10.1201/b17391

Preudhomme, M. (2019). *The automated weeding robot for a vegetative crop*. Available: https://www.naio-technologies.com/wp-content/uploads/2019/04/brochure-DINO-ENGLISH

Rains, G. C., & Thomas, D. L. (2009). *Precision Farming: An Introduction*. The University of Georgia Cooperative Extension.

Recio, B., Rubio, F., & Criado, J. A. (2003). A decision support system for farm planning using AgriSupport II. *Decision Support Systems*, *36*(2), 189–203. doi:10.1016/S0167-9236(02)00134-3

Robertson, G. P., & Swinton, S. (2005). Reconciling agricultural productivity and environmental integrity: A grand challenge for agriculture. *Frontiers in Ecology and the Environment*, *3*(1), 38–46. doi:10.1890/1540-9295(2005)003[0038:RAPAEI]2.0.CO;2

Robertson, M., Carberry, P., & Brennan, L. (2007). The Economic Benefits of Precision Agriculture: Case Studies from Australian Grain Farms. *Controlled Traffic and Precision Agriculture Conference*, 1–7.

Schieffer, J., & Dillon, C. (2015). The economic and environmental impacts of precision agriculture and interactions with agro-environmental policy. *Precision Agriculture*, *16*(1), 46–61. doi:10.100711119-014-9382-5

Schneider, U., & Kumar, P. (2008). Greenhouse gas mitigation through agriculture. *Choices*, *23*(1), 19–23.

Sung, J. (2018). The Fourth Industrial Revolution and Precision Agriculture. *Autom. Agric. Security. Food Supplies Futur. Gener.*, 1.

Taylor, J., & Whelan, B. (2016). *A General Introduction to Precision Agriculture*. www.usyd.edu.au/su/agric/acpa

Tomás, J. P. (2017). *Three precision agriculture IoT case studies*. Available: https://enterpriseiotinsights.com/20170516/smart-farm/20170516smart-farmthree-precision-agriculture-iot-case-studies-tag23-tag99

Tran, D. V., & Nguyen, N. V. (2006). The concept and implementation of precision farming and rice integrated crop management systems for sustainable production in the twenty-first century. *Int. Rice Comm. News.*, *55*, 91–102.

Trendov, N. M., Varas, S., & Zeng, M. (2019). *Digital Technologies in Agriculture and Rural Areas*. Food and Agriculture Organization of the United Nations Rome.

University of Stellenburg Business School. (2017). The Future Of The Western Cape Agricultural Sector In The Context Of The 4th Industrial Revolution, Review. *The Fourth Industrial Revolution (4IR),* 1–21.

Chapter 9
Use of Smart Farming Techniques to Mitigate Water Scarcity

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ABSTRACT

Scarcity of water resources due to increased demand as a result of exponential increase in population leading to accelerated requirement of food and industrial goods has led to a situation where many countries are facing severe water crisis. About 70% of water is being used for irrigation. As a result of this, in many cases untreated wastewater is also used for irrigation which further poses various threats to human health. Various studies have proposed that applying information technology in the irrigation techniques can help in reducing the water consumption in the farms. The smart farming techniques developed through the use of information technology can help the farmer in managing the water resources, reducing the wastage of water and to even measure the quality of water. Smart farming techniques can aid in solving biggest crisis and can help in attaining sustainable development goals.

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1. INTRODUCTION

Water is the most important aspect of life on earth and it is the most common fact that this blue planet is running out of usable water. It is projected that by 2050, 9.7 billion people will be living in water deficit areas while 3.9 billion people will face "severe" water crisis. Utilization of water in 20th century has increased many folds due to increased population, increased agriculture for food and industrial needs and increased industrialization. The usage is expected to further increase by 2050. Composite Water Resources Management Report as formulated by NITI Aayog perceives that currently about 600 million Indian are facing high to severe water crisis (Composite Water Resource Management, 2018). Shortage of water resources has turned out to be the biggest challenge for sustainable living, human health and normal functioning of ecosystem. By 2025, about one fourth of total population of world will be living in areas having acute water shortage (Seckler et al.,1998).

Water is a crucial resource in pace of sustainable development goals to attain "zero hunger" or to eliminate poverty. Climate change and recent urge to meet food security has further increased the utilization of water across the globe. As a result of which the scarcity of water is being evident. Increased urbanization has decreased the recharge of ground water and thus there is irreversible extraction of groundwater, leading to various issues for the life on earth.

Conventional cultivating system is one of the crucial reasons behind wastage of water and is responsible for about 70% of water utilization out of which 90% could be prevented by using proper techniques. So, while talking about water conservation the most important aspect is to have planned and newer irrigation technologies which are utilizing relatively less water. This can increase water accessibility, decrease soil degradation due to water logging/ run off, increase the crop production and feed the projected 9 billion people by 2050 (What India Wants, 2014; How to feed the world 2050).

Water use efficiency can be increased by growing the crops as per the local environment especially in arid and semi-arid areas, using drip and spray irrigation techniques, monitoring soil texture, water holding capacity and soil moisture.

2. INDIAN AGRICULTURAL LANDSCAPE

Farming contributes about 17% to India's GDP. With an estimation of roughly $390 billion, it is a standout amongst the most significant financial aspects in India. Around 60% of India's population relies upon agriculture. Despite the fact that India is the main producer of different harvests, there is potential to improve the yield to meet sustainable development goals.

Irrigation in India depends heavily on monsoons. Rainfall is uncertain, irregular and uneven or unequal. 80% of rainfall in India occurs in four months, from June to October. There is an immediate need for sustained, efficient, reliable irrigation for the rest of the eight months. Water is a finite, crucial resource. In most places around the world, water is being used for industrial consumption and also for agricultural use. It is also an important part of wetlands and other natural ecosystems that are of huge value to us. Irrigation can contribute towards losses of water in many ways. Water can seep out of tanks or transmission canals before getting to the plants. After water is applied to plants in the field, some of it can get into the groundwater system, where it is no longer available to the roots of the crop, or it might run off the field altogether.

Locally, the nature of ground water has been degraded. Metropolitan and modern squanders and synthetic manures, herbicides, and pesticides have percolated the soil, invaded a few aquifers, and reduced the ground-water quality. Other contamination issues incorporate sewer spillage, defective septic-tank activity, and landfill leachates. In some seaside regions, escalated siphoning of crisp ground water has made salt water interrupt into new water aquifers. In this manner treatment of water is vital. The motivation behind waste water treatment is to reduce amount of natural and inorganic substances and pathogens to make it potable or to be used in agricultural fields.

Treatment of water requires decrease of BOD, COD, nitrate level, and so on. Globally, just 20% of wastewater gets appropriate treatment(UNESCO 2012).Treatment limit relies upon economic constraints of the nation, along these lines treatment limit is 70% of produced wastewater in high-income nations, contrasted with just 8% in low-income nations.

2.1. Challenges Faced by Indian Agriculture

In 1960, a farmer fed 26 people. Today, a farmer feeds 155 people, which was brought about by a biotech revolution in most countries. By 2050, it is estimated that a farmer will need to feed 265 people("Digital agriculture: helping to feed a growing world," 2019), something that can only be achieved now by a digital agricultural revolution. There is an immediate need for technical improvements in the agricultural biz, to be able to feed the increasing populations and tackle hunger. It is very important to bring about this revolution sooner rather than later to avoid lock-ins: sceptics and advocates of technology need to engage to secure the future of the human race. There is also an immediate need to reduce the ecological footprint of farming. Minimized or site-specific application of inputs, such as fertilizers and pesticides, in precision agriculture systems will mitigate leaching problems as well as the emission of greenhouse gases(Miguel, 1998). Although there is not a global water shortage yet, more than 40% of people of the world live with some or the other form of water scarcity(Mehta, 2012; Dwivedy N., 2011).

The current agricultural practices followed by Indians are neither economically nor environmentally sustainable for the future. Poor irrigation systems and lack of technology in use characterize the Indian Agricultural System, the problems faced by which can be briefly categorized into the following categories

1. Poor Infrastructure: Agricultural as well as Industrial Infrastructure of India is of poor quality. Irrigation systems are not well developed. We do not have cold storage for our farmers, neither can we provide them with good roads. Equipment used by farmers is of poor quality that hampers work. Irrigational pumps cannot effectively irrigate all parts of the fields.
2. Adoption of modern agricultural practices and use of technology is not what is needed to feed the growing population of India, which is further hampered by lack of knowledge and illiteracy. Technologies such as IoT, which research has suggested can be of huge benefit to agriculture, is not being made use of.
3. Allocation of water is not efficient and is inequitable. The infrastructure, which is poor, is further deteriorating. Water is a resource that is scarce and requires proper and effective management, which our Agricultural Industry and policy makers have proved incapable to do so.
4. Farmers still rely heavily on monsoon and rainfall for irrigation, which means that irrigation facilities are inadequate. Weather plays an important role in determining if the harvest will be good or not, and hence the agricultural industry of India has a big risk factor associated with it.

5. Farming in India has a very huge ecological footprint, which needs to be reduced. Fertilizers and pesticides that are not good for the environment are being used for bettering production from crops. Use of such pesticides leads to leaching problems, as well as the emission of greenhouse gases from farms.

Not all food produced in India gets to its consumers. A report by CNN suggests that about one third of all food that is produced in India rots because the farmer is not provided enough resources to sell his product. All the above problems, are what build up to a large number of farmers committing suicide in India. Farmer suicide accounts for 11.2% of all suicide in India(Accidental Deaths & Suicides in Inida, 2015).

2.2. Mitigation Strategies Being Adopted

The development of agriculture is compulsory step that needs to be taken to get rid of hunger and poverty that India is facing in the present times. Bold and strong steps need to be taken for agricultural development. There is an immediate need for new technology that focuses on getting better food production from crops. Sustainable growth of agriculture is dependent on emerging technologies like Nanotechnology, Internet of Things, Smart Agriculture, Precision Agriculture, Remote Sensing, GPS, GNSS, Big data, Cloud computing and other technologies that are in development these days. Researchers, both with agricultural and engineering backgrounds have been trying to reduce the amount of water wasted whilst irrigating plants. With the development of Internet of Things, various modules for irrigating fields smartly have been developed.

1. The government of India is recognising where to play a role in developing infrastructure. It does not have to play a central role in every Industry, as it did in telecommunications by privatising it. Outcomes are being taken care of, with care being taken of expectations of promises made. The government is focusing on development of HYV seeds, new hybrids of different crops, research in areas of vaccines that would help combat crop infections, development of better quality of crops. Cost reducing drip irrigation is being adopted, which helps reduce water usage. Better fertilizers and seeds are being used, with many MNCs playing a key role in seed production and distribution. Not only from domestic financial agencies, Indian agricultural sector has been given $3.8 billion loan which was sanctioned by World Bank, which would help in development of agriculture("Agriculture Infrastructure," 2011).
2. In (Doshi, Shah, & Shaikh, 2017), the author talks about how the Internet of Things has brought about a change in automation, and how it can be better used for remote monitoring and sensing of data, be it in homes, the industry, the farms, or any other places. The paper specifically talks about an IoT platform Blynk, how it has a similar UPI for all devices that makes development easy, provides many different types of Widgets for a better interface, has different connection abilities. In (Kodali & Sarjerao, n.d.), the author uses a Message Queue Telemetry Transport protocol for communication between a sensor and the microcontroller that he uses for development of an irrigation system.
3. In (Vinnikov et al., 2002), the authors talk about what are important parameters for determining when plants should be irrigated, how floods and droughts can be predicted by critically monitoring soil moisture and the impacts of climate change lessened. The author presents an intensive study

on how and when should irrigation be done to maximise effective use of water. In (Sahu & Behera, 2015), the author talks about how irrigation systems can be made using cheap microcontrollers and other homemade moisture sensors.

4. In (Ghosh & Hingoliwala, 2016), the authors use a microcontroller, the Arduino Uno along with a combination of LCD screens, pH sensors and humidity sensors to develop a Drip Irrigation System, for improvement of cultivation. In (Morais, Valente, & Serôdio, 2005), the author talks about how wireless sensor networks with low data rates can be used for application in agriculture and the benefit of them versus traditional instrumentation based on wired, discrete solutions. The author uses a dual probe, heat-pulse based humidity sensor to measure the dankness of the soil and then routes the data to a base station where it is analysed to perform local control tasks. Effective power supply was a huge problem to the system proposed in this model. In (Kamilaris, Gao, & Prenafeta-bold, 2016), the author talks about how in the past, wireless sensor networks were very expensive and how they hindered a cost-effective solution for better irrigation. An irrigation system was developed which highlighted deficits in the ZigBee module and an algorithm was developed to overcome them.
5. It is well known that agriculture these days has a huge impact on the environment. It plays a huge role in methane, nitrous oxide and carbon dioxide emissions. The age-old practice of using ploughs to prepare land needs to be done away with. Better irrigation is being developed. We need to make use of the correct irrigation system which will lead to less water wastage and lower operating costs. This can be done by regularly testing soil moisture(Kamilaris et al., 2016).

In the past few years, India has emerged as a huge agricultural exporter, with produces increasing from just over \$5 billion in the year 2003 to a record of more than \$39 billion in 2013 (India's Agricultural Exports Climb to record high, 2014). India claimed the spot of the planet's 7th largest exporter of food products in 2013, a spot previously held by Australia. The Indian administration's support for both production and exports has significantly contributed to the fast growth in consignments, which are hugely destined for developing nations("India ' s Agricultural Exports Climb to Record High," 2014).

3. GLOBAL USE OF TECHNOLOGIES TO BETTER THE PROCESS OF AGRICULTURE

Technology has played a very important role in development of the agricultural industry. It has made possible the growth of crops in even deserted areas. Plants these days have been engineered to survive the droughts and harsh conditions. Genetic engineering has made possible improvement of genes of plants with a goal of making plants stronger and more resistant to droughts and pests. Farmers use mobile apps to calculate amount of grass available in a field. This saves them time and money, and the improved knowledge of if there is enough fodder for cattle. Farmers have electrified every process of agriculture. E-commerce is being used for timely agriculture.

Precision Agriculture, often abbreviated as PA, is a farming management concept based on observing, measuring and responding to inter and intra-field variability, and many other parameters in crops. The aim of most precision agriculture research is to define a decision support system (DSS) for better management of farms with the goal of optimizing returns on input resources and also preserving resources involved. The bringing in of technologies such as Global Positioning Systems (GPS) and Global

Navigation Satellite System (GNSS) has improved the development of precision agriculture. Farmers, using GPS and GNSS can measure the exact location of plants and parameters in a field and hence spatial variability of as many variables as can be measured (some of which maybe crop yield, terrain features/ topography, organic matter content, moisture levels, nitrogen levels, pH, EC, Mg, K, and others). Drones like the DJI Phantom which are relatively inexpensive and can be operated by novice pilots, has further contributed a lot to the development of precision agriculture.

The phrase "Right Place, Right Time, Right Product" is what bests defines precision farming. PA is a more controlled, accurate technique that replaces repetitive and labour-intensive part of farming. It provides farmers with better knowledge about harvesting, plant rotation, nutrient management, pest attacks amongst other things. Profitability, efficiency and sustainability are what are goals for PA. This section describes some of the latest technologies that have reformed agriculture.

3.1 Internet of Things

The Internet of Things (IoT) technology is a revolution that is affecting and shaping positively all forms of human life. Any device that has an on/off switch and is controlled by power will eventually be connected to the Internet and hence also to each other. Everything you can think of, from cell phones to coffee makers, from headphones to washing machines, from lamps to wearable devices, will eventually be connected to the Internet. Components of machines for example a jet engine of an airplane or the drill of an oil rig, will also eventually end up being connected to the internet. Research and development are focusing on extending Internet connectivity beyond standard devices, such as desktops, laptops, smartphones and tablets, to any range of traditionally dumb or non-internet-enabled physical devices and everyday objects. This has made these devices possible of being remotely controlled and send data over a network to any other device in the world (which is also connected to the Internet). The concept of a network of smart devices was discussed and researched upon as early as 1982, with a modified Coke machine at Carnegie Mellon University becoming the first Internet-connected appliance, able to report its inventory and whether newly loaded drinks were cold. Mark Weiser's 1991 paper on ubiquitous computing, The Computer of the 21st Century, produced the contemporary vision of IoT(Weiser Mark, 1991), much of what we are doing today was possible because of such research.

Agriculture all around the world is undergoing a revolution triggered by the increasing use of Information and Communication Technologies (ICT) and IoT (Prem P Jayaraman et al. 2016). Robotic, autonomous vehicles, for better management of resources, are in a development and continuous improvement cycle these days. Data on biomass development and fertilization status of crops is available to farmers real-time (though a very expensive technique) with the development of unmanned aerial vehicles with autonomous flight control. Smart farming is the integration of calculation of yield, human and material resource management, purchases and costs, risk management logistics, maintenance into a single field, and intelligently taking decisions on the above listed parameters(Heil & Bittner, 2018). The influence of digitization in the field of agriculture is not limited to only the traditional areas of farming, but also covers the increasing developments in livestock economy (and all other aspects of agriculture) through sensor technologies and actuators. Fundamental technologies for Smart Farming include sensors, GPS, GNSS etc. IoT-based cultivating can give incredible advantages including increasingly proficient water use, or improvement of information sources and medicines.

3.2 Remote Sensing

We have seen remote sensing being developed for use in agriculture from 1960s. When it comes to monitoring and managing land, water, and other resources, remote sensing can be an invaluable tool. It can help determine everything from what factors may be stressing a crop at a specific point in time to estimating the amount of moisture in the soil. This data enriches decision-making on the farm and can come from several sources including drones and satellites or even cheaply available sensors. Sensors enable real time understanding of current farm, forest or other fields. Instead of prescribing field fertilization before application, high-resolution crop sensors inform application equipment of correct amount that is needed. Optical sensors or drones are able to identify crop health across the field.

3.3 Big Data

Farmers are using drones these days to control their fields and manipulate plant growth. Drones are being used to image fields and collect information about entire farmland area. This data is then linked to a database in order to be able to visually represent data, for example, digital maps of a field. Additional data from other measurements can also flow into this data such as infrared images, biomass distribution and weather data. The administration, management and interpretation of these data are further elements of big data. This data is used in combination with decision making algorithms in order to automatically determine management measures. Automation is expected to increase in the future because of these changes(Heil & Bittner, 2018).

3.4 Cloud Computing

Cloud computing can be used to aggregate data from tools like soil moisture sensors, satellite images and weather stations to help farmers make better decisions about managing their fields. Cloud computing has analytical benefits, which helps us better understand production from crops(Tongke, 2013). Agricultural industry is better utilising data than ever before. Data is gathered on the parameters within fields, the plants, the weather that might occur, and the machinery used in fields and all other sorts of sensor-based inputs. This information is then stored in the cloud, which provides users with speed, storage and computing power to make better decisions, analyse data collected in a better way, so that it can be useful to the farmers. Farmers can see their fields and crops on the map and pinpoint exact areas where more fertilizer or water is needed. By providing decision support and automation, these cloud-based solutions help solve agricultural problems and increase the efficiency and productivity of farms(Hori, 2010).

3.5 Artificial Intelligence and Machine Learning

Agriculture is seeking rapid adoption of Artificial Intelligence and Machine Learning in all of its aspects. Chatbots are being provided to farmers to keep them technologically updated, about how and when plants should be irrigated amongst all things. Microsoft is currently working with some 150+ farmers in India to provide advisory services for sowing, land, fertilizer, irrigation and so on. This initiative has already resulted in 30% higher yield per hectare on an average compared to last year(Bagchi, 2000). Artificial Intelligence contributes to farming by providing us with decision support systems that help make better decisions related to disease detection, crop readiness identification, field management, identification of optimal mixes for agronomic products, monitoring health parameters of crops, automation and other fields.

Machine learning models can be trained on plant images and then used to recognize levels of stress in various types of crops. The entire process can be classified into the stages of identification, classification, quantification and prediction for smarter farming. Fusion of AI with ML can help achieve higher yield from crops.

Robotics also has helped our farmers in digital farming. Mobile and field robots are being used for measurement of plant's geometry and non-visible radiation bands. This data is then fed to some recommendation engine which helps achieve higher yield and better quality crops utilising lesser resources. Installed applications guide farmers and help them in the process of sowing and growing crops.

In (Kamilaris et al., 2016), the authors develop a framework that supports large-scale data analytics & event detection, providing seamless interoperability among sensors, other services, processes, operations, farmers, including online information sources and linked open datasets and streams available on the web.

3.6 Drones and Other Aerial Unmanned Vehicles

As per a recent study, the total market for drones that are being used for agriculture exceeds $32 billion(Bagchi, 2000). They have made agriculture easy and hold a lot of importance in terms of managing bad weather conditions, gains by productivity and management of yield etc. Drones are being used to produce 3D maps of farms to better understand terrain details. The level of nitrogen in soil is also better managed by the use of drones. Water and other resources needed for plant growth can be sprayed by drones in large fields. They are of huge help for crop monitoring and health assessment. High-resolution cameras in drones collect precision field images which can be passed through convolution neural network to identify areas with weeds, which crops need water, plant stress level in mid-growth stage. Unmanned aerial vehicles are quickly becoming a very helpful tool for farmers. Imaging data from a drone can be a good indicator of vigour levels of crop and canopy stress. Sensors in drones that capture multiple parameters help farmers to determine water needed, fertilizers required and use them only on parts of the field where they are required rather than the whole field. Crop production and growth hence increase by a lot in such cases. Many drones are available commercially that achieve an uptake rate of 75% and help in cutting planting costs by 85%(Ahirwar, Swarnkar, Bhukya, & Namwade, 2019).

4. CONCLUSION

One of the biggest problems faced by agricultural scientists is the problem of efficient irrigation. Water is a limited resource, most of which is not available easily near farms. Water needs to be effectively managed so that the ever-growing human population can be fed effectively and easily. There is an immediate need to scientifically develop irrigation systems. Modern, relevant technology can hence be made use of to benefit the process of Precision Agriculture. Using the concepts of Internet of Things, the process of irrigation of plants is made easier and more efficient. Usage of Water and Labour can be reduced greatly if technology is used by farmers, to monitor water content of the soil over the cloud, keeping track of water quantity used and using the ability to switch on/off water pumps remotely.

In the future, the process of irrigation can be made better by developing a smart irrigation system that relies on multiple sensors for input data for taking the decision to switch on an actuator. The system can be provided local weather data so it can predict when water will not be needed, hence better management of water resources.A combination of Artificial Intelligence and Machine Learning can be used to create irrigation systems that are intelligent and can take real time decisions from the information provided in the knowledge base. Drones can be used with the information from AI and ML based algorithms to provide water to plants aerially. For visualization and more intelligence, this data can be stored in the cloud, that would provide better analysis and computing power.

REFERENCES

Accidental Deaths & Suicides in India. (2015). Retrieved from https://ncrb.gov.in/StatPublications/ADSI/ADSI2015/adsi-2015-full-report.pdf

Ahirwar, S., Swarnkar, R., Bhukya, S., & Namwade, G. (2019). Application of Drone in Agriculture. *Int. J. Curr. Microbiol. App. Sci*, *8*(01), 2500–2505.

Bagchi, A. (2000). *Artificial Intelligence in Agriculture*. MindTree.

Composite Water Management Index. (2018). *NITI Aayog*. Retrieved from http://pibphoto.nic.in/documents/rlink/2018/jun/p201861401.pdf

Digital agriculture: helping to feed a growing world. (2019). Retrieved from https://consulting.ey.com/digital-agriculture-helping-to-feed-a-growing-world/

Doshi, H. S., Shah, M. S., & Shaikh, U. S. A. (2017). Internet Of Things (IoT): Integration of Blynk for Domestic Usability. *Vishwakarma Journal of Engineering Research*, *1*(4), 149–157.

Dwivedy, N. (2011). Challenges faced by the Agriculture Sector in Developing Countries with special reference to India. *International Journal of Rural Studies*, *18*(2), 2–7.

FAO (Food and Agricultural Organisation Of United Nations). (2014). *Coping with water scarcity in agriculture a global framework for action in a changing climate*. Retrieved from http://www.fao.org/3/a-i6459e.pdf

Ghosh, S., & Hingoliwala, H. A. (2016). Smart Irrigation : A Smart Drip Irrigation System Using Cloud, Android And Data Mining. *2016 IEEE International Conference on Advances in Electronics, Communication and Computer Technology (ICAECCT)*, 236–239. 10.1109/ICAECCT.2016.7942589

Hamshere, P., Sheng, Y., Moir, B., Gunning-Trant, C., & Mobsby, D. (2014). *What India wants: Analysis of India's food demand to 2050*. Retrieved from https://www.agriculture.gov.au/SiteCollectionDocuments/abares/publications/AnalysisIndiaFoodDemandTo2050_v.1.0.0.pdf

Hori, M. (2010). *Application of Cloud Computing to Agriculture and Prospects in Other Fields*. Retrieved from https://www.fujitsu.com/global/documents/about/resources/publications/fstj/archives/vol46-4/paper15.pdf

How to Feed the World in 2050. (n.d.). Retrieved from http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

India's Agricultural Exports Climb to Record High. (2014).Retrieved from https://www.fas.usda.gov/data/india-s-agricultural-exports-climb-record-high

InfrastructureA. (2011). Retrieved from https://business.mapsofindia.com/india budget/infrastructure/agriculture.html

Kamilaris, A., Gao, F., & Prenafeta-bold, F. X. (2016). *Agri-IoT: A Semantic Framework for Internet of Things-enabled Smart Farming Applications*. doi:10.1109/WF-IoT.2016.7845467

Kodali, R. (2017). *A low cost smart irrigation system using MQTT protocol*. doi:10.1109/TENCON-Spring.2017.8070095

Mehta, P. (2012). Impending water crisis in India and comparing clean water standards among developing and developed nations. *Archives of Applied Science Research*, *4*(1), 497–507.

Miguel, A. (1998). *Ecological impacts of industrial agriculture and the possibilities for truly sustainable farming*. Retrieved from http://ls-tlss.ucl.ac.uk/course-materials/BENVGDA8_69592.pdf

Monitoring Soil Moisture for Optimal Crop Growth. (n.d.). Retrieved from https://observant.zendesk.com/hc/en-us/articles/208067926-Monitoring-Soil-Moisture-for-Optimal-Crop-Growth

Morais, R., Valente, A., & Serôdio, C. (2005, July). A Wireless Sensor Network for Smart Irrigation and Environmental Monitoring : A Position Article. *Efita/Wcca*, 845–850.

Prem Prakash Jayaraman, A. Y. D. G., & Zaslavsky, A. (2016). *Internet of Things Platform for Smart Farming*. doi:10.339016111884

Sahu, C. K., & Behera, P. (2015). A low cost smart irrigation control system. *2015 2nd International Conference on Electronics and Communication Systems (ICECS)*, 1146–1152. 10.1109/ECS.2015.7124763

Schönfeld, M., Heil, R., & Bittner, L. (2018). *Big Data on a Farm—Smart Farming*. doi:10.1007/978-3-319-62461-7_12

Seckler, D., Barker, R., & Amarasinghe, U. (1999). Water Scarcity in the Twenty-First Century. *International Journal of Water Resources Development*, *15*(1-2), 29–42. doi:10.1080/07900629948916

Tongke, F. (2013). *Smart Agriculture Based on Cloud Computing and IOT*. Retrieved from https://pdfs.semanticscholar.org/62ee/b701c40626811a1111ca5d1db37650f1ea0b.pdf

Vinnikov, K. Y., Liu, S., Speranskaya, N. A., Hollinger, S. E., Namkhai, A., Entin, J. K., ... Srinivasan, G. (2002). The Global Soil Moisture Data Bank. *Bulletin of the American Meteorological Society*, *81*(6), 1281–1299. doi:10.1175/1520-0477(2000)081<1281:tgsmdb>2.3.co;2

Weiser, M. (1991). *The Computer For The 21st Century*. Retrieved from https://www.ics.uci.edu/~corps/phaseii/Weiser-Computer21stCentury-SciAm.pdf

WWAP (World Water Assessment Programme). (2012). *The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk.* Paris: UNESCO. Retrieved from http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/WWDR4%20Volume%201-Managing%20Water%20under%20Uncertainty%20and%20Risk.pdf

KEY TERMS AND DEFINITIONS

BOD: Biochemical Oxygen Demand (BOD)is an important water quality parameter which is defined as the measure of broken down oxygen required by natural living beings to break down organic material present in a given water sample at a certain temperature over a particular timespan.

Cloud Computing: Cloud computing is a distributed network that provides on-demand provisioning of computer system resources, especially data storage and computing power, without direct active management by the user.

COD: Chemical Oxygen Demand (COD) is a characteristic proportion of the measure of oxygen that can be consumed by reactions in a solution. It is usually communicated in mass of oxygen expended over volume of solution which in SI units is milligrams per litre (mg/L).

DSS: Decision Support Systems (DSS) are information systems that support organizations in decision making.

GNSS: Global Navigation Satellite System (GNSS)is a satellite framework that is utilized for global coverage to pinpoint the geographic area of a client's receiver anyplace in the world. It provides autonomous geo-spatial positioning.

GPS: Global Positioning System (GPS) is a satellite-based system that gives geolocation and time data to a GPS receiver anyplace on or close to the Earth where there is an uninterrupted light of sight to at least four GPS satellites.

HYV: High yielding variety seeds (HYV seeds) are seeds of preferable quality over ordinary quality seeds. The produce from these seeds is more as compared to the typical ones. These seeds are a superior choice of seeds so as to get a solid and surplus harvest.

MNC: Multi-national corporation.

Chapter 10
Smart Agriculture With Autonomous Unmanned Ground and Air Vehicles:
Approaches to Calculating Optimal Number of Stops in Harvest Optimization and a Suggestion

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ABSTRACT

This study researches smart agriculture and its components, robotic systems and machine learning algorithms, development of agricultural robots, and their effects on the industry. In application, it is aimed to collect the harvest of autonomous unmanned aerial vehicles and UGVs in communication with each other by means of time minimization of the target. It wanted to be tested with different approaches for an optimal number of stops by using particle swarm optimization. Deterministic, binary mixed (0-1) integer modeling was used to determine the optimal picking time of the apples allocated to the stalls with the k-means method. With this modeling, it has been determined which unmanned aerial vehicle will be collected and how it is calculated whether the air vehicle has collected the apple or not using 0-1 binary modeling. The route of the unmanned UGV was made by using the nearest neighbor, nearest insertion, and 2-opt methods. This study has been extended and reviewed by the summary paper at International OECD Studies Conference March 2020, Ankara, Turkey.

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INTRODUCTION

Twenty-first century robotics and sensing technologies have the potential to solve long-standing problems in the agricultural field. It is possible to make crops more efficient and more sustainable by switching to an agricultural system using robotic systems. Many researchers in the world carry out robotic automation studies that will reduce the cost and increase the quality in greenhouses where fruit and vegetable production is made. Autonomous robotic pickers are tested, monitoring vegetable and fruit growth and harvesting crops. For livestock farmers, sensing technologies help manage and control the health of their animals. In order to improve soil quality, monitoring and maintenance works are carried out to eliminate harmful pests and diseases without resorting to the indiscriminate use of agricultural chemicals.

Although some of these technologies are already available, most of them are still at the research stage in start-up companies. Large-scale companies that produce agricultural equipment do not want to invest in autonomous agricultural technology yet. The reason for this is the fear that the economic model established by these companies in the current production and sales markets will change. Start-up companies working with digital agricultural technologies will also change the way we produce food forever if they manage to implement their projects in the agricultural sector. Our current food production will double, and this rate will increase until 2050, and will meet the food demand of 70% of the global population.

After the industrialization process that started with the industrial revolution, engineers and scientists have been creating solutions by designing great inventions and systems for the great problems that humanity has faced for centuries. Agriculture 5.0 will be the first major problem that scientists and engineers will face in the first half of the 21st century. The concept of Agriculture 5.0 states that farms use sensitive farming features and implement digital agriculture by implementing equipment including unmanned operations and autonomous decision support systems. Therefore, Agriculture 5.0 refers to the use of autonomous robots and some artificial intelligence systems Zambon (2019).

In traditional farming in the world, the workers in the seasonal working class go to agricultural work from different regions in the world to different countries in order to meet the global agricultural labor force every year. Due to the global epidemic of Covid-19, seasonal workers cannot leave, so many countries face the danger of deterioration in the field Brelie (2020). In addition, the rate of migration from villages to cities continues to increase every year. As a result of these, The World is moving away from the agricultural society every year and the population is growing rapidly in the cities. These problems show us that we will have great labor problems in the agricultural sector in the coming years ILO (2020). Autonomous robotic systems in agricultural production provide production by working 30 times more than an agricultural worker Hooijdonk (2020); Walch (2020). We need to face the fact that the world will face other outbreaks like COVID-19 in the future, give up the classic human-worker method and accelerate the transition to robotic-agricultural production.

According to a research conducted by Forbes Walch (2020), agricultural robots can harvest crops in the field in higher amounts and faster than human labor. Although robots are not as fast and efficient as humans in most sectors today, this is not the case for the agricultural sector. Agricultural robots rapidly fulfill repetitive routine tasks on the farm everyday thanks to the rapidly developing autonomous robotics and artificial intelligence technologies Bechar (2017); Shamshiri (2018). These developments started a new era in agriculture as Agriculture 5.0.

According to the study of Reddy et al., In the countries with high rates of using digital agriculture, agricultural robots have been shown to greatly increase productivity and reduce farm operating costs. As mentioned earlier, robotic applications are rapidly increasing in the agricultural sector Shamshiri (2018).

Many of these agricultural technologies are still very expensive for farmers, especially those with small farms Lamborelle (2020). Farmers with small-scale lands and small-scale economies in direct proportion to this are not yet able to access robots and systems in this technology in the World. However, with the increase of production year by year, the cheapening of technology and state-supported agricultural development packages, small farmers will also use this technology.

Agricultural production and crop yields in the world decreased in 2015. In order to overcome these problems and meet the increasing demand with high efficiency, the concept of agricultural robot was introduced to the world. Robotic innovations have reached an increasing trend in the global agricultural sector and the stock market. According to the verified market intelligence report, agricultural robots can complete agricultural work in a much shorter time and with higher quality compared to farmers Verified Market Intelligence (2020).

The value of start-up firms working in agricultural technology between 2013 and 2017 has increased around 800 million dollars Cb Insight (2020). Start-up companies, which use robotics and machine learning to solve problems in agriculture, have been on the rise since 2014 in parallel with the development of artificial intelligence. Venture capital fund in the field of artificial intelligence has increased by 450% in the last 5 years. This new style of agriculture concept can also be explained as "less resources, more production". Because when the reports of United Nations Food and Agriculture Organization (FAO) are analyzed, the world population will reach 9.1 billion in 2050, FAO (2009). Providing sustainable food production for the growing world population by preventing climate changes will be the most basic and critical agenda in the coming years.

In developed countries, modern farming systems are used and thanks to these modern systems, developed countries obtain more products than expected. Therefore, developed countries also started to have comparative advantages in agriculture. With the rapid increase in the world population, per capita consumption has increased, but it has brought many problems. These problems are;

- Unawares used chemical fertilizers and pesticides,
- Groundwater is not used efficiently,
- Decrease in productive agricultural areas,
- Property issues,
- Problems caused by mechanization,
- Destruction of forests for agricultural land or housing construction,
- Unawares agricultural activities in erosion regions Kılavuz (2019).

BACKGROUND

The agricultural sector is becoming an advanced technology industry, creating new opportunities for technology use and product development. Autonomous systems and agricultural tools with customized use come to the forefront in the progress of the industry. The agricultural platform can be broadly classified as area and task. Task-specific robots are designed to perform a specific task on a predefined product, while general purpose robots are designed to perform a variety of tasks in different areas.

With the advances in technology, agricultural robots can now perform various agricultural operations such as crop imaging, pest and weed control, spraying water and insecticide, harvesting. These processes are fully autonomous or semi-autonomous, depending on the farmland and application. Although there are agricultural robots with high speed and precision accuracy, their applications in agriculture remain limited due to unstructured environments and difficulties. For example, a robot with seed sowing capacity may not have distance information between the seeds to be sown to achieve maximum efficiency. A water / insecticide spraying robot may not have control over the amount of water / insecticide to be sprayed depending on soil conditions and crop type. Although robots have become part of agricultural practices, they are not yet smart enough to make their own decisions based on various physical, natural and environmental factors. Sub-algorithms used in machine learning together with the developing technology continue to optimize the current model by storing historical data. As a result, autonomous robots used in agricultural technology are getting more intelligent in the future.

Fruit harvesting platforms are used to reduce human movement during harvesting, to minimize the time outside picking and to achieve optimum working conditions. The use of these platforms, in other words, increases productivity during the harvest period.

Smart agriculture has the potential to provide a more productive and sustainable agricultural production based on a more resource efficient and precise approach. Smart agriculture should provide added value to the producer in the form of better decision making or more efficient business activities and management. In this sense, smart agriculture is strongly related to three technology fields such as interconnected management information systems, precision agriculture and agricultural automation-robotics.

Agricultural automation and robotics; It is the process of applying robotic, automatic control and artificial intelligence techniques in all kinds of agricultural production, including farmbots and farmUAVs.

Agricultural robots increase production efficiency for producers in various ways. Some of those; autonomous UAVs, autonomous tractors and robotic arms. These technological innovations are used in creative and innovative applications. Agricultural robots' autonomies slow, repetitive and boring tasks for farmers, allowing them to focus more on increasing overall production efficiency. Autonomous robots are electro-mechanical devices that can find a method to perform a task assigned to them, as well as autonomously capable of performing static tasks dynamically or dynamically to prevent possible hazards by using the data obtained from the environment with the help of sensors (sensors) to protect itself.

Agricultural robots, which are the most common uses in the agricultural sector, can be listed as follows:

- Weed control,
- Harvesting and picking,
- Autonomous mowing, pruning, seeding, spraying and thinning,
- Separation and packaging,
- Service platforms.

Harvesting and picking robots use image processing and an arrangement of robotic arms to determine what to choose. Apple's quality control and grading can only be done by preventing repetitive processing in a single operation. Data analysis about the product processed by the harvesting robot can assist in determining the business income and regulating the packaging and processing processes.

Nowadays, an operator using components that develop and become widespread with the advancement of technology only guides the main machine in the orchard; the remaining fruit harvesting machines are available on machines that are done automatically. Examples of these machines are the robotic fruit picker designed for apple harvesting ffrobotics (2020).

After the collector is positioned by the user in the area to be harvested, the sensors and cameras on the machine determine the location of the fruits in the three-dimensional space plane. In the next stage, the position information of the fruit is evaluated in the processor and the robotic arms move towards the fruit, tear it off in the axis of the fruit stem and leave it on the carriage. After this process, the conveyor transfers the fruits to the frame located on the back of the machine and rotating on its own axis on a tray. This machine is what a harvest worker should do; can decide whether the fruit is ripe or not, rip the fruit and place it in the case. Producing company ffrobotics (2020) emphasizes that the machine is ten times more efficient than a harvest worker.

There are also fruit harvesting machines that operate without the need for an operator. An example of this type of machine is the SW 6010 strawberry harvesting machine developed by Agrobot (2020). SW 6010 is the first autonomous robot on the market that can detect and collect strawberries, by analyzing the strawberries one by one and gently harvesting them so as not to damage the fruit. It is possible to use in the field and greenhouses, it has a working width of 6 meters and a length of 4 meters, and it is possible to adjust between the lines. By scanning the plants in the order, they entered with color and infrared sensors; It performs operations such as reaching the harvest maturity, determining the location of the fruit in the three-dimensional space plane. Then the robotic arms take the fruit off the handle and place it in the crates at the bottom.

Ben-Gurion University researchers have developed a pepper picking robot called SWEEPER. Working with a series of machine learning algorithms, SWEEPER robot travels on agricultural land and scans peppers. The robot, which also examines whether pepper is ripe with its data such as color and height, can collect peppers without damaging its flowers. Using the machine learning algorithm, the robot was trained using more than 1000 pepper photographs for pepper selection. Researchers also state that the robot's algorithm can be trained to collect fruits and vegetables such as oranges, tomatoes Arad (2020).

Tevel-tech start-up company in Israel has started to implement the apple harvesting project with autonomous unmanned aerial vehicles and UGVs Tevel-tech (2020). By contacting a program designed for the use of farmers, they found a collection process that required intensive labor and cost in a short time and less costly solution. In the coming years, we will encounter more projects with the harvest collection processes of UAV/UGVs for agriculture by working in interactive with swarm formation. The transition to Agriculture 5.0 will accelerate with the proliferation of active harvesting of such autonomous unmanned systems.

This study is founded by European Union. Russian, German, Turkish and Serbian partners work together on HARMONIC, Project Number: 217E138. This project supported by the Scientific and Technological Research Council of Turkey (TUBİTAK) and European Union.

Collaborative activity of groups of heterogeneous robots, as well as their delivery/transportation to the point of direct solution of applied problems, are ones of the main unresolved problems in the agriculture robotics. The main aim of the research in this project is development of theoretical basis of autonomous functioning of the mobile platform for serving group of unmanned aerial vehicle (UAV) under high level, mission based, remote control via intuitive user interface during agriculture operations. A distinctive feature of the project is the presence of built-in parking spaces for several UAVs.

Unlike the current works, an optimal joint functioning of groups of heterogeneous unmanned vehicles will be developed during the project. The main tasks of the project are:

1. development of theoretical basis of autonomous functioning the mobile platform served UAVs;
2. development of theoretical basis of group interaction of heterogeneous UAVs at solving agriculture operations;
3. development of theoretical basis of human-platform-UAV interaction and control including collaborative learning and time-critical interaction components via gesture, voice, etc.

The main impact of the project will be in creation of agriculture robotic system capable to minimize the effort and injuries of people in agrarian operations; maximize the coverage area of automation farming; minimize use of fertilizers through using UAVs and principles of precise agriculture. The project includes optimization applications for autonomous unmanned ground and air vehicles and smart agriculture.

Many studies are conducted in the literature including Vehicle Routing Problems (VRP) for different usage areas of unmanned aerial vehicles (UAV).

In the study of Guzey et al., it is aimed to collect the harvest by the time minimization of the previously determined apples in the agricultural land in communication of autonomous unmanned aerial and UGVs. Due to the fact that the current problem is very large, the main problem is solved by dividing it into small sub-problems in order to make time optimization. K-means clustering method was used to determine the locations of the UGVs' stops and to analyze it. Julia programming language is used for calculations. In the study, the optimal number of stops for 500 apples was found to be 3. The model prepared to optimize the apple picking times of air vehicle at each stop was resolved with the help of the Gurobi solvent and the results were achieved. As a result of the study, the average waiting time of the UGV at each stop was approximately 439 seconds Guzey (2020).

In the study conducted by Murray and his colleagues, they first came up with the idea of a model that carried the truck first, and then the last point with the UAV. This idea is called "Flying Sidekick Traveling Salesman Problem". Within the scope of the study, a UAV and a truck were used in deliveries. Vehicles can carry simultaneously. After delivery, the UAV must return to the truck. Mixed integer linear programming (MILP) and heuristic methods were used in the study Murray (2015).

In the study of Olivares et al., The use of a UAV type Quadcopters in the internal logistics of a manufacturing plant, especially during the assembly and customization of products. The aim of this study is to model and optimize high energy consumption during operation, which is a major disadvantage. In the study, an internal logistics modeling was carried out to locate the warehouses, clusters and subsets. In addition to this process, a variety of ways have been created using a genetic algorithm for each Quadcopter. In addition, the weight, material and route to be carried by each Quadcopter were determined. Finally, the amount of electrical power to be discharged from the battery of each quadcopters for a specific route is also optimized, depending on the weight carried, the number of workstations visited and the number of quadcopter aerodynamic efficiency Olivares (2015).

In a study conducted by Bekhti et al., The route creation scenarios for autonomous unmanned aerial vehicles were analyzed using the monitoring capacities of regional wireless networks. The main purpose of the study is to minimize the transportation to the target point with the shortest route, and to achieve this purpose, monitoring the location information of unmanned aerial vehicles via wireless network. At the end of the study, the best solution could not be obtained, and an appropriate solution was offered by reducing the accuracy rate of the location information to be followed Bekhti (2017).

In a study conducted by Wang et al. "Vehicle Routing Problem with UAVs" In a system with multiple trucks and UAVs, in which transportation times were optimized. In this study, many bad scenarios were analyzed, and time-saving scenarios were proposed in which both trucks and UAVs were used instead of just trucks Wang (2016).

The article titled "Truck-UAV optimization in cargo distribution network using K-mean and genetic algorithm" conducted by Ferrandez et al. Is the basis for the application used in this study since it is the closest study to the harvest optimization area used in Unmanned Aerial Vehicle (UAV) and Unmanned UGV(UGV) Ferrandez (2016).

MAIN FOCUS OF THE CHAPTER

Issues, Controversies, Problems, Solutions and Recommendations

The rapid growth of the human population on a global scale forces us to find a permanent solution to the nutritional problem we need in the long term. It is estimated that the global population will reach approximately 10 billion in 2050 and it is estimated that the agricultural production capacity should increase by 70% in order to maintain our current nutrition standards FAO (2009). However, considering the decrease in arable agricultural lands as a result of the climate changes to be experienced in the following years, how this capacity increase will be faced is an important question today.

Today, industrial agriculture practices in the agricultural sector constitute 11-15% of global greenhouse gas emissions and it is a fact that if this uncontrolled increase continues, it will accelerate climate change. Another result of the global population growth is the rapid increase of the population in the cities. This increase also causes rural areas and labor to decrease. As a result of the high technology and input costs in the agricultural sector and the need for energy to increase in parallel with this, the process, which continues until 2050, should abandon old agricultural methods and implement digital transformation in agriculture as soon as possible to increase the production capacity by 70% FAO (2009).

Agriculture is experiencing a very important transformation in the world. The digitalization of agricultural applications enables the production of plant and animal products with higher productivity and lower environmental impact.

Agriculture on a global scale will face great challenges in the coming years. Some of these challenges are:

- Rapid population growth in the world,
- Climate change,
- Increased energy demand,
- Scarce resources,
- Rapid population growth in cities,
- Decreased productivity of arable land,
- Competition in increasing world markets and
- Lack of credit and arable land in many developing countries.

Agricultural production has increased more than threefold between 1960 and 2015 with the use of agriculture 2.0 (Green Revolution technologies), soil, water and other natural resources for agricultural purposes. In the same period, there were remarkable increases in the industrialization and globalization of food and agriculture. Although agriculture has become more productive at the global level, nature has again paid the losses of the increase in food production and economic growth. Almost half of the forests that once covered the planet have disappeared, groundwater resources are gradually decreasing, and biodiversity continues to be depleted. Our groundwater resources are contaminated with nitrates, herbicides and pesticides. Burning fossil fuels emits billions of tons of greenhouse gas emissions to the atmosphere every year, leading to global warming and climate change.

The development in digital technology and applications plays an important role in the increase of agricultural production and economic growth. When it comes to digitalization and modernization reform in agriculture, rural areas and especially farmers are important. Our ability to address these issues correctly is great importance for the future development of the agricultural sector on a global scale. In many studies conducted in the world, it was concluded that the development of digital technology and applications is seen as an important factor in economic growth and developments in agricultural production. Field work, improving the mechanization of machinery and equipment is a continuous process. We see the widespread use of more modern equipment reflected in the technical and technological level of the agricultural sector in today's applications.

The technological transformation that the agricultural activity, which dates back 10 thousand years, has undergone the last century, has brought the agricultural activity to a completely different level. This period brought intense production, increased efficiency and changing needs. Today, this new understanding, which can be called the "new version" of agriculture, which is not the only purpose, is that agricultural robots are actively used, is more sustainable, environmentally friendly and energy efficient, is called "Agriculture 4.0". Today, with the developing technology, the agricultural sector is experiencing a great digital evolution and now the future of the agricultural sector is shaped by this digital evolution. In order to reveal these digital technologies more clearly, it is important to analyze the main stages of agricultural development.

In agriculture, it is aimed to maximize efficiency with the internet of things. Since natural resources are used at the required level, the cost decreases. Similarly, all the factors required for production are analyzed and presented to the manufacturer simultaneously with smart systems on the farm. In this way, waste of resources is prevented, and quality products are produced. In addition, rapid decision-making mechanisms are created with machines that communicate and work synchronously. The producer is given the opportunity to manage and observe the entire farm from a tablet or phone, and by reducing the workforce, efficient, quality and natural production opportunities are created.

Smart agriculture; When it comes to livestock and crop farming, it is much more controlled and accurate than traditional farming. In this farm management approach that effectively uses Agriculture 4.0, the key component is the use of IT (Information Technologies), however, various technological applications such as sensors, control systems, robotics, autonomous vehicles, and autonomous equipment are used. The adoption of high-speed internet by farmers, the use and reliability of mobile devices, the use of low-cost satellites for image and positioning are important technological applications that affect the spread of smart agriculture.

Unmanned aerial vehicles (UAVs) used in the agricultural sector are a good example to see how technology has changed over time. Today, agriculture continues to become an integrated technology field that includes UAVs. Unmanned aerial vehicles are used to develop various agricultural applications in agriculture. These applications are; product health assessment is carried out in areas such as irrigation, crop spraying, planting, soil and land analysis. The most important benefits of unmanned aerial vehicle use are product health imaging, mapping, ease of use, time saving and potential to increase efficiency. Unmanned aerial technology provides real-time data collection, processing-based strategy and planning, as well as a high exchange of high-tech products in the agricultural sector.

Unmanned aerial vehicles collect multi-spectrum, thermal and visual images after they take off. From this flight data, there are many reports such as crop health indices, crop count and yield estimation, crop height measurement, shade zone mapping, field water quantity analysis, exploration reports, stock measurement, chlorophyll measurement, nitrogen content in wheat, drainage mapping, and weeds.

Advanced technological developments enable autonomous agricultural robots to accomplish the agricultural tasks required for smart agriculture easily and safely. The advanced agricultural tools used today compress the soil over time, and this compression reduces the fertility of the soil over time. Compacted soil needs more than a decade to restore its fertility. Autonomous imaging and data collection tool, which works alone, is insufficient in large agricultural lands, and small vehicles that work in communication with each other rather than large and single vehicles provide a more effective solution. The technological studies required for the management and control of the system consisting of these autonomous tools by a single farmer have been carried out by the researchers for a long time. A task control center and intelligent coverage planning algorithms need to be developed to enable team members to communicate and collaborate with each other and to solve the assigned tasks safely and efficiently.

One of the topics that has been suggested by many researchers for a long time is the Multiple Robot system, also called "Swarm Robotics", which can work together to perform a specific agricultural task. Multiple robots need to use artificial intelligence and genetic algorithm methods to create an ecosystem in collaboration with each other. This system becomes even more useful when robots start learning interactively with each other and increase their performance over time. For example, a robot swarm can collect soil samples in coordination with the control center and contribute to the creation of food maps. The efficiency of this process may not be very good at first, but performances that punish the bad behavior of each robot can be improved over time by applying the "good behavior-bad behavior" method in the deep learning algorithm. These robots are of great benefit for the future of digital agriculture.

The methods used in application will be explained in this section.

The K-Means algorithm is an unsupervised learning algorithm. Unsupervised learning is a machine learning technique where you don't need to check the model. Instead, you need to allow the model to work on its own to discover information and is mainly concerned with unlabeled data. Unsupervised learning algorithms enable more complex processing tasks to be performed compared to supervised learning.

Cluster analysis is defined as grouping the objects in the data set with their common properties or decomposing them into sub-data sets that are defined as clusters. In this process, the objects in the cluster are intended to be as similar as possible, but as different as possible from those in other clusters.

Another aim is; It is desired that the variance of the objects in the cluster is low and the variances between the clusters are high. Since the datasets used in clustering are divided into sections and existing data structure and patterns are revealed, they are constantly used in data mining to discover meaningful information.

Examples of clustering methods are classified in various ways, as there are a large number of them available today. These classifications are analyzed under 3 main headings. These; compartmental methods, hierarchical methods and mixed methods obtained by different ordering forms of these sets. The first method is the algorithms that divide the data sets used in clustering into k sub-sets. For this reason, one of these frequently studied topics is the selection of k, which should be known before the current analysis of an algorithm. The parameter here specifies the number of sets in the data set used. It can be said that the optimal choice of *k* depends on the successful and correct clustering of the clustering process. Classification algorithms will be obtained as a result of a positive or negative clustering regardless of *k*. However, there is no value that can be accepted as accurate in these clustering operations. Clustering method is used to find the closest number to this value and to reach the result. In other words, the correct selection of *k* makes cluster analysis more successful and it is also at the top of the classification clustering algorithm problems.

The K-means method was introduced in 1967 Developed by J.B. MacQueen MacQueen (1967). It is one of the most widely used unsupervised learning methods among the existing clustering methods. The way this method is assigned is a sharp clustering algorithm, as it allows each variable to be assigned to only one cluster. It is a method based on the understanding that the center point of the cluster of variables expresses the set. The method tends to find clusters of equal amounts. The most common use for calculating the K-means method is Sum of Squared Error (SSE). Clustering with the lowest SSE value gives the best results. Sum of squares the distances of the variables to the center points of the set to which they belong is calculated by Equation (1).

$$SSE = \sum_{i=1}^{K} \sum_{X \in C_i} dist^2\left(m_i, x\right) \tag{1}$$

As a result of this division, it is aimed to distribute *k* clusters intensely within itself and separately from each other in a cluster. The aim of the algorithm is to determine *k* clusters that will reduce the SSE function. The algorithm divides the data set consisting of n data into *k* sets by using the *k* parameter determined by the user. The cluster similarity value measured by the average value of the variables in the cluster constitutes the center of gravity of the cluster.

Defining variables of a system by parameters and showing the connection between them by functions is called “mathematical model”.

Mathematical modeling is defined as the process of creating physical, symbolic and abstract models of situations that occur in real life. Mathematical modeling is a much more important process with its complex structure rather than just modeling a situation. All of the mental tools used in mathematical modeling are called mental models. In general, mathematical models are the external representations of the thoughts in our brains that have been transformed into a mathematical form, enabling the interpretation and solution of problems encountered in real life. In other words, mathematical modeling is a process that requires the mental modeling process Lesh (2003).

In the study conducted by Berry and Davies (1996), mathematical modeling is analyzed under seven basic steps. In the modeling process, the real-life problem is addressed in primary care. In the second step, a mathematical model that defines the current situation is created. Then, using the mathematical model, the mathematical solution of the problem is made. The results obtained from the solution are interpreted and their accuracy is analyzed. If the correctness of the results is suspected as a result of the analyzed, the existing model should be questioned again and revised when necessary. In the last stage, when the existing solution is analyzed according to real life, if a problem is not observed, the solution is turned into a written or oral report Berry (1996).

Linear programming (LP) is a method frequently used in optimization problems. The simplex algorithm, which is used effectively in the solution of linear programming problems, was proposed in 1947 by George Dantzig. With the simplex algorithm, linear programming has started to be used extensively in many sectors. Linear programming is still used in the solution of optimization problems in many sectors such as military fields, education and banking. As a result of a research conducted among Fortune 500 member companies, 85% of these companies used linear programming method.

Linear programming tries to make the objective function optimal (max-min) by adhering to variables and constraints. In general, linear programming can be said to be a deterministic mathematical technique that includes the optimum distribution of scarce resources.

In the linear programming model, there are three basic elements: goal function, constraints (constraint functions) and positivity (non-negative) constraints. A LP model includes constraint equations in the form of linear equations and / or inequalities and the linear goal function to be optimized. A LP problem is generally expressed as follows:

$$Z_{\max/\min} = \sum_{j=1}^{n} c_j x_j \tag{2}$$

Or,

$$Z_{\max} = C_1 X_1 + C_2 X_2 + \ldots + C_n X_n \tag{3}$$

Constraints,

$$\sum a_{ij} x_j \leq, =, \geq b_i, i = 1, \ldots\ldots\ldots, m \tag{4}$$

$$x_j \geq 0, j = 1, \ldots\ldots\ldots, n \tag{5}$$

The assumptions required to achieve consistent results in Linear Programming are listed below.

- Severability,
- Proportionality,
- Summability,
- Certainty,
- Linearity.

Although the application areas of Linear Programming are very extensive, the most frequently used areas are:

- Production Program,
- Nutrition Program,
- Ad Environment Selection,
- Capital Budgeting,
- Distribution Program,

- Inventory Control,
- Production Line Balancing.

Problems that some variables should be integers and others are real numbers are called mixed integer programming problems. Mixed integer programming and integer programming have many similarities in terms of solution method. As in integer programming, the optimal solution is obtained by the simplex method without requiring an integer condition. The mixed integer linear programming problem can be expressed as a model as follows.

$$Z_{\max} = 5x_1 + 3x_2 \tag{6}$$

Constraints,

$$2x_1 + x_2 \leq 12 \text{ (7) } x_1, x_2 \geq 0, integer \tag{8}$$

A.Land and A.Doing proposed a general counting method for use in integer programs in a study they conducted in 1960, Land (1960). This method, which is referred to as “Doing method” in the literature, was applied to traveling salesman problems in the following years. In 1965, Egon Balas developed an algorithm used in 0-1 integer programming Balas (1965).

In some cases, more than two possible (0–1) value options are needed in decision variables. These variables can also show the problem that will turn into an integer form as 0-1. In 0-1 integer programming applications, we see that many divisibility assumptions are not valid, and some problems are related to “yes” or “no” decisions. In such decisions, two possible choices are only “yes” or “no”. For example, should we make this investment? or should we set up the factory in this area? Similarly, two-choice decisions are shown with decision variables whose values are constrained by 0 and 1. Thus, the j, “yes” or “no” decision is shown as follows:

$$X_j = \begin{cases} 1, & if\ j\ yes \\ 0, & if\ j\ no \end{cases}$$

The general structure of 0-1 integer problems is expressed as follows Hillier (1986).

$$Z_{\min} = \sum_{j=1}^{n} c_j x_j \tag{9}$$

$$\sum_{j=1}^{n} c_j x_j \geq b_i, i = 1, \ldots\ldots\ldots, m \tag{10}$$

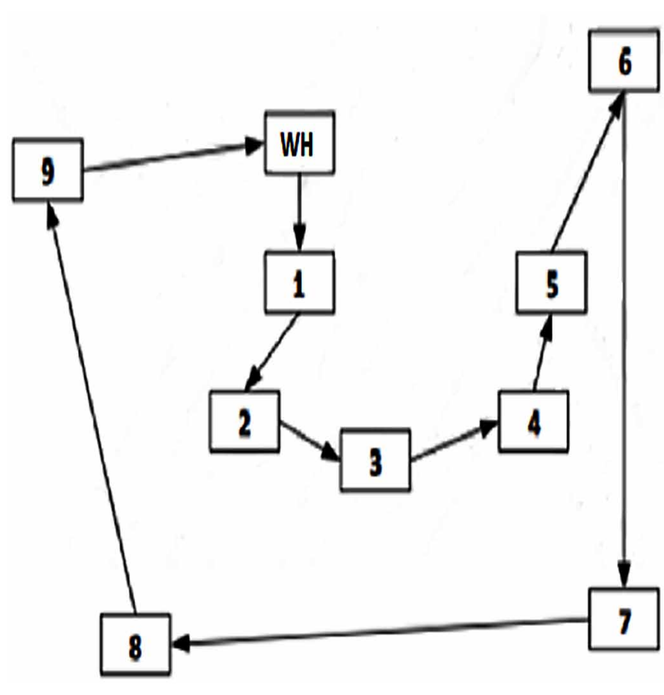
$$x_j = 0\,or\,1, j = 1, \ldots\ldots, n \tag{11}$$

In Nearest Neighbor Algorithm Method, one stop is randomly selected among the available stops and assigned as the starting point of the tour. Afterwards, the closest stop to the selected stop is determined and added as the next stop in the current tour. Adding is continued until all stops are included in the tour and the tour is not allowed to close until all the stops are added. In this method, the decision of which stop is selected as the beginning and which end of the current route to lead causes different length tour results. However, the solutions that are far from the global best are obtained because there are long returns to join the other stops left during the selection of the nearest stop.

Bellmore and Nemhauser (1968) brought the Nearest Neighbor algorithmic heuristic method to the literature (Bellmore, 1968). In this study, they have achieved an exemplary TSP by using this algorithm to the optimum result. Generally speaking, this heuristic method is very simple to use and can be used on TSP and Vehicle Route Problems (VRP) with small-scale samples.

It can be shown as an example of the Nearest Neighbor algorithm, starting from the nearest customers on the route of the vehicle and returning to the warehouse, provided that it does not exceed the time and capacity constraints after meeting all the demands, respectively. A sample route drawn using the Nearest Neighbor Heuristic is shown in Figure 1.

Figure 1. Nearest Neighbor Heuristic Sample[1]

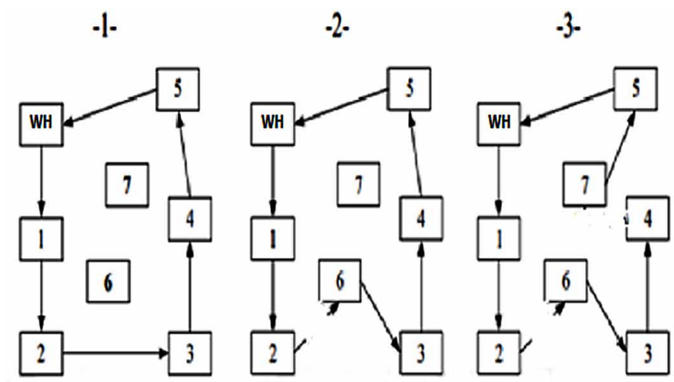


In Nearest Insertion Algorithm Method, the solution starts with a tour between two stops. Afterwards, it is ensured that the stops nearest to this tour are included among the stops in the current tour, and the inclusion of the tour is tested. After this process, the stop that will provide the smallest possible growth in the tour is determined and included in the tour.

This process is repeated until all the stops are included in the tour. In this method, the selection of the stop where the solution is started, and the addition order rule can change the solution. The solution stages of the tour starting from the warehouse are shown in detail in Figure 2.

The Nearest Insertion and Neighboring methods are often used to create a starting solution. But DePuy et al. (2005), in their study, propose a meta-heuristic method that can be used to solve Traveling Salesman Problems and similar combinatorial problems DePuy (2005).

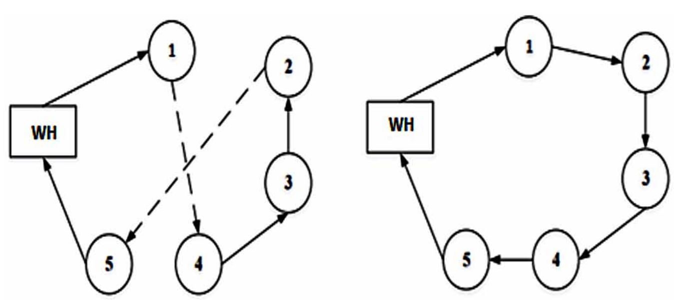
Figure 2. Nearest Insertion Heuristic Sample[2]



2-Opt Algorithm Method is the in-route change approach first used by Croes (1958). First, two springs of the current route are cut and connected and connected to two different nodes that are not consecutively to obtain a new route that has never been previously sorted. 2-Opt change is also called transport, Croes (1958).

As can be seen in the routes drawn as an sample in Figure 3., the locations of the nodes in the route were changed by assuming that the activities in the route (1,4) and (2,5) were not optimum in terms of both total distance and cost. Thanks to the new activities in direction (1,2) and (4,5) on the changed new route, the route was shortened, and the new route gave a closer result to the optimum compared to the past.

Figure 3. 2-Opt Heuristic Method Sample[3]



Particle Swarm Optimization is a population-based optimization algorithm based on the behavior of bird swarms that search. This method was proposed by Kennedy and Eberhart. Each solution in the PSO algorithm is considered to be the social particle that makes up the swarm. While these particles move in the solution space and search on their own, they are also affected by the search behavior of other particles in the swarm Kennedy (1995).

Pang and his colleagues studied the PSO algorithm and TSP problems solving methods by aiming the transformation between continuous-discrete solution spaces. In this study, while position update and speed calculation are performed in continuous space, local search operations are performed in discrete space. Using the chaotic operator, the problem of jamming to the local best solution is avoided and it changes the position and velocity vectors positioned in space by random numbers and randomly changes them. In order to analyze the effectiveness of the use of chaotic operators, four different versions of the algorithm have been tested in different comparison problems Pang (2004).

The model developed in this study consists of modeling the problem by dividing it into two sub-problems.

First stage; UGV must stop at one point in order to find the optimal time. Ferrandez et al. Proposed the K-Means Method to find optimal stop coordinates Ferrandez (2016). This method is used in the model proposed in this study. This process is managed by a conditional loop.

In the second stage; Deterministic, Binary Mixed (0-1) Integer Modeling was used to determine the optimal picking time of the apples allocated to the stops with the K-Means Method. With this modeling, it has been determined which UAV will collect and how it is calculated whether or not the UAV collects the apple using 0-1 Binary Modeling. The 5 UAVs on the UGV platform are calculated to reach the optimal time, regardless of which apples are collected.

In the third stage; First, the route of the UGV was made by using the Nearest Neighbor and Nearest Insertion Methods, which are included in the heuristic solution paths in the Traveling Salesman Problem. Secondly, 2-Opt, one of the Heuristic Traveling Salesman Problem solution methods, was used again Field (2020). This method is called tour developer and it was used to improve the current route of UGV.

In the last stage; The object we created by using these three stages gives us the time used by UAVs for harvest in a certain number of stops and the total harvest time of UGV. The PSO algorithm that uses this object will allow us to find the optimal stop that gives us the minimum harvest time from the possible stops. Therefore, as a result of this proposed model, the ideal number of stops and locations where UGV will stop, and the information about which apples and which UAV will be collected at these stops can be easily accessed.

Finding the locations of these stops with the minimum number of stops; When using the PSO Method, it is necessary to find the smallest number of stops. In order for the object developed in the proposed model to work properly, the number of stops must be in accordance with the range of UAVs, and the lower limit of the number of stops must be found at this step.

The algorithm works as follows in the process of finding the locations of these stops with the minimum number of stops. Initially, the number of stops was taken as three. The coordinates of the apples were found using the K-Means Clustering Method and apples were assigned to three clusters to obtain the center point of each cluster. If the distance of this center point from the farthest apple in the cluster is within the collection area (Maximum flight range of UAV) of the UAV, the cycle is terminated, otherwise the cycle is repeated by increasing the number of stops by “1”.

Table 1. Indices, Descriptions and Definition Sets

Indices	Descriptions	Definition Sets
Э	Apple indices	I= {1, 2,…,i_{max}}i_{max}: Total number of apples on the field
J	Stop indices	J= {1, 2,…j_{max}} j_{max}: Total number of stops on the field
K	UAV indices	K= {1, 2,…,k_{max}}k_{max}: Total number of UAVs on UGV

Table 2. Parameters and Descriptions

Parameter	Description
A_{ij}	A is a matrix that shows at which stop each apple should be collected. If the value is "0" apple i will not be collected from the stop j, if it is "1" it will be collected.
U_{ij}	U is the distance of each apple in minutes to the stops.

Harvest time used by UAV; According to the number of stops found with K-Means Method; The coordinates of the stops begin with the information assigned to these stops and the distance from these apples to their stops.

The indices used in the model are given in Table 1, parameters and definition sets are given in Table 2 and the decision variables are given in Table 3. Later, constraints and objective function were explained, and an optimization model was established.

Table 3. Decision Variables and Explanations

Decision Variables	Explanations
D_{ijk}	It is a variable that takes the value "1" if the apple i is collected by the UAV k at the stop j and "0" if it is not collected.
SE_{ijk}	It is a continuous type variable that shows the charging time in minutes the UAV k spends to collect the apple i in the Stop j.
SD_{jk}	It is a continuous type variable that shows the total time, in minutes, UAV k spent to collect and charge apples at the stop j.
SDM_j	It is a continuous type variable that shows the total time in minutes spent by the UGV at the stop j. This period is obtained from the UAV with the highest collection and charging time of the UAVs at the stop j.

Decision variables and explanations for the proposed model are presented in Table 3.

The constraints in the proposed model for the problem are as follows:

With the constraint given in Equality (12), each apple is ensured to be collected at any stop by any UAV.

$$\sum_{j=1}^{j_{max}}\sum_{k=1}^{k_{max}} D_{ijk} = 1, \forall i \in I \tag{12}$$

With the constraint in Equality (13), the UAV is provided to collect apples only within their range at each stop. The UAV consumes the charging time as much as it goes on collecting apples. The UAV consumes 120% (30/25) of charging time since it carries the apple on return. Therefore, the total flight time of the apple, 2.2 times the distance from the station in duration, must be less than 30 minutes.

$$2{,}2 * A_{ij} * U_{ij} * D_{ijk} \leq 30, \forall i \in I, j \in J, k \in K \tag{13}$$

The value obtained with the Equation (13), Equation (14) ensures that the UAV k in the model acquires the charging time in minutes that it takes to collect the apple i at the stop j.

$$2{,}2 * A_{ij} * U_{ij} * D_{ijk} = SE_{ijk}, \forall i \in I, j \in J, k \in K \tag{14}$$

Equality (15) and the total time in minutes the UAV k spends to collect apples and charge at the stop j.

$$\sum_{i=1}^{i_{max}} 2 * A_{ij} * U_{ij} * D_{ijk} + SE_{ijk} = SD_{jk}, \forall j \in J, k \in K \tag{15}$$

With the equation (16), the total time in minutes spent by the UAV, which has the highest time of collecting apples in the stop j, is obtained.

$$SD_{jk} \leq SDM_{j}, \forall j \in J, k \in K \tag{16}$$

The objective function for the suggested model can be created as in Equation (17).

$$Z_{\min} = \sum_{j=1}^{j_{\max}} SDM_{j}$$

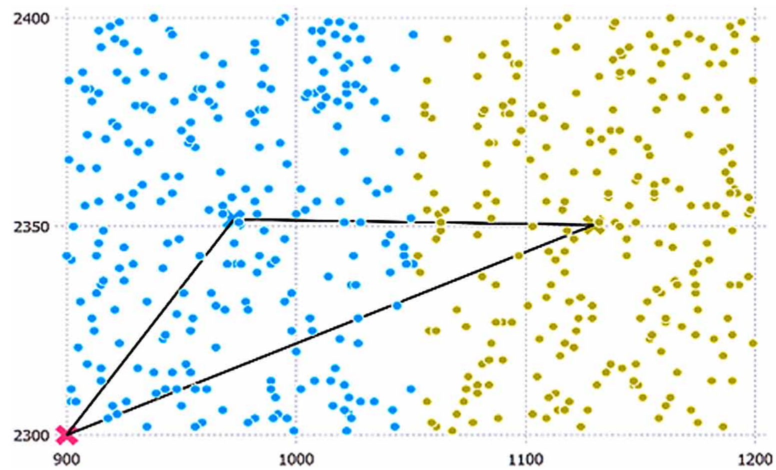
The objective function given in Equation (17) tries to minimize the total time spent in minutes by the UAV with the highest picking and charging time at each stop.

Harvest time used by UGV; By using the heuristic methods of the Traveling Salesman Problem with the stop coordinates found with the K-Means Method, analysis is performed.

The route of the UGV was made by using the Nearest Neighbor and Nearest Insertion Methods, which are included in the heuristic solution paths in the Traveling Salesman Problem. Secondly, 2-Opt, one of the Heuristic Traveling Salesman Problem solution methods, was used again. This method is called tour developer and it was used to improve the current route of UGV.

Optimum number of stops for minimum harvest time; The object we created by using three stages in optimization model gives us the time used by UAVs for harvest in a certain number of stops and the total harvest time of UGV. The PSO algorithm that uses this object will allow us to find the optimal stop that gives us the minimum harvest time from the possible stops. Therefore, as a result of this proposed model, the ideal number of stops and locations where UGV will stop, and the information about which apples and which UAV will be collected at these stops can be easily accessed.

Figure 4. Cluster Structure and Stops



The model proposed in this study was analyzed on a computer with Intel® Core ™ i7-2670QM @ 2.2GHz processor and 6 GB RAM hardware. Julia programming language was used for the analysis of the coordinates of the apples, the clustering, the calculation of the distances and the software of the mathematical model for analysis Bezanson (2017). The Julia package programs used are listed below:

- JuMP package Dunning (2017),
- JuliaStats/Clustering.jlpackage,
- JuliaStats/Distances.jlpackage,
- TravelingSalesmanHeuristic Field (2020),
- JuliaData/DataFrames.jlpackage,
- Giovineltalia/Gadfly.jlpackage,
- JuliaGraphics/Cairo.jlpackage,
- JuliaGraphics/Fontconfig.jlpackage,
- Giovineltalia/Compose.jlpackage,
- JuliaLang/Random.jlpackage,
- JuliaPlots/Plots.jlpackage,
- Sglyon/PlotlyJS.jlpackage,
- Stdlib/LinearAlgebra.jlpackage,
- Felipenoris/XLSX.jlpackage,
- Jump-dev/cbc.jlpackage.

In application, the number of apples (i_max = 500) and the number of UAVs on UGV (k_max = 5) were taken. JuliaStats / Clustering.jl package was used for the "rand" function and K-Mean Clustering Method to obtain the positions of the apples. The fact that the UGV is in motion during distribution or collection in the Flying Sidekick Traveling Salesman Problem (FSTSP) causes inefficiency in application. This is because the stop is at the optimal point to collect a certain number of apples. Heuristic TSP method was used in the route of the UGV.

In order to avoid problems in black and white printing, simulations obtained with multiple stops are not preferred, and as seen in figure 4., the scenario with UGV stop number 3 is preferred.

In application, the UAVs are allocated to the stops within its range and the minimum number of stops meeting this condition has been used. In figure 6., optimal values regarding the total harvest collection times at the determined stops are given. JuliaStats / Distances.jl package was used to calculate the distance of the stops obtained from apples. In the iterations made to find the number of stops (number of clusters) and their positions, the number of stops (j_max = 3) was obtained. In figure X., clustering structure and stops for 500 apples are presented. The "X" given in the figure 4. represent the stops.

In application, using the object obtained from the first three stages is optimized with the PSO algorithm at the last stage.

By using the algorithm developed for harvest optimization, it is aimed to find the optimal number of stops provides the lowest duration. Accordingly, when all possible stops are analyzed, it requires; i_{max}-2 times K-Means, (i_{max}* i_{max}+1)/2 times mathematical model and i_{max} times analysis of Traveling Salesman Algorithm. When it is necessary to analyze all the stops according to the number of 500 apples, it requires the analysis of 498 times K-Means, 125250 times the mathematical model and 500 times the Traveling Salesman Algorithm.

It takes more than 36 hours to reach the final solution, even if the time required to resolve each of these 125250 mathematical models is considered to be 1 second. For this reason, under the assumption that the harvest time has a function that decreases up to a certain number of stops and increases after this number of stops, Particle Swarm Optimization technique is thought to be used in this study to find the optimal number of stops.

Accordingly, the code was written in the Julia programming language and results were obtained. In all testing's, the optimal solution was found as 500th stop in maximum 5 iterations. The results obtained show that the harvest time has a monotonous decreasing trend according to the number of stops. For a more detailed analysis, the algorithm was run for all possible stops and the results given in Figure 5. was reached.

As can be seen in Figure 5., the harvest time is a decreasing function except that it is stationary between 50 and 250 stops. Therefore, it is clearly seen that the optimal stop to be reached by using any

Figure 5. Time used by UAV/UGV and total time with charge

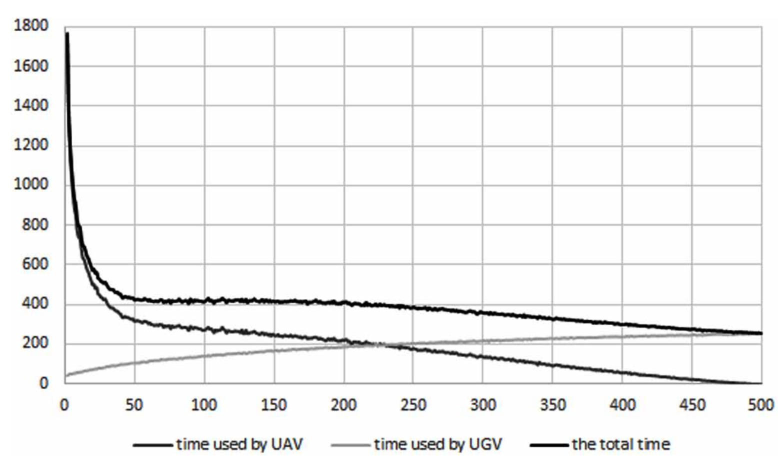
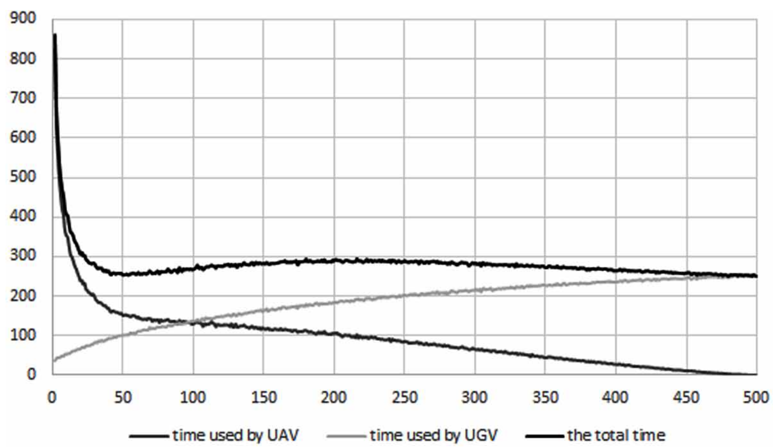


Figure 6. Time used by UAV/UGV and total time with no charge

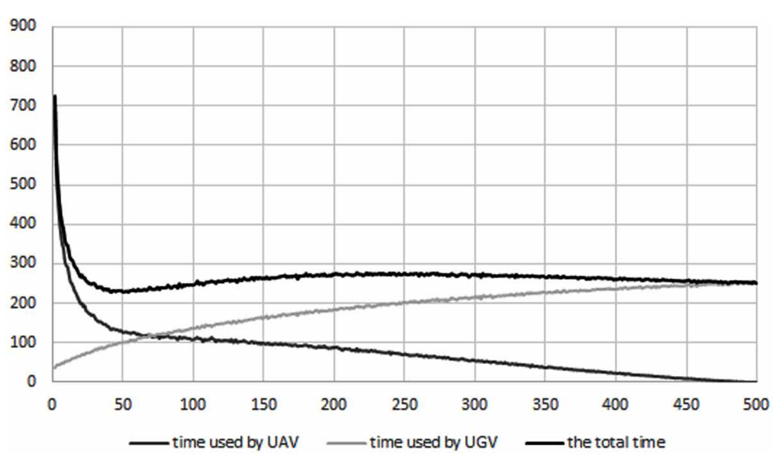


mathematical model will be the 500th stop. When the process was analyzed, it was understood that UGV was acting without recurring, without returning between stops, without spending time for recharging. On the other hand, UAVs spend more time for charging than their flight time. They have to go back and forth between each target and the stop while tracking the same speed as UGV.

As a result of all this, the process carried out with UAVs is less efficient when compare to the process carried out with UGV. In the study conducted by Ferrandez et al., it was proposed to have a spare battery for each UAV (Ferrandez, 2016). Thus, the time spent by UAVs for charging is planned to be reduced to zero. When the scenario used in this study is updated accordingly, the Figure 6. was reached.

As can be seen in Figure 6., the harvest time is a function that decreases rapidly to the 50th stop, increases between 50 and 200 stops and decreases between the 200 and 500 stops. Although the times around the 50th and 500th stops are very close to each other, the optimal stop is found as the 500th stop, with very little difference. Finally, when a 20% improvement in the speed of UAVs considered, the Figure 7. was reached.

Figure 7. Time used by UGV, UAV (%20 speed improvement) and total time with no charge



The positive effect of all these improvements is clearly visible between the 25th and 75th stops. The minimum point of the function for the harvest time is clearly in this range. In this way, the optimum number of stops can be found using the Particle Swarm Optimization Algorithm without making calculations for all stops.

After the current improvements were made, the PSO algorithm was run with the parameters presented in table 4 and the 42nd stop was found as the optimal stop with 228.25 min. The result obtained is exactly the minimum point of the total time in figure 7.

Table 4. Parameters

Parameter	Value
Variable Number	1
Particle Number	5
Minimum inertia weight	0.4
Maximum inertia weight	0.9
Cognitive acceleration constants C1	2
Social acceleration constants C2	2
Initial velocity	10
Maximum iteration number	50

In order to use the PSO algorithm for harvest optimization, the following assumptions must be provided. Otherwise, the optimum number of stops will be equal to the number of apples.

1. Charging time should be left out of the process by using a spare battery in UAVs,
2. UAVs should be faster than UGVs.

The algorithm should be added to the PSO algorithm until the result produces a different result from the number of apples, so that the result is not affected by the trap zone in the first part of the graph, which is the rapid decrease. In addition, instead of repeating the PSO algorithm for a certain number of times, running the best values of all particles until they equal the global best value produced healthier results in less time.

FUTURE RESEARCH, DIRECTIONS

This study can set an example for future studies. When smart agriculture can be applied with all its components, it will also provide great benefits to environmental problems through optimization of inputs. In our next study, the load carrying capacity of the UAV will be added and flight ranges and battery ratios of different weights will be simulated. In addition to that developing fault diagnosis and fault tolerant control of UAVs and UGVs will be integrated to the model.

CONCLUSION

In this study, it is aimed to collect the harvest of the autonomous UAVs and UGVs in the agricultural land, in accordance with the time minimization of the apples whose targets have been determined previously. Due to the fact that the problem studied is very large, the main problem is separated into small sub-problems in order to optimize the solution and the solution is provided.

It is understood from the UN reports that the world population will increase to 10 billion in 2050 and the food demand will increase by 70%. Countries that do not consider this population increase and do not invest in technology in the field of technology will have to purchase food and agricultural machinery from abroad. Today, in agricultural reports, there is more room for innovative agriculture, agriculture 4.0 and sensitive agriculture practices.

This change also affects farmers, manufacturers, marketers, retailers, consumers, governments that interfere with the flow of goods and products. Today, value of the smart agriculture market is almost$ 26.8 billion. It is expected that smart agriculture practices will reach the volume of 30 billion dollars in 2030 and this will be the factor that will affect the agriculture sector the most with this positive momentum caught by the market.

Although there is a lot of agricultural land available in the world, it is not possible to obtain a productive harvest due to reasons such as labor cost and technology shortage. Countries with small surface measurements, such as the Netherlands and Israel, have a voice in the world in the agricultural field by implementing successful and long-term digital agriculture policies. If the Agriculture fully fulfills the requirements of 4.0 and plans to switch to Agriculture 5.0 in the long term, the world will be able to meet the need for food that will increase in the future.

REFERENCES

Agrobot. (2020, July 4). Retrieved from www.agrobot.com/

Arad, B. S. (2020, May). Development of a Sweet Pepper Harvesting Robot. *Journal of Field Robotics*, 1–13. http://www.sweeper-robot.eu/

Balas, E. (1965). An additive algorithm for solving linear programs with zero-one variables. *Operations Research*, *13*(4), 518–545. doi:10.1287/opre.13.4.517

Bechar, A., & Vigneault, C. (2017). Agricultural robots for field operations. Part 2: Operations and system. *Biosystems Engineering*, *153*, 110–128. doi:10.1016/j.biosystemseng.2016.11.004

Bekhti, M., Achir, N., Boussetta, K., & Abdennebi, M. (2017). Drone Package Delivery: A Heuristic approach for UAVs path planning and tracking. *EAI Endorsed Transactions on Internet of Things*, *3*(9), 1–12. doi:10.4108/eai.31-8-2017.153048

Bellmore, M., & Nemhauser, G. L. (1968). The Traveling Salesman Problem: A Survey. *Operations Research*, *16*(3), 538–558. doi:10.1287/opre.16.3.538

Berry, J. (1996). *Mathematics learning and assesment: sharing innovative practices*. Arnold.

Bezanson, J., Edelman, A., Karpinski, S., & Shah, V. B. (2017). Julia: A Fresh Approach to Numerical Computing. *SIAM Review*, *59*(1), 65–98. doi:10.1137/141000671

BrelieH. (2020, June 26). *Euronews*. Retrieved from https://www.euronews.com/2020/04/17/french-farm-producers-suffer-during-the-covid-19-restrictions

Croes, G. (1958). A Method for Solving Travelling-Salesman Problems. *Operations Research*, *6*(6), 791–812. doi:10.1287/opre.6.6.791

DePuy, G. W., Moraga, R. J., & Whitehouse, G. E. (2005). Meta - RaPS: A simple and effective approach for solving the traveling salesman problem. *Transportation Research Part E, Logistics and Transportation Review*, *41*(2), 115–130. doi:10.1016/j.tre.2004.02.001

Dunning, I., Huchette, J., & Lubin, M. (2017). JuMP: A Modeling Language for Mathematical Optimization. *SIAM Review*, *59*(2), 295–320. doi:10.1137/15M1020575

FAO. (2009). *Global agriculture towards 2050*. UN Food and Agriculture Organization.

Ferrandez, S. (2016). Optimization of a truck-drone in tandem delivery network using k-means and genetic algorithm. *Journal of Industrial Engineering and Management*, *9*(2), 374–388. doi:10.3926/jiem.1929

ffrobotics. (2020, July 4). Retrieved from www.ffrobotics.com

Field, E. (2020, May 20). *The Traveling Salesman Problem (TSP).* Retrieved from https://www2.seas.gwu.edu/~simhaweb/champalg/tsp/tsp.html

Güzey, A. (2020). Smart Agriculture with Autonomous Ground and Air Vehicles: An Application on to Harvest Optimization. *Ankara Hacý Bayram Veli Ьniversitesi Эktisadi ve Эdari Bilimler Fakültesi Dergisi*, *20th International Symposium on Econometrics, Operations Research and Statistics EYI 2020*, 207-220.

Hillier, F. S. (1986). *Introduction To Operations Research*. Holden-Day,Inc.

Hooijdonk, R. (2020, June 26). Retrieved from Robotics Business Review: https://www.roboticsbusinessreview.com/agriculture/4-ways-robotics-change-agriculture-in-2019/

ILO. (2020, June 26). Retrieved from International Labour Organization: https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_740893/lang--en/index.htm

InsightCb. (2020, May 29). Retrieved from https://www.cbinsights.com/research/agriculture-farm-tech-startup-funding-trends/

Kennedy, J. (1995). Particle swarm optimization. *IEEE International Conference on Neural Networks*, 4, 1942-1948. 10.1109/ICNN.1995.488968

Kýlavuz, E. (2019). Dünyada Tarim 4.0 Uygulamalari Ve Türk Tariminin Dönü°ümü. *Social Sciences, 14*(4), 133-157.

Lamborelle, A. (2020). *Farming 4.0: The Future of Agriculture*. Retrieved from https://www.euractiv.com/section/agriculture-food/infographic/farming-4-0-the-future-of-agriculture/

Land, A., & Doig, A. G. (1960). An Automatic Method of Solving Discrete Programming Problems. *Econometrica*, *28*(3), 497–520. doi:10.2307/1910129

Lesh, R., & Harel, G. (2003). Problem Solving, Modeling, and Local Conceptual Development. *Mathematical Thinking and Learning*, *5*(2-3), 157–189. doi:10.1080/10986065.2003.9679998

MacQueen, J. (1967). *Some methods for classification and analysis of multivariate observations*. Academic Press.

Murray, C., & Chu, A. G. (2015). The flying sidekick traveling salesman problem: Optimization of drone-assisted parcel delivery. *Transportation Research Part C, Emerging Technologies*, *54*, 86–109. doi:10.1016/j.trc.2015.03.005

Olivares, V., Cordova, F., Sepúlveda, J. M., & Derpich, I. (2015). Modeling Internal Logistics by Using Drones on the Stage of Assembly of Products. *Procedia Computer Science*, *55*, 1240–1249. doi:10.1016/j.procs.2015.07.132

Pang, W. (2004). Modified particle swarm optimization based on space transformation for solving traveling salesman problem. In *Third International Conference on Machine Learning and Cybernetics*, (pp. 2342-2346). Shanghai, China: Academic Press.

Shamshiri, R. (2018). Research and development in agricultural robotics: A perspective of digital farming. *International Journal of Agricultural and Biological Engineering*, *11*, 1–14. doi:10.25165/j.ijabe.20181104.4278

Tevel-tech. (2020, July 4). Retrieved from www.tevel-tech.com/

Verified Market Intelligence. (2020, May 26). Retrieved from https://www.verifiedmarketresearch.com/product/global-agriculture-robots-market-size-and-forecast-to-2025/

WalchK. (2020, June 26). Retrieved from Forbes: https://www.forbes.com/sites/cognitiveworld/2019/07/05/how-ai-is-transforming-agriculture/#3e36b1f84ad1

Wang, X. (2016). The vehicle routing problem with drones: Several worst-case results. *Optimization Letters*, *11*, 1–19.

Zambon, I., Cecchini, M., Egidi, G., Saporito, M. G., & Colantoni, A. (2019). A. Revolution 4.0: Industry vs. Agriculture in a Future Development for SMEs. *Processes (Basel, Switzerland)*, *2019*(7), 36. doi:10.3390/pr7010036

ENDNOTES

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Chapter 11
Smart Sensors for Smart Agriculture

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ABSTRACT

Agriculture is the primitive and crucial occupation for the people. Urbanization, which indirectly affected the lives of people in the agricultural sector by increasing level of environmental pollution, climate change, degradation of soil and water quality, increasing population, decreasing income from the farming industry, etc. come as a new challenge and makes mass migration of rural people to the cities. To overcome this problem, new technologies are emerging that play a pivotal role in developing smart agriculture based on IoT technology by using smart sensors. Smart agriculture helps improve crop yield, livestock tracking, soil moisture monitoring, remote water tank level monitoring, temperature, and humidity sensing, the security of farmland, monitoring the environmental conditions, and equipment tracking. This helps farmers protect and monitor their property remotely, etc. Internet of things (IoT)-based smart sensors is the new technique for the smart agriculture system. IoT-based smart agriculture system consists of various sensor nodes placed in different locations, internet service, smart remote devices, or computer systems with the internet that monitor the operation of sensor nodes, WiFi, a camera with a microcontroller, and different interfacing sensing nodes for service. Some of the examples of such sensors are temperature sensors for temperature sensing, soil moisture sensors to check the moisture content in the soil, PIR sensors used in the detection of animals, people and other objects present in the farm field, GPS-based remote control robots that perform spraying, weeding, security, moisture sensing, etc. This chapter will have the following sequence introduction of the agriculture sector with the problems it is facing now and a new technique to overcome the current issues, need of IoT in the agriculture sector, the link of IoT technique with wireless sensor network in full detail study of IoT-based system, IoT-based applications, benefits of IoT technique in the agriculture sector, and future scope.

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INTRODUCTION

The agriculture sector is an essential sector of an economy for food security. Agriculture is the primitive and crucial occupation for the people of India, about 70% of the Indian population depends upon agriculture for their livelihood, and it contributes around 16% of Indian GDP. However, due to urbanization which indirectly affected the lives of people in the agricultural sector by increasing level of environmental pollution, climate change, degradation of soil and water quality, increasing population food demand, decreasing income from the farming sector, etc. come as a new challenge and makes mass migration of rural people to the cities, emission of greenhouse gas (GHG), uses of fertilizers, water drainage system scarcity and production of agri-waste. Agriculture produces food by using different resources like nutrients, soil, and water. To overcome these problems, optimization of agricultural productivity is essential to meet the growing world population demand. Smart agriculture (SA) is the new method mainly focusing on farming practices that increase productivity, security, and management and changing in input resources while reducing GHG emissions. Sustainable agriculture provides the perfect solution for balancing agricultural production and environmental degradation. Smart farming provides smart technologies for smart agriculture to improve and optimize agrarian activities like increasing yields, promoting climate change, and supporting low emission from the agricultural sector, increasing the overall quality and quantity of farm products. SA has included proper farming management on water usage, fertilizer application, crop management, animal security through livestock tracking, soil moisture monitoring, temperature, and humidity monitoring, etc. using internet-of-things (IoT) and various smart sensors. IoT and sensors can improve management by optimizing the waste collection, transportation, and utilization for resource recovery.

IoT based smart sensors are the new trending technique for the intelligent agriculture system. It is mostly used in linking devices and assembles information. IoT enabled sensor networks and cloud computing help in the transmission of data in real-time among different destinations. It performs monitoring, prediction, decision planning, and making decisions. IoT based network consists of physical objects where sensors collected and transfer the real-time. IoT technique has been in use in different fields like health care, agro-industries, ecological monitoring, traffic monitoring, restaurants food management system, military applications, smart cities, waste management, transportation, smart agriculture, home automation, smart meeting, smart environment, smart water, security and emergency, and many more.

IoT can be used in different methodologies of agriculture. IoT is based on devices that can analyze the sensed data and then transmit it to the end-user. IoT based smart agriculture system consists of various sensor nodes that are placed in a different location as per the application need, internet service, intelligent remote device or computer system with the internet that monitor the operation of sensor nodes, WiFi, a camera with microcontroller and different interfacing sensing nodes for service. Some of the examples of such sensors are temperature sensors for temperature sensing, soil moisture sensors to check the moisture content in the soil, PIR sensors used in the detection of animals, people and other objects present in the farm field, GPS based remote control robots that perform spraying, weeding, security, moisture sensing, etc.

IoT IN AGRICULTURE

As per the survey conducted by Unites Nations- Food and Agriculture Organization states that as the population size is increasing, the demands of food will also increasing so by 2050. To overcome this issue, worldwide food production becomes essential to be increased by 70%. This is linked to the declining natural deposits, agricultural site area, changing weather situations making food safety a very significant area of discussion for most countries. Agriculture sector is a primary source of food products and also agriculture helps in the growth of an economy. The agricultural sector plays a vital role in the employment generation for the people. In many parts of the world, farmers are still dependent upon the traditional farming method, which results in extra labor time, low yield of crops and fruits, poor quality of produce, soil degradation, etc. These issues can be solved using automatic machinery, proper supervision, monitoring and coordinate system, and infrastructure development. So it has become necessary to develop new modern technologies for the agriculture sector's overall development. Using IoT based technique one can increase of the crop production with lower cost and this can be achieved by monitoring the soil efficiency, temperature and humidity monitoring, rainfall observation, fertilizer effectiveness, animal tracking, storehouse monitoring, water tank dimensions monitoring, theft detection, equipment tracking, tracking and monitoring remotely, and so on. The world is moving towards IoT technologies, combined with data analytics (DA), to encounter the world's food shortage demand in the coming years. The use of IoT technologies and DA together would enhance the agrarian sector utility, which will helps in providing high operational planning and top crop yield.

Combining the traditional way of farming with upcoming future technologies such as the internet of things (IoT) and wireless sensor networks (WSN) can help in the westernization of agriculture at a lower cost. WSN assembles the information from discrete classes of smart sensors and transmits that information to the central server using various wireless protocols. Additional components that harm the crop yield are insect's attack, overdose use of pesticides, attack by wild animals and birds, unpredictable nature of the monsoon, water scarcity, improper water usage, and lack of farming knowledge.

IoT application in agriculture will empower the framers with decision making on devices and automatic technology which will combine product knowledge and services for excellent farm productivity, profit and quality management. However, IoT system contains few challenges also such as security, privacy, and business model ownership solution and data governance (Parasher, Singh, & Kaur, 2019).

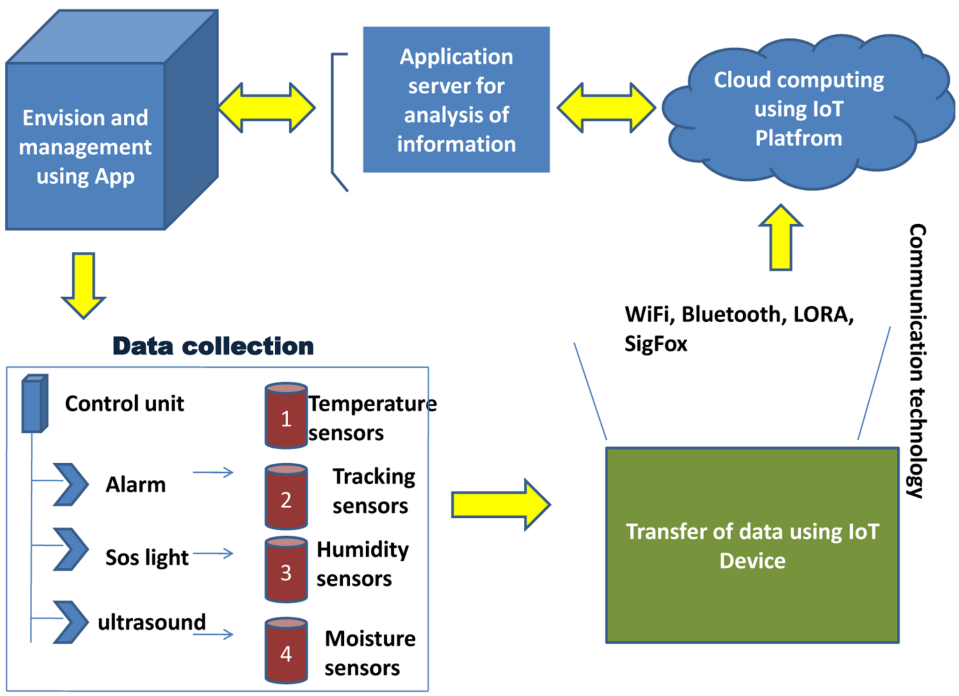
IoT BASED WIRELESS SENSOR NETWORK

IoT helps in combining the bodily world with the virtual world by making use of the internet as a means of communication and exchanging information. IoT is defined as a technique which interlinked calculating devices, various mechanical and digital instruments with different objects, animals or humans to provide their unique identification and having the capability in transferring the data over a system that does not require human to human or human to computer interconnection.

With the technology enhancement, WSN's have been in use for smart agriculture practice and food manufacturing while keeping the focal point on environmental analysis, accuracy, machine functionality, process control automation, and traceability. WSN comes with a few advantages such as self-organize, self-arranged, self-identification and self-cure, this makes WSN the best choice in smart agriculture applications.

WSN is a kind of network that contains radio frequency (RF) transceivers, smart sensors, microcontrollers and biasing source. The arrival of IoT technology makes a switch from the use of WSN to IoT as the principal technique to shift agriculture to smart agriculture. IoT combines many techniques that are presently in use, such as WSN (Bera et al., 2016) (Potdar et al., 2009), radio frequency identification (RFID) (Fernández-Caramés et al., 2017), cloud computing (Parasher, Kedia, & Singh, 2018), interface systems and end-user applications.

Figure 1. IoT Architecture for Agriculture

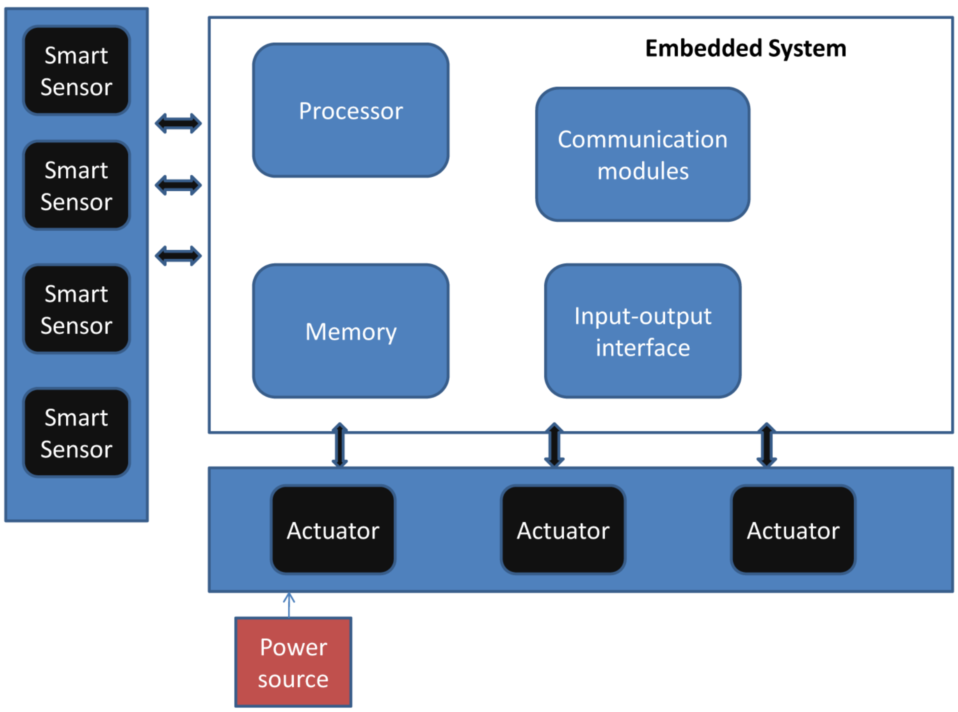


IoT ecosystem for smart agriculture comprises four significant blocks: 1) IoT devices or smart sensors, 2) information technologies, 3) internet 4) data storage, and processing block unit, as illustrated in Figure 1. These four blocks are essential for IoT based applications. A detailed description of the IoT blocks is given below.

1. *IoT Devices/Smart Sensors:* IoT devices contain an embedded system that interconnects with smart sensors and actuators. This system requires wireless connectivity. IoT devices are also called IoT sensors or smart sensors (Chokkareddy et al., 2019). Figure 2 shows the architecture of IoT devices/sensors. The embedded system contains field-programmable gate arrays (FPGA) or microprocessor, communication units, memory block, and input/output interfaces. Smart sensors are used to detect and analyze distinct farm land parameters such as nutrients level of soil, weather forecasting and elements affecting crop productivity. Smart sensors are classified as location sensors, optical sensors, mechanical sensors, electrochemical sensors, and airflow sensors. Smart sensors are employ to sense the various information like air, and soil temperature at multiple soil levels, rainfall, leaf

wetness, chlorophyll, wind speed, wind directions, humidity, solar radiation, atmospheric pressure, etc. below table 1 present some of the smart sensors and their applications. The IoT devices are portable, durable, power-efficient, excellent computational, reliable, low-cost, and coverage.

Figure 2. IoT Device Architecture



2. *Information Technology:* Information technology plays an integral part in the arrangement of the IoT system. Present information technology is divided on the basics of standard, spectrum, and applications. The information standard is classified into short-range and long-range information standard. Information spectrum is classified into an authorized and unauthorized spectrum. An IoT application depends on the sensors or backhaul network and arrangement criteria.

    a. *Spectrum:* the unauthorized spectrum uses the ISM band, but the drawback of using this band are security issues, infrastructure cost, and electromagnetic interference. Electromagnetic interference is produced by ISM IoT devices, which interfere with radio communication, which uses the same frequency. In contrast, authorized spectrum is used by the dedicated user such as cellular communication and provides efficient traffic management, lower interference, more reliability, improved quality of service (QoS), more security, and low cost and more extensive coverage area. This also has some disadvantages, such as power consumption and the need to purchase the subscription for data transmission.
    b. *Standard:* There are many standards use in the wireless communications such as 802.11ah, 802.11p, SigFox, LoRa WAN, Telensa, 3GPP NB-IoT, EC-GPRS, WiMAX, Bluetooth,

ANT+, MiWi, ZigBee, Z-Wave, Wireless HART, NFC, etc. They are divided into short-range and long-range communication standards. Examples of the short-range standards are near field communications-enabled devices, Bluetooth, ZigBee, Z-Wave, passive and active radio frequency identification (RFID) systems. They can cover up to 100m of distance. The long-range communication standards include miles up to 10's of kilometers. The long-range communication standards are classified as the low power wide area (LPWA), examples are LoRa, Sigfox, NB-IoT. LPWA uses little power and covers a more considerable distance (Salman & Jain, 2017).

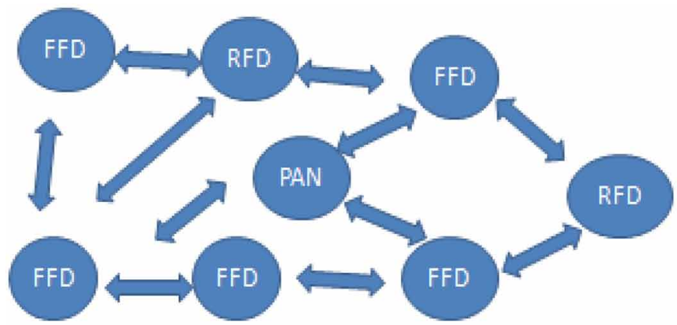
c. *Implementation criteria:* information technology depends on the application in an IoT device or smart sensors. The communication technology can be used as IoT devices such as nodes/sensor nodes or as backhaul networks. The nodes transmit fewer data and cover very short distances with low power consumption, whereas the backhaul network supports high data rates and can be used for very long distances. Some of the communication technologies argue bi-directional links. The bi-directional link allows for forwarding error correction, handshaking for data reliability, encryption of data, over-the-air firmware updates, and communication between devices.

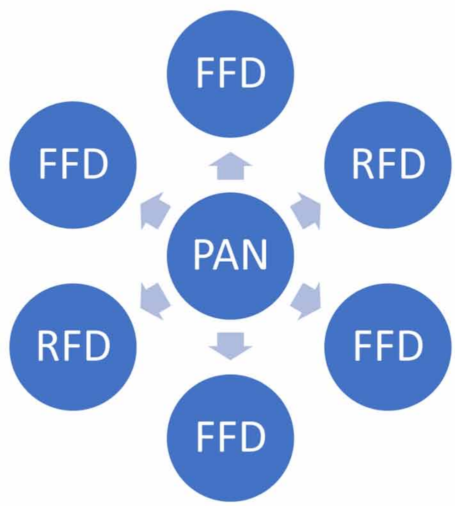
Communication technology selection also depends upon the type of topology to be used. There are different types of topologies like peer-to-peer (P2P), start, mesh, and ring and bus topology. In each of these topologies, IoT devices or smart sensors play various roles and functions. It can be used as the personal area coordinator (PAN) or as an end device and full function device (FFD) or reduced function device (RFD). Figure 3 shows two kinds of topologies and their function performed. In the P2P topology, the PAN functions as FFD and starts the communication while the end devices can either function as an FFD or RFD. The end device, which acts as FFD, can have multiple connections while the end device that acts as RFD can only connect to one FFD and cannot connect to another RFD. The star topology consists of PAN that initiates the communication and accepts connection from other devices. The end devices can only establish connections with the PAN coordinator.

d. *Internet:* internet helped increase the coverage area of wireless communication systems, mobile devices, and other internet connectivity services. As per the Machina research report, the agricultural devices connected to the internet will grow from 13million at the end of 2014 to 225 million by 2014. The internet makes the main network layer, where the path is created to carry and exchange data and network information between other sub-networks. When an IoT device is connected to the internet, it makes the availability of data anytime and anywhere. The use of the internet for data transmission requires high security for real-time data transmission and easy accessibility. Internet plays a significant role in cloud computing, where extensive details are accumulate for storage and processing. Cloud computing is use in the management of user interface, services, organizer, coordinator for sensor nodes networks, data processing unit, and data computing.

For heterogeneous systems, device connectivity over the internet, IoT interface and connectivity protocols are developed like service-oriented architecture (SOA), cloud-based, and actor based IoT interface, which are used to support IoT technology. The SOA contains multilayer architecture. Some of the layers are sensing, accessing, networking, interface, and application layers.

Figure 3. (a) Peer to Peer Topology & (b) Star Topology





e. *Information storage and processing units:* data management in an agriculture sector includes vast, vigorous, composite, and spatial data that need information storage and processing unit. Difficulty of information or data is defined as structured or nonstructural data, they are present in the nature of messages, pictures, audio, or video data. They are also being of different types like historical, sensed, or live streaming, business, or market-related data. Cloud computing help in the collection of a large amount of data from smart sensors, and data are stored in the cloud, which involves organizing various applications that are critical in providing services and management of end-to-end IoT architecture (Kaur, Tomar, & Singh, 2018). Lately, edge and fog computing are promoted, where various IoT devices or smart sensors carry out calculations and analysis to reduce response time for essential uses, reducing the budget and uplift QoS.

Various agricultural data management systems have been implemented to manage the different structure of data, such as On-farm systems, Farmobile, Cropx, Farmx, Easyfarm, KAA, and Farmlogs. This management system will allow data storage, data organization, and data analysis (DA).

In the implementation of IoT devices or smart sensors, there are critical technical variables that are necessary to observed. In wireless integration, these variables should be noted: communication distance, data flow, battery life, mobility, dormancy, security, flexibility, and cost. Between all communication technologies, LPWA is winning over so much attentiveness, especially with the exposure to NB-IoT (Li et al., 2018). The NB-IoT guarantee compelling characters that are low device power requirement, little device cost, easy implementation, backup of large number of small-output devices, broad distance coverage can support transmission and receiving of data.

IoT APPLICATIONS FOR SMART AGRICULTURE

There are various applications of IoT in smart agriculture, such as crop monitoring and livestock tracking, machinery tracking, irrigation monitoring, and water standard monitoring, weather forecast monitoring, soil parameters monitors, infection and pest control monitoring, automation and accuracy monitoring. Some of IoT applications are discussed below, based on the following parameters: monitoring, tracking and tracing, agriculture machinery, precision agriculture, and greenhouse production (Wang et al., 2006).

Monitoring

In the agriculture sector, various parameters need to be monitored; this depends upon the section of agriculture under contemplation. Some are explained below

Crop Farming Monitoring

In crop farming monitoring, many environmental factors affect farm output. This information helps understand the design and process management of farms, such as monitoring rainfall patterns, leaf wetness, temperature, humidity, soil moisture, salinity, climate, dry cycle, pest presence, human activities, etc. This information helps in detail study and record management in improving the quality of farm produce. This reduces the risk and increases the profit, as solar radiation tells us about plant exposure in the sunlight, here farmers clarify whether plants are rightly exposed or overexposed. Soil moisture gives details about the moisture, humidity, wetness, and etc.; details of soil help improve soil quality and reduce the plant disease risk. Timely and accurately collecting features of weather monitoring, such as changes in climatic and rainfall conditions, this will enhance the yield outcomes. These details can also help farmers in taking preventive actions on planning, management, and cost of labor. This will help farmers to make a corrective, fast, and necessary estimation in earlier based on the details given. Pest action detail can be gathered and send to different remote locations, which give the live information to farmers for pest control and used to give suggestions to farmers based on the track evidence of pest attacks.

Aquaponics Monitoring

Aquaponics(Lee & Jhang, 2019) is defined as a mixture of aquaculture and hydroponics systems, where fishes excreta are used to the farms plant which provide the crucial nutrients required by all the plants. In these farms, it is crucial to monitor continuously water quality standard, water proportion, temperature, well-being of the fishes, salinity quantity, pH level, humidity, and sunlight. Correct details can enhance fish and plants production as it let nutrients movement between the plants and fish. These details can also be used in the automation motive with the least human involvement.

Forestry Monitoring

Forestry is an essential activity in the carbon sink cycle, and it also fosters over two-third of world's known different animal and plant species. Forestry monitoring includes factors like soil, air, temperatures and humidity monitoring, and also monitoring of various gases level in the atmosphere, for example, oxygen, carbon monoxide, carbon dioxide, toluene, argon, hydrogen, methane, iso-butane, ammonia, ethanol, hydrogen sulfide, water vapor, ozone, and nitrogen dioxide. These factors help in informing early alert and warning systems against field and forest fire and also provide monitored information against diseases related to forestry.

Livestock Farming Monitoring

Parameters to be monitored in livestock monitoring are highly dependent on the animal class, like the milk of buffaloes and cows can give detailed advice about their health conditions by analyzing milk conductivity. Many other parameters such as temperature, humidity, productivity, pest attack, and water standard can also be monitored. The placement and execution also help farmers track and identify their livestock's position by tagging every animal with RFID tags; this helps protect animals from the theft. Also, monitoring of storage, which contains water, fuel, farming essentials, and animal foods, can also be analyzed and monitored. This information can also help the farmers for better planning and budget analysis for the future. While various suggestions have been given in the domain of livestock monitoring, the acquisition of multiple solutions in small-scale and medium-scale farms is very much restricted, mostly in under-develop countries due to lack of interest, knowledge, placement of such arrangements, cost-related issues, and awareness. The ability to implement cost sufficient agricultural based IoT technique is still a very open domain with many new challenges.

Tracking and Tracing of Asset

An IoT technology is very beneficial in asset tracking to boost organization supply chain process and planning (Parasher et al., 2019). An IoT technology can give details to enhance agricultural organizations for more significant decision making, management, planning, and intelligently link with various business partners while saving time and finances. Details, like position, assets identification can be identifying using RFID tags and cloud-computing based global positioning system (GPS). Tracking and tracing of various assets in the agricultural supply chain process makes the customers to know the market's actual history. Hence this will improve the customer's belief on the agriculture products' safety issues and health linked issues. Tracking is a process that captures, collects, and stores information related to the supply chain process from top to bottom. It also makes the agriculture output to be differentiated from bottom to top. Tracking and tracing of assets make various information that are stored along with the supply chain process, so that all the customers and various business partners are guaranteed on the source, position and life history of an agriculture output.

Many variables can be tracked like the growing environmental issues, manufacturing conditions, pest related concerns, management, storage situations, shipment and time required to reach the market. These variables are linked directly to the health of customers. The critical variables which harm the growing environmental issues like soil, air, and water. Various manufacturing regulations are depending on utility of herbicides, fertilizers, and pesticides. Further, the quality of food and vaccines which are given to the livestock can be trace since they could create well-being and safety issues. Agricultural outputs mostly damaged by pest attacks along the whole process, which could damage the quantity and quality of the agriculture output. Tracking an agriculture outputs can help the farmers to enhance productivity and manage supply chain process. A tracking and tracing network must have information about the load, storage unit, transport facilities, process system, and yield information. The load information contains the details of whole manufacturing process of the products, like the geographical area of origin, the latest status, end station information, and details of various business partners in the whole supply chain process. This network should also contain memory bank to save data over an interval of time for research and development utility. Data transmission is referred to as the process of integration and equalization of the aggregate data. The tracking and tracing network should also be able to manage the collected details, and finale yield is given to everybody includes in the whole supply chain process. Significance of various RFID tags in tracking involves in the every manufacturing stages, product processing, product shipment, storage, allocation, market sales, and many other after-sales services is highlighted in it. It helps collect, store, and visualize information along with a considerable distance at the fastest rate.

Farming Tools

IoT-based farming tools that can help in increasing farm productivity and decreases food product losses. The correct surveying of the utilities of GPS technology and global navigation satellite systems (GNSSs) (Zhu et al., 2018), the farming tools can be use in automatic pilot mode. Farming tools that are involve in vehicles, unmanned aerial vehicles (UAVs) and robots can be distantly handle the available details accumulated via the IoT technology for accurate and help in capital requirement of farmland areas. Farming tools can also gather information and these information's can enable farmers in surveying their field land for proper organization, like fertilization, irrigation and nutrition, such as CLAAS, a farming tool manufacturer has applied IoT technology on their instrument, allowing their tools to be run in automatic pilot mode. Another method is Precisionhawk's UAV sensor (Bacco et al., 2018), which can give details to the farmers, like the speed of the wind, air pressure, etc. along with other related factors. This method can also be used for image sensing and surveying of agricultural lands.

Accuracy in Farming

Accuracy in farming can be defined as the assembly of real-time information obtained from different farm parameters, using that information for analysis in quick and smart decisions making in order to gain crop productivity, least environmental degradation, and lowering of cost. Accuracy in agriculture depends on several technologies, like smart sensor nodes, GPS technology and larger DA for enhanced farm productivity. Smart and quick solution obtained from DA also results in the least wastage of agriculture resources, such as water, nutrients, pesticides, etc. Accuracy in farming shows new issues for the researchers in the field of robotics, image processing, mapping of the land, meteorological information sensing, etc. With more use of GPS (Michael et al., 2006) and GNSS, farmers are capable of locating the exact location and surveying sites with various information factors, that are then used by multiple new technologies for accurately allocate farm resources, such as seeds, fertilizers, spray, pesticides, and many other services. Accuracy in agriculture sector can enhance productivity. Also, it become necessary to give methods that are easy to use by farmers and also help in getting various training sessions, which will make the small and medium scale farmer's more beneficial from these arragements.

Greenhouse Technology

Greenhouse technology is also known as glasshouse technology. In this method plants are grown under controlled environmental conditions. This technique provides the advantage of producing various kinds of plants at any location and at any time by delivering comfortable ecological state. Various research works have been carried out, linking the application of WSNs in greenhouse technology to monitor various environmental conditions. Many pieces of research work have presented on how IoT technology can be related to greenhouse technology in order to decrease human intervention, power-saving, creating more efficient greenhouse-site monitoring and direct linking of greenhouse farmers to consumers (Liu et al., 2007).

VARIOUS ADVANTAGES OF IoT TECHNOLOGY FOR AGRICULTURE SECTOR

There are various advantages of IoT technology for the agriculture sector. Few of the benefits are given in the following section:

1. *Collective Farming:* IoT technology can help encouraging collective farming, specifically in rural and remote areas. IoT can be supported to develop services which enable the rural agriculture society to have shared farm detail storage, data sharing and increasing communication between farmers and agriculture specialists. The use of cellular applications has helped in sharing IoT-related details like tools, right fertilizers, weather conditions, and so on. Data can be easily shared among the rural community by using free or paid mobile services.
2. *Security:* The agriculture sector issues are not just extended to more production of food grains but also in its capability for safety, security, and good quality food supply. There are various issues reported several in food quality supply to the market, such as food adulteration, counterfeit, artificial enhancement of the vegetables, or fruit size. These issues are posing primary concern on health and can have a negative impact on the economy. Few elements of the food deceit discussed here are product coherence, task coherence, mankind coherence and statistics coherence can be labeled using IoT technology. IoT can be used to provide management coordination and subjective traceability of food items.
3. *Competition benefits:* The increased pressure for more food generation and the use of new creative technologies are making agriculture more competitive sector. It empowers a system where sharing of information using IoT technology in the agriculture sector will create new hope in marketing, monitoring and management. Reducing the costs and wastage in farm inputs, like fertilizer and pesticides, lead to enlarge productivity of food. The application of real-time information for resolution making will help in competition management necessary for farmers who accepted the IoT technology ecosystem.
4. *Prosperity formation and Dispersal:* Implementation of IoT technology could give new ideas for occupation generation, which benefits farmers by ignoring various misuse of "intermediate men" and can be in a face to face association with the customers leading to more substantial gain.
5. *Low cost and destruction:* Sole benefits of IoT technology is its capability to detect remotely placed devices and tools. IoT technology helps in saving time and money in agriculture applications by surveying the large land area as compared to human handling of the field using farmers' own vehicle

or by walking in the field. IoT technology increases farmer's decision-making ability by letting them know the timings about when to apply pesticides and insecticides. This could help them to reduce the farming cost and destruction of crops.

6. *Operational effectiveness:* The operational efficacy is related to the decision making process in the agriculture sector, as the role of government department and non-governmental organizations. Gathering of information from agriculture schemes using IoT becomes a guiding tool for agricultural organizations' interference. Such interference can help control and manage diseases spread, farmland fire, government schemes, and resource budgeting. Also, farmers can benefit from IoT and DA techniques to get a precise and timely conclusion in the name of the management and operation of the farm. Automatically documenting the health position of livestock and crops will help in the efficient, timely, accurate analysis and prescription of medicine by agriculture doctors or officers to farmers (Singh, Dixit, & Kaur, 2019). These procedure helps in reducing operating costs. The performance and timely delivery of food items in the agriculture sector's supply chain cycle gets improved using IoT.
7. *Consciousness:* IoT ecosystem can run low-cost applications and manage entry to WSN in the agriculture sector. Details like market analysis, price, good and services can be obtained from mobile applications. Also, various government policies, law and regulation standards regarding various agriculture farm output can be easily available. Also, customers those are attracted to organic food and fresh products can easily find farmers and be alerted when these food products are available.
8. *Service Management:* IoT technology will allow real-time tracking, sensing of farm capital, protecting different types of equipment from stealing, replacing equipment parts and for well timed job continuation.

CHALLENGES

Many challenges are faced by using IoT platform. Some of the problems are security, privacy, authority, data merging, lack of association, diversity in IoT devices, and unpredictable business prototypes. Some of the issues that are faced in various sections such as business prototype, technological and regional problems are explained below:

1. *Challenges in business:* the gain in the agricultural sector is very less. So there is a need to equalize the challenges faced between the implementation of IoT technology and profit. Various problems are discussed below, such as cost and business prototype.
   a. *Cost:* various costs are linked to the implementation of IoT in the agricultural sector, like organization and management cost. Organization overall cost contains the procurement of multiple equipments such as base station support, gateways, sensors, IoT devices, etc. Management cost includes managing and continuously taking subscriptions for the regular use of the IoT platform that provides data sharing, managing IoT devices, data accumulation, etc. The success of the IoT platform depends on customer satisfaction based on privacy cost, security cost, and business-related to which give higher gain. Various IoT platforms provide free subscriptions with restricted functions, restricted IoT devices, and limited information that can be saved and used.

b. *Business prototype:* farmers want business prototype that will help them for the generation of more gain and money by accumulating data from their farm using IoT platform. Currently, different IoT platforms are providing restricted free subscription and full service with various levels of paid subscriptions. Information provided is investigated by IoT technology providers, and these are becoming a reason of the dispute by farmers for handling and claim of the details.

c. *Less required knowledge:* less essential awareness of IoT technology and its various usages between farmers is a primary reason for the steady implementation of IoT technology in the various agriculture applications. This is a significant reason, especially in third world countries, because the majority of farmers are from rural areas and uneducated. They are not so flexible in using new technologies.

2. Technological challenges:

   a. *Coupling:* implementation of large IoT devices in the agriculture sector for different purposes will cause coupling issues, especially among IoT devices using unlicensed spectrums like ZigBee, WiFi, SigFox, LoRa. Due to coupling, loss of information and less reliability take place. The use of unlicensed spectrum coupling more device costs adds on. Nevertheless, using a licensed spectrum in IoT technology can reduce unnecessary coupling. Frequency reuse also causes coupling among the IoT devices using a licensed spectrum.

   b. *Privacy and security challenges:* many security challenges at various levels of IoT network are need to be solved. The absence of required security can cause loss of information, lack of privacy, and attack on sensitive information like field parameters and other intellectual properties. This will create a problem in the competitive benefits of private farm owners. IoT devices are at risk of physical damage like theft attack or animal attack, change of physical address. Gateways are prone to traffic attacks, denial of service (DoS), and forward attacks. Various site information and IoT site-based services used in framing are prone to attacks like device capture attacks. In device capture attacks, attacker seizes the IoT devices and withdraws cryptographic information, which can attack informations stored in the device storage. Wireless signal jamming also takes place. Cloud servers are sensitive to data damage; unauthorized resources can affect automatic work in the farms.

   c. *Selection of Technology:* there are many IoT technologies that evolve currently; some are still under investigation. Selecting the correct technique is a big issue because there is still much research is required for the implementation of new technologies. Different parameters are considered before the selection of new technology like the area of the farm (small, medium, or large), location, kind of soil, and environmental conditions.

   d. *Accuracy:* IoT devices are placed in the open air with an environmental condition that will affect the placed sensors and damage their functionality with time and lead to failure in the communication system. Protection of placed IoT sensors and structures must be guarantee prevention of damage to expensive instruments in different weather circumstances like floods, heavy rainfall, cyclones, etc.

   e. *Local conditions:* different parameters need to analyze before the placement of IoT devices like IoT device placement anywhere and connectivity to the world without additional installation of any other equipment, the best location to place IoT device that will give required data, less coupling, and more reliability.

f. *Best of Resources:* farmers need to understand the best of resources mechanism to analyze the number of IoT devices needs, number of gateways, memory size for cloud storage, the volume of data to be transmitted in order to get more profit. This is required because of the differences in farm size and various kinds of sensors are used to analyze multiple farms parameters for particular crops and livestocks. This needs enlargement of sophisticated algorithms and mathematical prototypes that will determine the best use of the resources while lowering the cost and increasing agriculture output and gain.

3. Regional challenges:
   a. *Administrative challenges:* law and order issues related to power and possession of farm information between various farmers and authorized companies need to be resolved. Different Law and orders varies from one country to another country depending on the available resources like spectrum, technical issues, privacy, security, and market competition. Various laws and orders across different countries harm the uses of IoT applications in various agricultural applications.

FUTURE SCOPE

Future scope of IoT in smart agricultural applications will be based on the following trends:

1. Technological innovation: With the growing demand for new technologies, more IoT based solutions will increase to emerge in the market for the agricultural sector. Some of the trends that will affect are
   a. Implementation of LPWA Technologies: this technique will help the farm sector as it comes with many advantages like less power requirement and large-distance communication. Many researchers are growing their interest in this area due to the release of the 3GPP NB-IoT standard technology adopted by various telecommunication engineers. This would enable the research interest in IoT technology for the agricultural sector.
   b. Universal Programme: the use of IoT in the agricultural sector is not limited to the specific crops or livestock; it is shifted towards the generic program that would provide support to any type of crop or livestock. This enhances the use of IoT systems in various applications, i.e., managing and monitoring multiple crops and livestock and selling of produce goods to the local stores and consumers in the market. This would enhance the geographical and regional area overcoming the limitations and help in the IoT based agricultural sector.
   c. Security: analysis and various researches in the sphere of security for IoT device and point-to-point data security have gained many researchers' interest. Research is required in implementing IoT device that is fully secure using various security schemes like encryption algorithm. This algorithm supports digital signature and data encryption for the security of the data. Security of data is vital as it helps in protection from physical attackers and hackers.
   d. Spectrum and energy efficiency: Various technologies like ultra-narrow band channels (Sigfox and Telensa) and spread spectrum (LoRa and Ingenu) are acquired in order to get LPWA needs. As more LPWA solutions are out, new techniques will support broad distance coverage, battery life, data transmission, and a high path loss link budget. Most of the cellular NB-IoT systems that are in use today support various frequency bands that operate in frequency division duplex

modes. More research work is required that will promote operation in the time division duplex modes. It has opened new research challenges, like pilot contamination. LPWA is used to get a longer battery life span, energy-efficient system, which are still required in IoT devices as they depend on the sensor node in use. Many algorithms have been invented to support energy-efficient WSN, like cluster and in-network process algorithms. Other energy-efficient methods for IoT include sleep interval prediction of IoT devices based energy saving, previous usage, and the standard of information required for a specific application. IoT transceiver support transfer of power needed architecture and simultaneously wireless data and power transfer; energy-efficient IoT devices are the new research areas.

e. Quality of Service (QoS): quality of service is required in each and every network layers of IoT network architecture. Potential of a device that wants to send critical data using IoT with any of the information technology is still a research area. NB-IoT communication technology provides high QoS as compared to LoRa. Even more, research is needed to provide QoS in all the different IoT layers.

f. Artificial intelligence (AI) and DA: Various researches are still required using AI in model growth and disease management by using data from the farm and climate-related information. Like the use of machine learning for the identification of any disease by uploading pictures using smartphones. DA algorithms that can process more and fast data as compared to the IoT communication are still under research.

g. Privacy and conservation: for IoT data violation, privacy, and preservation method is used that generates information from the data while conserving the privacy of an individual. This method will provide a fixed level of confidentiality by allowing the maximum use of the data. This method can further increase the privacy and conservation of data in agriculture, and also it required more research in this area.

h. Data Compaction: a large number of IoT devices are connected in any network. Now, it is necessary to expand advanced compactness and multiplexing technologies in the transfer and exchange of information from 100 to 1000 smart sensors to a central location. It is required to send photos and video related data during the use of NB-IoT cellular communication. Combining and multiplexing of information can help in collecting data from various farms land to one location and provide support, reliability and administration all in one-point.

i. Real-Time Analysis: 100 to 1000 various kinds of sensors are placed in the farm field for real-time analysis, easy to implement network management protocol is used that will support communication among objects and server with less elevated issues. Currently, the IoT network handles substantial data traffic and power requirement.

2. Application criteria: Now, research is more focused on reducing the cost of communication technologies used in IoT implementation. The latest work is developing on small scale testing and prototyping. For large scale projects, the need for IoT technologies is under evaluation in their usefulness in the agriculture sector. The future of IoT technologies will have large scale projects in supply chain management and agri-food applications. Also, the IoT role in agriculture can be seen in developing countries such as in south-east Asia, Africa, etc. not only in developed nations.

3. Business and market demand:

   a. Cost reduction: reducing power consumption, scaling down of physical size and high output productivity is required in reducing the cost of the IoT devices for smart agriculture use. In the future, cheaper sensors would use and research will focus on merging various placement criteria, explore the multiple usages of authorized and unauthorized communication technologies to get benefits of reduced installation and operation price.

b. New policy formation and regulations implementation: new strategies for enforcement and quality management in the usage of IoT technologies in the agriculture sector are necessary. The role of government and agricultural departments is essential to ensure the implementation of policies and regulations in agriculture for the right use of IoT technologies. This will enhance the interest of the farmers and other people who want to adopt IoT technologies and to develop agriculture into smart agriculture.

Table 1. Different types of Agriculture Sensors

Type of Smart Sensors	Functions	Applications
Airflow sensors	Measure the mass flow rate and pressure of air	Measure the type of soil, moisture level, compact, structure
Dielectric soil moisture sensors	Use in calculating the dielectric constant of soil	Soil moisture calculation, soil texture, salinity, and temperature changes
Electrochemical sensors	Detect specific ions present in the soil	PH, soil nutrient level,
Location sensors	Use signals from GPS	Measure latitude, longitude, altitude
Mechanical sensors	The probe is used that penetrate in the ground to take measure resistive forces	Measure soil compactness, tensiometer instrument is used to forces
Optical sensors	Use a light source to measure the soil parameters	Analyze clay quantity, presence of organic matter and amount of the moisture level in the soil. Examples are photodiodes and photodetectors.

REFERENCES

Bacco, M., Berton, A., Gotta, A., & Caviglione, L. (2018). IEEE 802.15.4 Air-Ground UAV Communications in Smart Farming Scenarios. *IEEE Communications Letters*, *22*(9), 1910–1913. doi:10.1109/LCOMM.2018.2855211

Bera, S., Member, G. S., Misra, S., & Member, S. (2016). Soft-WSN : Software-Defined WSN Management System for IoT Applications. *IEEE Systems Journal*, *12*(3), 1–8.

Chokkareddy, R., Thondavada, N., Thakur, S., & Kanchi, S. (2019). Recent Trends in Sensors for Health and Agricultural Applications. In *Advanced Biosensors for Health Care Applications*. Elsevier Inc. doi:10.1016/B978-0-12-815743-5.00013-5

Fernández-Caramés, T. M., Fraga-Lamas, P., Suárez-Albela, M., & Castedo, L. (2017). Reverse engineering and security evaluation of commercial tags for RFID-based IoT applications. *Sensors (Switzerland)*, *17*(1). Advance online publication. doi:10.339017010028 PMID:28029119

Kaur, G., Tomar, P., & Singh, P. (2018). Design of cloud-based green IoT architecture for smart cities. In *Internet of Things and Big Data Analytics Toward Next-Generation Intelligence* (pp. 315–333). Springer. doi:10.1007/978-3-319-60435-0_13

Lee, C. H., & Jhang, J. H. (2019). System design for the internet of things assisted urban aquaponics farming. *2019 IEEE 8th Global Conference on Consumer Electronics, GCCE 2019*, 986–987. 10.1109/GCCE46687.2019.9015214

Li, Y., Cheng, X., Cao, Y., Wang, D., & Yang, L. (2018). Smart choice for the smart grid: Narrowband internet of things (NB-IoT). *IEEE Internet of Things Journal*, *5*(3), 1505–1515. doi:10.1109/JIOT.2017.2781251

Liu, H., Meng, Z., & Cui, S. (2007). A wireless sensor network prototype for environmental monitoring in greenhouses. *2007 International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM 2007*, 2344–2347. 10.1109/WICOM.2007.584

Michael, K., McNamee, A., & Michael, M. G. (2006). The emerging ethics of humancentric GPS tracking and monitoring. *International Conference on Mobile Business, ICMB 2006*, 1–10. 10.1109/ICMB.2006.43

Parasher, Y., Kedia, D., & Singh, P. (2018). Examining Current Standards for Cloud Computing and IoT. In P. Tomar & G. Kaur (Eds.), *Examining Cloud Computing Technologies Through the Internet of Things* (pp. 116–124). IGI Global. doi:10.4018/978-1-5225-3445-7.ch006

Parasher, Y., Singh, P., & Kaur, G. (2019a). Green Smart Security System. *Green and Smart Technologies for Smart Cities*, 165-184.

Parasher, Y., Singh, P., & Kaur, G. (2019b). Green Smart Town Planning. *Green and Smart Technologies for Smart Cities*, 19-41.

Potdar, V., Sharif, A., & Chang, E. (2009). Wireless sensor networks: A survey. *Proceedings - International Conference on Advanced Information Networking and Applications, AINA*, 636–641. 10.1109/WAINA.2009.192

Salman, T., & Jain, R. (2017). Networking protocols and standards for internet of things. *Internet of Things and Data Analytics Handbook*, 215–238. doi:10.1002/9781119173601.ch13

Singh, P., Dixit, V., & Kaur, J. (2019). Green Healthcare for Smart Cities. *Green and Smart Technologies for Smart Cities*, 91-130.

Wang, N., Zhang, N., & Wang, M. (2006). *Wireless sensors in agriculture and food industry — Recent development and future perspective.* doi:10.1016/j.compag.2005.09.003

Yadav, E. P., Mittal, E. A., & Yadav, H. (2018). IoT: Challenges and Issues in Indian Perspective. *Proceedings - 2018 3rd International Conference On Internet of Things: Smart Innovation and Usages, IoT-SIU 2018*, 1–5. 10.1109/IoT-SIU.2018.8519869

Zhu, N., Marais, J., Betaille, D., & Berbineau, M. (2018). GNSS Position Integrity in Urban Environments: A Review of Literature. *IEEE Transactions on Intelligent Transportation Systems*, *19*(9), 2762–2778. doi:10.1109/TITS.2017.2766768

Chapter 12
Smart Agriculture Using WSN and IoT

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ABSTRACT

In India, the agriculture sector has an adverse effect and day by day the crop production is getting reduced. So, it is important to identify and implement a solution for the problem in order to increase the production. Smart technologies are introduced in this domain to improve the agriculture industry. The technologies like IoT, big data, cloud-based services, and GPS are gaining its importance in the field of agriculture. There is a rising need due to the requirement of higher precision in crop analysis, transformation of live data from the field and automated farming techniques for further improvement. The expected result of this is to have smart agriculture industry with the implementation of these smart techniques. In this chapter, the authors have discussed the challenges and benefits of IoT and various types of sensor for data acquisition.

INTRODUCTION

The smart devices are used for smart agriculture and the limitation to use it are its high cost and less alertness regarding the latest technologies among the farmers. The increase in the cost involves the usage of smart devices, and thus increasing the overall price of the end product which limits the farmers in adaption of new technologies. To increase the productivity of food products in the global market and

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to reduce human work load, time and cost farmers can easily migrate towards Internet of Things. Traditional approach in measuring the climatic factors manually are done and being checked every day. IoT technology is very efficient and reliable helps in gathering information these climatic conditions like climate, humidity, temperature level and fertility of soil. IoT provides online Crop monitoring system helps a farmer to connect with farm from remote at any time. Wireless sensor networks integrated with micro controllers are used for monitoring, automating the process and to control the farm processes. Now a day, there is large number of enhanced technologies with different tools and techniques make agriculture sector to work efficient. IoT integrates many devices to transfer the collected data into information without human intervention. Challenges in the field of agriculture start from the initial stage of cultivating the crops in the farm till the distribution of the crop to the consumer with the best possible price. Agriculture is the most important field for the development of a country.

Climatic changes and unstable rainfall due to global warming are affects the cycle of agriculture for the past decades. Following the traditional methods still decreases the production of raw materials gradually. Due to these effects in recent years, many smart technologies are combined to form a technique called smart agriculture which is been adopted by Indian farmers recently. Technologies like IOT (internet of things) integrate wireless sensor networks for remote monitoring to help large amount of applications to give its output more quickly and accurately. Developing countries like India are in situation to migrate new technologies and implementations for the quick production of food resources. Many projects are implemented in wireless sensor network which gather data by different sensor devices connected to several nodes and send it back through the wireless protocol. Environmental factors are predicted based on the collected information. Measuring and monitoring these environmental factors can help to predict the climatic condition but will not provide the final solution to improve the production of crops. There are large numbers of other aspects may drop the productivity to a larger extent. In order to eradicate the problem an automated system should be developed in field of agriculture. So, to provide a clear answer to such a complex problem, it is essential to implement an integrated model which takes care of all climatic features influencing the productivity in all stages. But there are difficulties in implementing a complete automation model in agriculture due to various technical issues since the data obtained are dynamic and subject to change. Though many research is done, no product is developed to provide it as a solution to the farmers to get aided. IoT has been incorporate with next massive thing in Internet (Olakunle et. al, 2018). This special aspect features and emerging prior services, IoT architecture, protocol and applications.

IoT provides a combination of various sensors and objects that can speak directly with one another without human interaction. The Things in the IoT incorporates physical devices, such as sensor devices, which observes and gathers all types of communities. The zenith rises of the IOT led to the consistent global connection of people, sensors, objects and services. Since time immemorial, human being has different traditional techniques in growing crops according to the requirement and financial structure. There are different methods of agriculture that depends on variety of attributes like weather, soil, temperature, moisture. There are two important techniques used in traditional farming namely shifting cultivation (slash and burn) and nomadic herding. Semi commercial systems comprises of rice based, root crop based, grain legume based, agrisilvicultural, silvopastoral and agrisilvopastoral methods. The knowledge about the smart farming and integration (L. Dan et. al, 2015) of different methods are done for improving the performance in crop production over time lead to the development of the country in agriculture field.

Commercial systems also include plantations, agro forestry and ranching. With new development of internet people can get connected to one another through internet but advancement in technology like

IoT hardware things around us can be connected, making everything automatic. There is a high order of accuracy and efficiency in automation systems and that is the reason of implementing IoT in the project. With changing times, farmers are facing many challenges still there are difficulties like destruction of crops by animals, water logging and they don't have awareness regarding air and soil parameters that cannot be predicted and avoided. In agriculture domain there are few researches based on IoT are proposed in order to monitor and maintain supply chain management system for agricultural products. IoT provides a wireless sensor monitoring system by adding the features of GSM and GPRS technology, which is the integral part of E-agriculture Productivity. The Smart e-agriculture depends on the various components which are pH Sensor, Humidity Sensor, GPRS Technology, Moisture Sensor, Relay, Water level Sensor, Arduino Uno microcontroller Output and Electric Motor. The main purpose of the Farm Management Information Systems (FMIS) (Fountas et. al., 2015) is to meet the requirements and reduce the production costs, follow the agricultural standards, measure high product quality and look for the safety measures. The technological advancement leads to drastic innovation in farming maintenance and provide tools for implementing farm specific models (Michael J. O'Grady & Gregory M.P. O'Hare., 2017). The purpose of IoT is to provide large production, minimize the cost and maintaining the quality for a long time, fulfill the standards of agriculture and finally to meet the demand with the Farm Management Information Systems.

Emerging IoT technologies which works with the support of devices like wireless sensor networks, network-connected smart phones, weather station and cameras which are capable of gathering large amount of environmental and data about crop for performance monitoring. It ranges from time series data collected by sensors, spatial data gathered from cameras, human observations collected and recorded via mobile smart phone applications. These data collected are analyzed to filter out outliers and predict personalized crop recommendations for any kind of specific farm. The key point in the development of green IoT techniques is energy efficiency (F. K. Shaikh et. al. 2017).

TECHNOLOGIES USED IN SMART AGRICULTURE BACKGROUND

Internet-of-Things (IoT)

Internet of things can be stated as a network that integrate all devices in the real time applications with the help of internet using devices like radio frequency identification (RFID), device sensors, GPS, device scanners and other information sharing devices (L. Mainetti et. al., 2013). Now a day's applications used for monitoring, controlling in different domains from house hold appliances, Industries to complex structure domain like Multi-national companies are implemented by Internet of Things. IoT has extended its applications in agricultural goods influenced by a model called Supply-Chain Operations Reference (Abdul Rasheeque KA & Savitha 2017). One of the application used popularly in planting is implemented by IOT gateway is the greenhouse monitoring automation system (Guohong Li et. al., 2014).

Cloud-Computing

In the field of Information Technology cloud computing is used by individuals and enterprises. It can be used in different fields like environment, medicine and maintenance sectors etc. For the farmers in rural areas, it will be facilitated by corporate sector to provide with necessary services in agriculture at reasonable cost (Patil et. al., 2012).

Big-Data Analytics

It contains huge volume of data that from a valuable information collected from the social networking websites, sensor information, remote sensing data, weather prediction and agricultural domain. In the agriculture field Bid data analytics helps to forecast the climatic conditions favorable for cultivation at time. This reduces the cost of the agro products using supply chain management (Ramya et. al., 2015).

Mobile Computing

Mobile-Computing is a technology that helps communication between devices at various end. It is used to provide fast and reliable communication services in daily day to day life applications. Mobile computing is mainly used in agricultural sector for providing fast information transfer in remote areas. It is mainly used to provide climatic information and agro product price news on daily basis to farmers through mobile devices which help them to sell their products in useful manner.

Wireless Sensor Networks and Sensors

It plays an important role in our day to day activities. This contains sensors that measure various environmental changes in the agricultural area such as humidity, pressure, temperature and various factors that helps farmers for timely prediction of cultivation.

Data Mining

Data Mining is used to retrieve knowledgeable data from the data repository. It has techniques like clustering that group the similar data, classification that identifies the crops and type of seeds, Association rule mining helps to find suitable crop for cultivation. It helps to classify the type of soil and crops using classification techniques in agricultural field (Nilesh et. al., 2015).

CHALLENGES IN AGRICULTURE INDUSTRY

- Information deficiency about production and its parameters.
- Not much information in weather forecast.
- Not aware of information about sales distribution.
- Poor Information and Communication Technology(ICT) infrastructure and illiteracy.
- Farmers are not aware of the benefits provided by ICT in agriculture.
- Lack of research skills in Marketing and center for research.
- Severe variations in the climatic conditions.
- Youngsters and educated people have less interest in agriculture profession.
- Machineries are higher cost.
- More manual work.

INTERNET OF THINGS

Internet of Things connects the real world things together with the field of electronics and communication and sensors to communicate the information reliably (Sanbo Li, 2012). IoT based devices are used for information collection and analysis (Tanmay et. al., 2016). It is transmitted to the user and based on it user can do remote monitoring and controlling in agriculture field.

Characteristics of IoT

- **Communication:** It is via the wireless protocols. All the things or components communicate with one another to share the data collected which can be used for monitoring and controlling
- **Connectivity:** With a secure network sensors and other equipments are connected
- **Things:** It is the one that collects the information and communicates across the IoT system which may be actuators. Many devices are available like heart monitoring, biochip transponders, automobiles with built-in sensors, field operation devices and rescue operations etc.
- **Data:** Data is the bonding agent in IoT, which is responsible for action and intelligence
- **Intelligence:** With the application of preprocessing and data analytics, sensors make the intelligent

IoT Devices

- **Action:** It can be done either manually or automated using actuators
- **Ecosystem:** It is the surroundings or field of the Internet of Things
- IoT characteristics has great influence in agriculture supply chain. It also gives the agricultural logistics (Xiaohui Wang &Nannan Liu, 2014).

Benefits of IoT to Agriculture

With the invention of IoT and its application in the field of agriculture farmers can reduce the cost of production and do input optimization. IoT in the field of agriculture enhances farming and has the following benefits

- Effective input minimizes the cost
- Avoids loss of crops or takes precautions by analyzing the weather as well as disease by continuous monitoring the crops (Dieisson et. al., 2018).
- Optimized usage of water using IoT with the help of sensors
- Planning of farm activities in a better way
- Reduction in man power and time
- Monitoring the crop growth
- Moisture and PH level management by using sensors for better crop growth
- Sales of crop can be improved in global market
- The equipment cost and the coverage of internet is the major challenges in using IoT.

Application of IoT in Agriculture

The application IoT is classified based on its function as Monitoring, Precision Agriculture, Tracking and Tracing, Greenhouse Production and Agriculture machinery. IoT has large impact in agriculture field and the main are crop and livestock irrigation and water quality monitoring soil monitoring disease and pest control machinery weather monitoring (Kodali et al., 2016), automation and precision

Monitoring

There are different areas and factors to be monitored in agriculture. Some of them are Crop Farming, Aquaponics, Forestry, Livestock farming and also other areas like water, fuel and animal feeds. The monitored and stored data can be used by the Farmers for planning and cost reduction.

Tracking and Tracing

It collects data along supply chain so that the complete history of the product is known which in turn gives the customer's trust. It collects the information about the input, output, storage, transfer and process.

Agriculture Machinery

It can aid in improving the crop production and decrease the loss of grain. With the help of GPS and GNSS they can map properly to operate the machinery in autopilot mode. The information about irrigation, fertilizing and nutrition (Kaloxylos A. et al., 2012) can be collected by this machinery to help the farmers to map their fields in this regard.

Precision Agriculture

The real time data collection and application of predictive analytics used for decision making for effective yield reduced impact of environment factors and cost (Lerdsuwan P. et al., 2017). It is done with the help of sensor nodes, GPS and also big data analytics.

Greenhouse Production

The advantage of this method is growing any type of plant in any time in any location by giving appropriate environmental conditions. It is also called as glasshouse technology. The environmental conditions are monitored using WSN. The application of IoT is done to minimize human resource, energy saving, monitoring efficiently and linking customers directly to.

CROP SELECTIONS

Selection of Crop Which Is Suitable for the Land Internet-of-Things (IoT)

To get higher crop growth rate, the crops require varied atmospheric conditions and environment but it is hard for the farmers to identify land and other conditions. It is possible to apply artificial intelligence in combination with IoT in unmanned aerial vehicle (UAV) to provide survey.UAV is used for in-flight surveillance which is a small airplane which collects data about the environment like visual, temperature, humidity, weather, thermal, and air pressure. It also provides information about crop like its height, counting, health, weed detection and the effect of different season.

Effective Irrigation

Watering plant in the correct time with right quantity in the precise place is the major role in the growth of plant. Supplying water is a big challenge in a remote place where there is insufficient or shortage of water resulting in crop damage. Watering for irrigation can be controlled by the usage of automated watering system by monitoring the humidity with humidity sensor. Humidity sensors are used for monitoring the moisture in the based on the data provided by sensor and automated watering without human interaction by using water valves. It also checks whether any leakage in the water pipes. The monitored data is sent to the farmer through a mobile phone for accessing and managing the process. So this will result in less wastage of water. It also keeps track of water consumption in the field in the drought field so that watering can be done efficiently.

Advance Weather Forecast Information

Weather and Climatic condition having great role in crop production at large scale. Continuous climatic change and weather change may affect the crop growth resulting in greater loss to farmers. When weather forecasting is done priorly and informed to the farmers they can make decisions regarding plantation of crops. It can prevent many problems in future. This can be achieved with IoT by getting weather forecast accurately in real-time. Based on the collected information, farmers can pre-plan the farming and prevent the loss in future by proper decision making.

Plant Growth Evaluation

It is necessity to constantly measure the performance, analyzing the weather condition for evaluation of plant growth by providing required irrigation facility and perfect weather condition otherwise plant growth will be affected. Regular field visit and evaluation is a time consuming process so IoT technology is applied to perform the same process by monitoring using sensors. Many types of sensors are available for different purpose to monitor temperature, soil, pressure, humidity and etc. With these information farmers can make decision and plan the time for irrigation. They can also analyze the harvest time and increase the plant growth rate.

Nutrients Level in the Crops

The correct level of nutrients is very important for good quality of food. The level of nutrients can be managed in the production by using smart farming by the usage of IoT. The nutrient level checking, managing and controlling by using the nutrient analyzer sensor. The sensor checks the presence and quality of ion when the water passes through it by relating specific ios in the side of the membrane. The six ion presence is simultaneously measured and send to the smart phone. With this information farmer can provide appropriate mix of nutrients to increase the plant yield and production maturity rate is changed.

CROP MONITORING

In the IoT based agriculture crop monitoring plays an important role (Burrell J., Brooke T., & Beckwith R., 2004). There is a necessity to understand the growth of crop in small scale environment. The crop growth research and study is needed as the global climate changes. Scientific guidance and remedies for improving the production of agriculture is provided by the growth pattern and the environmental parameters. To improve the overall performance, it can model the growth pattern of crop in different environments in different regions. Two types of sensor nodes are used to monitor the crop by providing networking to transfer information. The environmental parameter gaining platform that gathers information about soil and meteorological information (Aline Baggio, 2005). The images of the growing crop is provided by the image capture platform through which we can monitor the crop growth directly. Through the internet we can access the information from the sensor nodes in the agricultural condition monitoring sensor network.

PRECISION AGRICULTURE (PA)

PA requires a decision support system in agricultural field. It is an important term in agriculture field. The initial development of PA was done in Minneapolis in 1992, and then it has become the research and implementation topic worldwide (Al-Fuqaha A. et al., 2015). For improved crop production and maintenance this kind of farming is used for better decision making. PA is usually outlined as “Information and Technology based farm management system to identify, analyze and manage variability at various fields for optimum profit, property and protection of the land resource”. The main intention in the precision agriculture research is to provide a Decision Support System (DSS) for entire farm management and optimizing returns on inputs with resource preservation.

To improve the running cost and performance it necessity to manage and distribute the input information on a website at specific interval. With increase in the input prices for production of the goods, the farmers are searching for better approaches to expand power and cut costs (Banu S., 2015). One or many Technologies are used for different models of agriculture sector. Various functionalities will be given the assistance of multiple technologies. The basic functionality within the Precision farming is Precision Irrigation. It gives a new approach for the issues in agriculture field based on the environmental concern to balance productivity.

This includes summary of existing Precision Irrigation systems, explicit crops and area, for open agriculture and greenhouse system. IT additionally mentions the android Apps built for Precision Agriculture in continuing section. Data collection has been carried for environmental monitoring of the field with different sensors as per the systems requirement. PA applications includes data collection, reporting, integrating GPS data into geographic information systems, Tractability systems such as animal tracking identification and web cameras to view the field.

The growing mobile technology and mobile enabled data services give a way to overcome existing asymmetry of information in all fields like agriculture, health care and education. There is an enormous gap between the supply and delivery of agriculture inputs and agriculture infrastructure which will form a bridge by the mobile technologies. The android Apps that associate open supply development platform to create the terribly powerful applications to developers. There are several systems for development of Precision agriculture, from basic ones to a lot of technologically advanced ones. Precision Agriculture is classified according to requirements or need of the farmers.

For the technique of automated irrigation various methods have been used such as irrigation scheduled depending on canopy temperature distribution, Irrigation systems based on water content of soil, measured with the help of dielectric moisture sensors to control actuators and to minimize the usage of water and schedule irrigation of crops using crop water stress index (CWSI), estimation of the plant EvapoTranspiration (ET), and irrigation by means of infrared thermometers. The decision support system is integrated with the ET to find the water requirement of the plants. Authors Joaquin Gutirrez, et al. (2014) proposed Automated Irrigation System for agricultural crops. It contains sensors to monitor soil-moisture and temperature. Based on the information given by the sensors and the threshold values, a techniques were provided to control watering to plants using a microcontroller-based gateway.

The advantage of PA technologies is listed below:

- The optimized usage of chemical spraying and manure to preventing ground water.
- By using precision irrigation to minimize fresh water withdrawals
- By effectively analyzing pest and fungal infection to prevent crop damages by responding rapidly and effectively.
- By applying new types of polyculture.
- Transferring information regarding PA diagnostic techniques to smart phones or tablets and making the information available to smaller farms and by directly signaling a problem on the field to provide online service for further probing.

Sensing Technologies

Sensing technologies are used to get the data which can be used to take actions to optimize the crop yield and minimize the effect of environment. There are different types of methods for precision farming which utilizes these data.

Topography and Boundaries Information

For getting accurate topographic illustration of any field is recorded using GPS with high precision which can be used for predicting weed and yield map. With the help of the data, we can identify the wetlands, field boundaries and roads available to help the farmers to plan for farm.

Yield Monitoring Systems

They are attached with the crop harvesting vehicles in order to give details about crop weight yield based on the distance, time and location measured using GPS and stored which can be used for analysis.

Yield Mapping

It builds yield map by mounting g GPS sensors on equipment used for harvesting to collect spatial co-ordinate and combining it with yield monitoring.

Weed Mapping

It generates maps by locating the location with the help of GPS and data logger to get the operator interpretation. The yield, fertilizer and spray map can be overlapped with this. The equipments can be mounted with visual recognition system to get the information.

Salinity Mapping

It is used in sled and towed across the fields affected by salinity using salinity meter. The evolving issues and changes in the salinity over time are interpreted by salinity mapping.

Variable Rate Fertilizer Application Tools

It uses yield map and the pattern identified by the optical surveys about the plant health aimed to control liquid, granular and gaseous fertilizer materials. It controls manually or can be automated by using an on-board computer with GPS.

Variable Spraying Controllers

It controls the quantity and mix of the spray applied by controlling on and off of herbicide boom spray after identifying and mapping the weed locations.

TYPES OF SENSORS

Many factors need to be considered for choosing a sensor. They are as given below:

- Accuracy - The extent to which the output matches to the correct value or a standard.
- Environmental condition - Checks the weather conditions such as temperature, moisture etc.
- Range - Checks the distance between the sensors.
- Resolution –It identifies even the smallest changes
- Cost
- Repeatability - Under the same environment repeatedly measuring the values.

Figure 1. Types of Sensors

S.NO	Types of sensors	Function
1.	Airflow	To measure the soil permeability
2.	Location	To find latitude, longitude and altitude using GPS
3.	Camera	To get the picture of the crop, environment features and monitoring
4.	Microphone	Helps with predictive maintenance of machinery
5.	Accelerometer	To find the agriculture activity, leaf Angle Index etc
6.	Gyroscope	To detect rotation of equipment
7.	Electrochemical	To find the ions in the soil using electrodes
8.	Dielectric soil moisture	To measure the dielectric constant in the soil using electrodes
9.	Optical	light is used to measure the soil properties
10.	Mechanical	To measure resistance and soil compaction using probes

Types of Sensor Deployment in E-Farming

The different sensors deployed in E-Farming (Abdul Rasheeque KA & Savitha., 2017) is listed below

Temperature Sensor (Lm35)

This sensor helps to measure the temperature with an electrical output. It also checks the temperature which is good for the crop. It also gives information about the temperature priory. Temperature sensor gives more accurate results than any other devices like thermostat.

Humidity Sensor Hr 202

Humidity sensor is used to check water level in the land. This measures how much water is required for the crop. The HR202 is a humidity-sensitive resistor prepared from organic macromolecule materials. It is used in hospitals, storage, workshop, textile industry etc. The operating temperature range is from 20-95%.

Rh Water Level Sensor

Water level floats sensor is also known as float balls, which are spherical and cylindrical in shape. They may also incorporate into switch mechanisms. These are made from flexible material that is buoyant in water and other liquids.

AGRICULTURAL INFORMATION TECHNOLOGY (AIT)

AIT is the effective tool applied to make use of the resources effectively in all aspects of agriculture to improve the productivity. Agriculture Information Management is a sub technology of AIT used for agricultural information management and effective decision making for efficient productivity. The data collection, monitoring and automation will surely increase the production and decrease the cost which is achieved by data insights, low cost sensors and by applying IoT technologies which we call it as smart agriculture. The usage of database in cloud computing which allows management of information related to performance of production by plants and analyzing them for making decision. For monitoring and controlling the production and farms in rural areas using scalable network architecture can be done.

Benefits of Smart Agriculture

- Improving crop Production –This can be done by proper water, pesticide, correct planting and harvesting which will in turn increase the productivity
- Water Conservation – Correct application water by analyzing the requirement by using soil moisture and weather prediction sensors.
- Real-Time Data and Production Insight –With the IoT farmers can monitor the level of production, moisture in the soil, intensity of sunlight to make decision remotely.
- Lowered Operation Costs –The reduction in cost, effective consumption of resources and human error can be achieved by automating the process.
- Increased Quality of Production – Farmers can understand the process by analyzing the quality and adjust the treatment to increase the quality.
- Accurate Farm and Field Evaluation – Time to time analysis of production rate will give accurate prediction for future yield.
- Improved Livestock Farming – Location tracking and geo fencing can also provide efficient management and monitoring of live stock.
- Reduced Environmental Footprint –The usage of water and production improvement per land unit has direct and positive impact on footprint of environment.
- Remote Monitoring – Farmers can monitor their fields in different location by remotely monitoring with the help of internet connection.
- Equipment Monitoring –The usage of equipment for maintenance and monitoring based on the production, labor and prediction of failure.

They can improve the agriculture by the applications of IoT by

- Daily supply chain transformation with SmartMoo IoT Platform
- IoT for Transforming Agriculture
- IoT: The Internet of Tractors

Smart Agriculture has five methods as follows.

1. Sensing of agricultural parameters.
2. Collection of Data.

3. Information Transmission from fields for decision making.
4. Analyzing data for decision support and early warning.
5. Remedial action to be taken after warnings.

It has User, Server and Data side

Data Side

The data is gathered from different sensors which are interfaced in the system such as

- Temperature sensor
- Humidity sensor
- Gas Sensor
- Solar sensor
- Soil moisture sensor

These data can be used for decision making to increase the production rate.

Server Side

The data transmitted by the sensor to the server is analyzed for various attributes like soil ph level, humidity, light etc and accordingly decision will be taken and monitored by the system

User Side

The user can be provided with the data to their mobile phone. He can analyze the data sitting in remote place based on the updation he can take necessary measures to improve the crop growth.

Application of Agricultural Information Cloud

- Planting management
- Effective production and management measures
- Controlling and tracing of farm produce security
- Monitoring the plant growing

Information Management Systems for Agriculture

Smart agriculture with data driven requires enormous data collection which is complex, dynamic and spatial data that needs storage and processing of data (Liu H., Meng Z., & Cui S., 2007).

Many information management systems for agriculture are developed to manage and perform data analytics on the different types of data. Few commercially existing platforms are

OnFarm

OnFarm is a free, standard and enterprise farm management tool which performs analysis of data and displays from different sources.

Phytech

Phytech is plant IoT platform used for decision making to increase productivity and optimize irrigation by direct sensing, data analytics, plant status and recommendations

Semios

Semios concentrates on network coverage, frost, pests, diseases and irrigation for orchards. It provides notification about the events in the field using Real time monitoring services.

EZFarm

EZfarm is an IBM project which performs water management, monitoring of soil and health of plant.

KAA

KAA provides crop monitoring from remote, mapping the resource, predictive analytics for crop and livestock, livestock tracking, stats on livestock feeding and produce, smart logistics and warehousing

Farmlogs

Farmlogs is farm management software which records the activity and crop health imagery automatically.

Cropx

Cropx which gives increase crop yield delivers, water management and saving energy cost services by monitoring the soil.

The process of sensor data acquisition is digitization of data from the sensor so that it can be collected, stored, and analyzed for decision making.

Moisture Sensor

The resistance value can be used to analyze the soil moisture. The soil with moisture has less resistance so more current will pass through it while the dry soil has high resistance and less current. An Arduino microcontroller with a soil moisture sensor can be used for resistance analysis by inserting two probes in the soil moisture sensor into the soil.

Temperature Sensor

The change in the temperature will change the relative humidity in the air. The DHT11 temperature and Humidity sensor can be used which has thermistor and moisture measuring component.

Solar Panel

The sensor is connected with low power solar panel which generates DC power when it gets exposed to the sunlight. The Arduino converts the output to digital values which can be stored for analysis.

Gas Sensor

A sensor like MG-811 is connected and a potentiometer is used to set the threshold value of CO2. A digital signal (ON/OFF) will be produced based on the CO2 concentration (voltage is low when it is high) based on the information collected by sensor CO2 content can be calculated. CO2 is very important for the growth of the plants. Based on the requirement sprinkler can be used by the farmer.

Soil pH Sensors

The acidic nature of the soil can affect the productivity of the crop. The hydrogen ion content in the soil can be measures with the help of PH meter which has reference and conductor electrode. They inserted into soil to bring conduction which increase or decreases based on hydrogen ion in the soil.

High Resolution Cameras

The plants are monitored for disease symptoms by monitoring the plants using high resolution camera. The images collected are compared with the stored data in control center in order to identify the symptoms and intensity of damage is measured to make recommendations.

Arduino Board

ADC is done by the Arduino board which acts as a bridge between the zigbee and the sensors. It is the sensor panel's control center. It communicates with zigbee and transmits the data to centre hub. The data is processed in central hub and stored for decision making.

ZigBee

Zigbee can act as a transmitter and receiver with Arduino and raspberry pi on both sides as host. The zigbee communication protocol is well suited due to its light weight and less power consumption.

Raspberry Pi

It is a small pocket size computer which can be used for performing computing and networking. It can be connected to internet so that system can be automated with controlling device in remote location.

It is major component of IoT, It is a powerful controller and supports decision making. It can be connected with zigbee so that it can transmit and receive data from different sensor modules. Raspberry Pi is available in different versions.

PIR Sensor

It is used to sense the infrared radiation reflected and emitted by an object which can be used to identify the movement of animals, human or objects. When it detects there will be change in the temperature which converts the change into voltage and can be used for decision making.

SOFTWARES

PROTEUS 8 Simulator

It is widely used simulation software for different microcontroller which has all electronic components in it. This software can be used for testing prior to real hardware testing so that damage can be avoided because of bad design.

AVR Studio Version 4

It generates. hex file, so it can be used to create, build the embedded c code and check for errors and burned in the microcontroller to do the preferred operations.

Dip Trace

It is a EDA/CAD software which has a Schematic Capture Editor, PCB Layout Editor with built-in shape-based auto router and 3D Preview & Export, Component Editor, and Pattern Editor used for creating schematic diagrams and printed circuit boards.

SinaProg

It is application to code and hex downloader with the software AVR Dude for programming AVR based microcontrollers and Fuse bit calculator to set fuse bits.

Raspbian Operating System

It is an open source Debian based optimized computer operating system for Raspberry Pi which has a set of codes and utilities. It has many precompiled codes for installation on Raspberry Pi.

CONCLUSION

The chapter discusses the challenges in the agriculture field. The environmental parameters and climatic condition changes based on the location and time which has direct impact on crop production in the field of agriculture which makes the decision making difficult for farmers. The IoT technologies have lead to great benefits to the farmer's and also improved the crop production rate and reduction in cost. The different data acquisition sensors and their usage in the field of agriculture is discussed. The new technologies in the field of IoT along with the WSN have given a great impact in the field of agriculture. The integration of these with AI and other data mining methods will lead to creation, innovation and implementation of new ideas for efficient production and marketing.

REFERENCES

Abdul Hakkim, V.M., Abhilash Joseph, E., Ajay Gokul, A.J., & Mufeedha, K. (2016). Precision Farming: The Future of Indian Agriculture. *Journal of Applied Biology & Biotechnology, 4*(6), 68-72.

Abdul Rasheeque, K.A., & Savitha. (2017). E-Farming Using Internet of Things. *International Journal of Latest Trends in Engineering and Technology*, 419-422.

Abedin, Z., Chowdhury, A. S., Hossain, M. S., Andersson, K., & Karim, R. (2017). An interoperable IP based WSN for smart irrigation system. *14th IEEE Annual Consumer Communications Networking Conference (CCNC)*, 1–5. 10.1109/CCNC.2017.8013434

Abhishesh, P., Ryuh, B., Oh, Y., Moon, H., & Akanksha, R. (2017). Multipurpose agricultural robot platform: Conceptual design of control system software for autonomous driving and agricultural operations using programmable logic controller. *Mechatronic and Manufacturing Engineering*, *11*(3), 496–500.

Ahmed, De, & Hussain. (2018). Internet of Things (IoT) for Smart Precision Agriculture and Farming in Rural Areas. *IEEE Internet of Things Journal, 5,* 4890-4899.

Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of things: A survey on enabling technologies, protocols, and applications. *IEEE Communications Surveys and Tutorials*, *4*(17), 2347–2376. doi:10.1109/COMST.2015.2444095

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop Evapotranspiration-Guidelines for Computing Crop Water Requirements-FAO Irrigation and Drainage Paper 56. Rome: FAO.

Baggio, A. (2005). Wireless sensor networks in precision agriculture. *The REALWSN'05 Workshop on Real-World Wireless Sensor Networks*, 1-2.

Banu S., (2015). Precision Agriculture: Tomorrow's Technology for Today's Farmer. *J Food Processing and Technology, 6*(8), 1-6.

Burrell, J., Brooke, T., & Beckwith, R. (2004). Vineyard computing: Sensor networks in agriculture production. *IEEE Pervasive Computing*, *3*(1), 38–45. doi:10.1109/MPRV.2004.1269130

Chieochan, O., Saokaew, A., & Boonchieng, E. (2017). IoT for smart farm: A case study of the lingzhi mushroom farm at maejo university. *14th International Joint Conference on Computer Science and Software Engineering (JCSSE)*, 1–6. 10.1109/JCSSE.2017.8025904

Cropx. (2017). Available: https://cropx.com/

Dan, L., Xin, C., Chongwei, H., & Liangliang, J. (2015). Intelligent agriculture greenhouse environment monitoring system based on IoT technology. *International Conference on Intelligent Transportation, Big Data and Smart City*, 487–490. 10.1109/ICITBS.2015.126

Dumbre, N., Chikane, O., Gitesh, D., & Phule, S. (2015). System for Agriculture Recommendation Using Data Mining. Internal Education and Research Journal, 1(1).

Dutta & Neogy. (2016). Enabling agricultural automation to optimize utilization of water, fertilizer and insecticides by implementing internet of things (IoT). *International Conference on Information Technology (InCITe) - The Next Generation IT Summit on the Theme - Internet of Things: Connect your Worlds*, 125–131.

Elijah, O., Rahman, T. A., Orikumhi, I., Leow, C. Y., & Hindia, M. H. D. N. (2018). An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges. *IEEE Internet of Things Journal*, *5*(5), 3758–3773. doi:10.1109/JIOT.2018.2844296

Erlich, Y. (2015). A vision for ubiquitous sequencing. *Genome Research,* 1411–1416.

FarmE. Z. (2017). Available: https://www-03.ibm.com/software/ usinesscasestudies/lb/en/corp?synkey=T869341Z93257N45

Farmlogs. (2017). Available: https://farmlogs.com/

Fountas, S., Carli, G., Sørensen, C. G., Tsiropoulos, Z., Cavalaris, C., Vatsanidou, A., Liakos, B., Canavari, M., Wiebensohn, J., & Tisserye, B. (2015). Farm management information systems: Current situation and future perspective. *Computers and Electronics in Agriculture*, *115*, 40–50. doi:10.1016/j.compag.2015.05.011

García-Lesta, D., Cabello, D., Ferro, E., López, P., & Brea, V. M. (2017). Wireless sensor network with perpetual motes for terrestrial snail activity monitoring. *IEEE Sensors Journal*, *17*(15), 5008–5015. doi:10.1109/JSEN.2017.2718107

Gutirrez, J., Juan, F. V. M., & Nieto-Garibay, A. (2014). Automated Irrigation System Using a Wireless Sensor Network and GPRS Module. *IEEE Transactions on Instrumentation and Measurement*, *63*(1), 166–176. doi:10.1109/TIM.2013.2276487

Huang, L., & Liu, P. (2014). *Key Technologies and Alogrithms' Application in Agricultural Food Supply Chain Tracking System in E-commerce*. Springer Berlin Heidelberg.

Imam, S. A., Choudhary, A., & Sachan, V. K. (2015). Design issues for wireless sensor networks and smart humidity sensors for precision agriculture: A review. *International Conference on Soft Computing Techniques and Implementations (ICSCTI)*. 10.1109/ICSCTI.2015.7489591

Jacob, Prasanna, Sultana, & Helix. (2018). A Comparative Analysis on Smart Farming Techniques using Internet of Things (IoT). Academic Press.

Jagüey, J. G., Villa-Medina, J. F., López-Guzmán, A., & Porta-Gándara, M. Á. (2015). Smartphone irrigation sensor. *IEEE Sensors Journal*, *15*(9), 5122–5127. doi:10.1109/JSEN.2015.2435516

Jain, D., Venkata Krishna, P., & Saritha, V. (2012). A Study on Internet of Things based Applications. Academic Press.

KAA. (2017). Available: https: //www.kaaproject.org/agriculture/

Kaloxylos, A., Eigenmann, R., Teye, F., Politopoulou, Z., Wolfert, S., Shrank, C., Dillinger, M., Lampropoulou, I., Antoniou, E., Pesonen, L., Nicole, H., Thomas, F., Alonistioti, N., & Kormentzas, G. (2012). Farm management systems and the future internet era. *Computers and Electronics in Agriculture*, *89*, 130–144. doi:10.1016/j.compag.2012.09.002

Karim, Karim, & Frihidab. (2017). Monitoring system using web of things in precision agriculture. *Procedia Computer Science, 110*, 402–409.

Kavianand, G., Nivas, V. M., Kiruthika, R., & Lalitha, S. (2016). *Smart drip irrigation system for sustainable agriculture. In 2016 IEEE Technological Innovations in ICT for Agriculture and Rural Development*. TIAR.

Khattab, A. A., & Yelmarthi, K. (2016). Design and implementation of a cloud-based IoT scheme for precision agriculture. *28th International Conference on Microelectronics (ICM)*, 201–204. 10.1109/ICM.2016.7847850

Kodali, R. K., Jain, V., & Karagwal, S. (2016). IoT based smart greenhouse. IEEE Region 10 Humanitarian Technology Conference (R10-HTC), 1–6.

Lee, H., Moon, A., Moon, K., & Lee, Y. (2017). Disease and pest prediction IoT system in orchard: A preliminary study. *Ninth International Conference on Ubiquitous and Future Networks (ICUFN)*, 525–527. 10.1109/ICUFN.2017.7993840

Lerdsuwan, P., & Phunchongharn, P. (2017). An energy-efficient transmission framework for IoT monitoring systems in precision agriculture. In *International Conference on Information Science and Applications*. Springer. 10.1007/978-981-10-4154-9_82

Li, Zhang, Zhang, & Langfang. (2014). *A Design of the IOT Gateway for Agricultural Greenhouse*. Academic Press.

Li, S. (2012). Application of the internet of things technology in precision agriculture irrigation systems. *IEEE International Conference on Computer Science and Service System*, 1009-1013. 10.1109/CSSS.2012.256

Liu, H., Meng, Z., & Cui, S. (2007). A wireless sensor network prototype for environmental monitoring in greenhouses. *International Conference on Wireless Communications, Networking and Mobile Computing*, 2344–2347. 10.1109/WICOM.2007.584

Mainetti, L., Mele, F., Patrono, L., Simone, F., Stefanizzi, M. L., & Vergallo, R. (2013). An RFID-based tracing and tracking system for the fresh vegetables supply chain. *International Journal of Antennas and Propagation*, *2013*, 1–15. doi:10.1155/2013/531364

Mat, K. M. R. M., Harun, A. N., & Yusoff, I. M. (2016). IoT in precision agriculture applications using wireless moisture sensor network. *IEEE Conference on Open Systems (ICOS)*, 24–29. 10.1109/ICOS.2016.7881983

Na, I. W., Varshney, S., & Khan, E. (2016). An IoT based system for remote monitoring of soil characteristics. *International Conference on Information Technology (InCITe) - The Next Generation IT Summit on the Theme - Internet of Things: Connect your Worlds*, 316–320.

Nemali, K. S., & Van Iersel, M. W. (2006). An automated system for controlling drought stress and irrigation in potted plants. *Scientia Horticulturae*, *110*(3), 292–297. doi:10.1016/j.scienta.2006.07.009

Nilesh, K., & Raut, C., Patel, & Bherani. (2014). Smart design of microcontroller based monitoring system for agriculture. *International Conference on Circuits, Power and Computing Technologies*.

Nitika & Pateriya. (2016). Development of IoT based Smart Security and Monitoring Devices for Agriculture. *6th International Conference - Cloud System and Big Data Engineering*, 597-602.

O'Grady, M. J., & O'Hare, G. M. P. (2017). Modeling the smart farm. *Information Processing in Agriculture*, *4*(3), 179–187. doi:10.1016/j.inpa.2017.05.001

O'Shaughnessy, S. A., & Evett, S. R. (2010). Canopy temperature based system effectively schedules and controls center pivot irrigation of cotton. *Agricultural Water Management*, *97*(9), 1310–1316. doi:10.1016/j.agwat.2010.03.012

Oksanen, T., Linkolehto, R., & Seilonen, I. (2016). Adapting an industrial automation protocol to remote monitoring of mobile agricultural machinery: A combine harvester with IoT. *IFAC-PapersOnLine*, *49*(16), 127–131. doi:10.1016/j.ifacol.2016.10.024

Onfarms. (2017). Available: http://www.onfarm.com/

Patil, V. C., Al-Gaadi, K. A., Biradar, D. P., & Rangaswamy, M. (2012). Internet of Things (Iot) And Cloud Computing for Agriculture: An Overview. *Proceedings of AIPA 2012*.

Pekoslawski, B., Krasinski, P., Siedlecki, M., & Napieralski, A. (2013). Autonomous wireless sensor network for greenhouse environmental conditions monitoring. *Proceedings of the 20th International Conference Mixed Design of Integrated Circuits and Systems - MIXDES 2013*, 503–507.

Phytec. (2017). Available: https://www.phytech.com/

Pivoto, D., Waquil, P. D., Talamini, E., Finocchio, C. P. S., Dalla Corte, V. F., & de Vargas Mores, G. (2018). MoresScientific development of smart farming technologies and their application in Brazil. *Information Processing in Agriculture*, *5*(1), 21–32. doi:10.1016/j.inpa.2017.12.002

Ramya, M. G. P. G. (2015). Environment Change Prediction to Adapt Climate Smart Agriculture Using Big Data Analytics. Academic Press.

Semios. (2017). Available: https://semios.com/

Shaikh, F. K., Zeadally, S., &Exposito, E. (2017). Enabling technologies for green internet of things. *IEEE Systems Journal, 11*(2), 983–994.

Sureephong, P., Wiangnak, P., & Wicha, S. (2017). The comparison of soil sensors for integrated creation of IoT-based wetting front detector (WFD) with an efficient irrigation system to support precision farming. *International Conference on Digital Arts, Media and Technology (ICDAMT)*, 132–135. 10.1109/ICDAMT.2017.7904949

Viani, F., Bertolli, M., Salucci, M., & Polo, A. (2017). Low-cost wireless monitoring and decision support for water saving in agriculture. *IEEE Sensors Journal*, *17*(13), 4299–4309. doi:10.1109/JSEN.2017.2705043

Wang, X., & Liu, N. (2014). The application of internet of things in agricultural means of production supply chain management. *Journal of Chemical and Pharmaceutical Research, 6*(7), 2304-2310.

Wang, X., Yang, W., Wheaton, A., Cooley, N., & Moran, B. (2010). Efficient registration of optical and IR images for automatic plant water stress assessment. *Computers and Electronics in Agriculture*, *74*(2), 230–237. doi:10.1016/j.compag.2010.08.004

Yan-e, D. (2011). Design of intelligent agriculture management information system based on IoT, *Fourth International Conference on Intelligent Computation Technology and Automation*, 1, 1045–1049. 10.1109/ICICTA.2011.262

Yuan, G., Luo, Y., Sun, X., & Tang, D. (2004). Evaluation of a crop water stress index for detecting water stress in winter wheat in the North China Plain. *Agricultural Water Management*, *64*(1), 29–40. doi:10.1016/S0378-3774(03)00193-8

Zaier, R., Zekri, S., Jayasuriya, H., Teirab, A., Hamza, N., & Al-Busaidi, H. (2015). Design and implementation of smart irrigation system for groundwater use at farm scale. *7th International Conference on Modeling, Identification and Control (ICMIC)*, 1–6. 10.1109/ICMIC.2015.7409402

Zhang, P., Zhang, Q., Liu, F., Li, J., Cao, N., & Song, C. (2017). The construction of the integration of water and fertilizer smart water saving irrigation system based on big data. *IEEE International Conference on Computational Science and Engineering (CSE) and IEEE International Conference on Embedded and Ubiquitous Computing (EUC), 2*, 392–397.

Zhang, Q., Yang, X., Zhou, Y., Wang, L., & Guo, X. (2007). A wireless solution for greenhouse monitoring and control system based on zigbee technology. *Journal of Zhejiang University. Science A*, *8*(10), 1584–1587. doi:10.1631/jzus.2007.A1584

Zhang, S., Chen, X., & Wang, S. (2017). Research on the monitoring system of wheat diseases, pests and weeds based on IoT. *9th International Conference on Computer Science Education*, 981–985.

Chapter 13
Smart Soil Monitoring System for Smart Agriculture

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ABSTRACT

Accurate and timely information is crucial to optimize resources. Sensors determine clay, organic matter, moisture, and nutrients of soil. Sensors at various locations are connected using different technologies. Its data will be automatically reported to cloud without any internet connection. Sensors broadcast data to local base stations (LBS) at different ranges of distances using WiFi, LPWAN, LoRa, Bluetooth, etc., and then to central base station (CBS), which is far away. Modulation, coding techniques, and line of sight keeps signal intact. Data from CBS goes to cloud for analysis, visualization, and trend analysis. This helps farmers to get frequent and real-time data without actual need of physical presence. It reduces manpower, water usage, and other costs of agriculture and has positive environmental impact. Integration with other data like weather forecasts gives more precise information. Convergence of technologies, sensors, cloud, automation, etc. without human interaction contributes to IoT.

INTRODUCTION

By the year 2050, population of world is expected to rise tremendously at 9.1 billion people as compared to 7.4 billion in 2016. Rise in income is driving people to expand their diets with more protein. As per report from Food and Agriculture Organization (FAO) of United Nations, farmers must increase their production by 70 percent as compared to current levels. Food growers must ramp up their production to feed the growing world population. Demand for food will be increased by approx 50 percent as com-

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pared to 2013 with the growth in population. It is estimated that urbanization growth will boost another 2.4 billion people in cities and towns(Ayaz et al. 2019). Growing urbanization leads to reduction of rural population and hence declining workforce for agriculture, even as demand for food is increasing. In addition to that, rural people are getting aged rapidly and there will be acute shortage of man power in coming future. Due to population growth and urbanization world's current farmland is becoming unsustainable, such that 25 percent of available agricultural land is already degraded. Water assets are already exceedingly utilized with near to 40 percent of world's rural population is facing water scarcity. Unbalanced fertilizers are used to restore yield which effects proportion of soil nutrients. Nitrogen (N), phosphorus (P), and potassium (K) are the major soil nutrients while iron, manganese, copper, zinc, boron, molybdenum, and chlorine are the minor ones of soil. Correct balance of these nutrients is essential for the plant growth and to have high yields. Macronutrient such as Nitrogen is responsible for the creation of amino acids; Phosphorous and Potassium helps in the formation of plant roots, photosynthesis and improves disease resistance. Soil fertility is decreased due to unbalance feeding of fertilizer without knowing the actual requirement of nutrient to a particular crop and irrigation at the wrong time of day.

The traditional approach of the agriculture is getting changed with evolution in science and technology. Integration of technology with agriculture improves and address the real need of consumers and maintains the demand and supply of food requirement. Modern farms and agriculture functions works differently due to progression in technology such as sensors, devices, machines, information technologies, fast communication networks. They use robots, sensors, aerial images, GPS technologies. Latest technology enables farmers to optimize resources and use fertilizers, water as per requirement. It is expected that with the advancement of technology, efficiency and productivity of agriculture will be increased as bigger and smaller farms are coming closure and getting more connected as compared to previous years. Collection of data is important to understand the patterns and data points are projected to increase by 4 million from an average farm. Internet of Things (IoT) makes it possible to analyze the structured and unstructured data so as to give more insights into food production (Kaur, Tomar, & Singh, 2018). IoT platforms are applying machine learning, artificial intelligence etc to data from field sensors and transforming agricultural systems into real AI systems. By analyzing and associating information about weather, seeds, soil, disease probability, pest attacks, farmers will make more informed decisions.

1. SOIL MONITORING AND ITS PARAMETERS

Food system in large part starts from soil. Taking care of land soil is essential for secured and sustained supply of food. It is often taken for granted and is an important natural resource. Composition and nature of soil varies with change in geographical location and also with climate, animals, and plants feeding on them, the soil's parent material, and soil's age. Basic components of soil are Minerals, Water, dead organic matter, air, and living microorganisms.

Depending upon the use of soil its composition may vary. For example, agricultural soil has about 45% minerals, 5% organic matter, 20-30% air, and similar portion of water. Further the exact composition depends on certain parameters like type of crop, terrain, temperature, humidity etc. Soil quality is the capability to deliver required nutrients, fertility, and components to plants for their desired growth. It changes and depends upon its usage and kind of crop farmers are cultivating. Key soil parameters are as Bulk density, texture, Water retention, Aggregation, temperature, moisture, soil organic carbon, and microbial biomass carbon. These properties are collected and a soil quality index is prepared. This index is for scientists and farmers to understand soil better. Quality of soil gets degraded with overuse of fertilizers, by not adapting crop rotation, floods, dry weather. This will not provide required nutrients to roots and due to reduction of organic matter content, recycling of nutrients is next to impossible. Building compost using yard waste, shredded leave, leftover vegetables, and fruits will help to restore organic matter to soil which will further boost the chemical and biological activities, hence improves soil quality.

Previously farmers used to cultivate the crop by just seeing the soil as the parameters are not accurately available for them to test the soil. After that soil laboratories got established where the soil samples are sent to get correct parameters, but it is a tedious process and is error prone. Different parameters of the soil such as water content, air temperature, soil temperature, water vapor content in air, acidity/alkalinity of soil are measured(Sujatha and Nithya 2017). In case the soil moisture is high and temperature is low then there will be no need of irrigation, similarly if the soil water content is low and air temperature is soaring then there is an immediate requirement of water supply. So depending upon the temperature and soil moisture, plants should be irrigated. pH of the soil is also an important factor which affects the plant growth. Acidic or basic nature of the soil affects the nutrient availability in the soil. Based on the reading related to pH level of soil, farmer can add different chemicals to increase or decrease pH of soil to bring it back to preferred level.

- **pH value**: The pH (potential of hydrogen)measurement of soil is a vital parameter in agriculture. Range for pH is from 0 to 14 and it is categorized as acidic (pH below 7), neutral (pH value of 7) while a pH above 7 is alkaline/base. Soil pH is a measurement of hydrogen ion (H+) activity, or effective concentration, in a soil and water solution. Highly acidic soil of pH 4-5 can have high concentration of iron, aluminum, and manganese which are toxic in nature and have adverse impact on the growth of plants. When the pH level of soil is too high then it reduces the plants ability to absorb essential nutrients from soil and again have impact on plant growth. Depending on the nature of plant, desirable pH level of soil should be between 5.5 and 6.5 (Vossen 2006). Aluminum sulfate and sulfur are common materials being used to lower the pH in soil while Limestone is used to make soil less acidic and more alkaline. Texture, mineral content, and climate impact the soil pH level. pH of newly formed soil is inherited from the parent material properties such as minerals content, clay and organic matter, the activities of organisms (plants, animals, and microorganisms) living in the soil, temperature and rainfall. The pH of the soil also affects the pH of groundwater or nearby water bodies such as streams or lakes.
- **Humidity:** It is the presence of water vapors in air which makes air moist or dry. Depending upon the type of crop, ideal humidity level also varies. Some crops require 50 percent and some plants grow well in 70 percent. But high humid level also brings in disease and virus which impact badly on growth of plants. Also in high humidity, plants will not be able to evaporate water and absorb nutrients from soil. In low humidity, plants will become dry soon and need more soil moisture. So, Irrigation requirement will depend upon the water vapor content in air. Capacitive sensors are used to measure humidity levels.
- **Temperature:** Soil temperature is the measurement of warmth or coldness of soil. It triggers many biological processes and influence the soil parameters as moisture, nutrients etc. Traditionally, a thermometer is being used where a probe is being inserted deep inside the soil to get correct reading. Ideal soil temperature for plants should be from 65F to 75F (18C to 24C). Also, pH of soil decreases with increase in temperature. Process of photosynthesis depends largely on the temperature, in high temperature and low temperature it usually slows down. When temperature

on surface is increased then it will take time to affect the soil temperature in same proportion. Soil heating effects the microorganism growth and indirectly the soil composition. To control the soil temperature, Mulch can be used which keeps the soil cool in summers and warm in winter. Water can also be to treat the dry soil.

- **Moisture:** Soil moisture is the amount of water in the soil and is affected by precipitation, air temperature, irrigation, soil composition, humidity etc. It is a critical parameter by which plants absorbs nutrients from the soil. Soil moisture generally ranges from 10% to 45% for the optimum growth. Low moisture content reduces plant output and microbial activity. Whereas high moisture will give rise to bacteria and disease which might impact the roots of plant and seed may not germinate. Irrigation should be dependent on the moisture reading and water should be supplied by considering its content.
- **Electrical conductivity (EC):** It is a measure which correlates physical and chemical properties of soil. It is measured by making a mixture of soil and de-ionized water. Water is then extracted from the paste and EC of extracted water is measured. It is commonly expressed in units of milli Siemens per meter. Correct balance of EC is very much important for the growth of plant. If EC is high then it hinders the nutrient uptake and results in environmental pollution. Lower EC may affect health and yield of plant.

Soil is analyzed by taking a sample from the field as composite sample where multiple samples from random locations are mixed to create a composite to be tested. It is generally tested for texture (Sandy, clay or silt), pH value, Electrical conductivity (soluble salts), nutrient content (N,P and K), and OM (Organic matter). These are the deciding factors for the crop to be used in soil as they give insights about chemical, physical, and biological status of soil.

2. SMART SOIL MONITORING SENSORS

As discussed above, soil monitoring is an important aspect of agriculture. Accurate and timely information about quality of soil is very crucial for health of crops. Having exact information will make it simple to take correct decisions on the water, fertilizers required for the irrigation of the field. By implementing the latest sensing and IoT technologies in agriculture practices, every aspect of traditional farming methods can be fundamentally changed. Currently, seamless integration of sensors and the IoT in smart agriculture can raise agriculture to levels which were previously unimaginable(Ayaz et al. 2019). Sensors are facilitating the monitoring of crops constantly with higher accuracy and are able to, most importantly, detect early stages of unwanted state.

Soil monitoring sensors deliver real-time readings of soil temperature, volumetric water content, and air temperature - directly from the field to the Internet. Smart sensors deliver data at customizable intervals, eliminating the need for manual readings. Accurately predict optimal planting times, reduce water usage, and minimize the plant stress that comes from over or under- watering. Analyze historical patterns to make better long- term crop management decisions. Most soil sensors are single-point sensors. They take a measurement at a single location. A single point sensor can measure soil moisture and temperature, or soil moisture, temperature and salinity.

- **Moisture Sensor:** Providing the optimum amount of water to plants is important and it depends a lot on the moisture content of soil. Soil with less moisture needs more water supplies as compared to soil which is already moist at roots of crop. Soil moisture sensors as shown in Figure 1 measures whether the moisture level is at appropriate level. It reads the resistance between two probes, a positive probe, and a negative probe. It works on the principle of dielectric constant where the current flows between the two probes. The resistance on the probes is measured which gives the information about moisture, greater the resistance the drier is the soil and lesser the resistance means soil is highly moist. These sensors can be portable and used for instant measurements or installed for long-term monitoring.

Figure 1. Moisture sensor

Dielectric permittivity is the most common type of soil moisture sensor (Heble et al. 2018). As the dielectric constant of water is 80 and dielectric permittivity of dry soil is 4, so measuring dielectric constant between the probes gives the indication of moisture availability. It is very much required that probes are correctly inserted into the soil with no air or gaps between probes and soil; and depth should be till the root level. Readings of responses are collected at data loggers from where it is communicated to cloud or central servers.

- **Profiling Probes:** This is used to measure the soil moisture across a vertical soil profile given in Figure 2. This probe tool is easy to use for obtaining precise soil moisture profile measurement. Depending upon the root depth these probes which are of range from one foot to four feet can be buried in soil. Separate sensing rings are attached with the elongated tube, depending upon the length of tube, number of sensing rings get varied. It consist of readout meter for portable readings, data logger for continuous monitoring, access tubes for housing the probes in the soil and assistance kit for installation. Access tube is dug in the soil into which profile probe slides down. Sensors in the probe emit electromagnetic field which penetrates into the soil. It measures the soil water content at various depths without the need of having separate sensors at different locations and depths. A single antenna is used for multiple sensors which are connected with a data logger. Data from the logger is shared with cloud for further analysis. Multiple access tubes can be installed and then a single profiling tube could be used for instant reading using readout meter. This way it saves a cost, one by removing the need of multiple single sensors at different depths, second by using multiple access tubes and a single profiling tube. Strengths are fast response, multiple measurements with one reading, flexibility, and ease of use.

Figure 2. Profiling probe moisture sensor

Soil Matric Potential (SMP) and Volumetric Soil water content (VSWC) are the two parameters being measured by moisture sensors. SMP gives the water availability in soil and VSWC measures the ratio of soil volume occupied by water. SMP is easily readable but VSWC needs expertise in irrigation management. Both SMP and VSWC sensors are available in different forms, and depending upon crop, irrigation system, soil, it can be used with different configurations.

- **Water Potential Sensor:** These sensors detect the energy required by plant roots to get water from soil, an example is shown in Figure 3. It is of two types as tensiometers and granular matrix sensors:

Figure 3. Water potential sensor

Tensiometer measures the tension that plant roots must have in order to extract water from the soil. It measures the direct availability of water to plants. It has a plastic tube, porous ceramic cup at base, water reservoir at top and a meter to read vacuum. It is buried into the soil upto a meter and the tube is filled with clean water. As soil dried out the water is poured out of the cup. It creates a vacuum at top which is read by the attached vacuum gauge meter. So with the water availability content in soil, meter reading gets changed and irrigation is planned accordingly. When soil is watered then water pour inside the ceramic cup and gauge display the low reading. Vacuum pump can be used to remove any air bubbles or porous tip can be dipped in a bucket of water for long time to remove any air and to get correct reading.

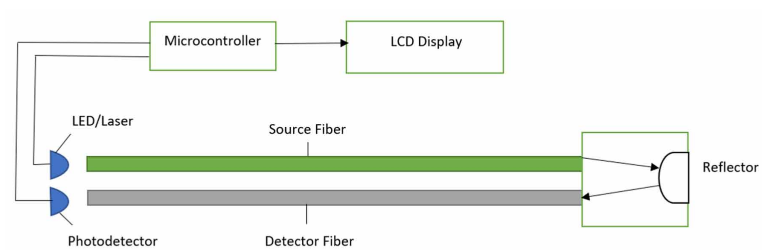
Granular matrix sensor has two electrodes embedded in it. This matrix comes in equilibrium with soil, as the soil get higher in moisture it reads a resistance and then resistance is converted into soil moisture level. Sensors are buried inside the soil upto the root zone of crop. Data from multiple sensors is logged into data logger which displays soil moisture from previous days. This value can be integrated with irrigation system to start and stop the water supply. Similar to tensiometers, they also get dipped in water before actual use to get correct reading. Inflow and outflow of water from the porous material of Granular matrix sensor is slow as compared to tensiometer. Due to this there is a lag between the soil moisture content and sensor reading. Further, this lag is greater when the soil get dry as compared to rewetting.

- **Capacitance Sensors:** It consists of two insulated metal electrodes that use the water in the surrounding soil as a dielectric to form a variable capacitor. Capacitive measuring basically measures the dielectric that is formed by the soil and the water is the most important factor that affects the dielectric. Higher water content in the soil will increase the capacitance value of the sensor. Because the electrodes of the sensor are insulated from the surrounding soil and its water, no corrosion can take place which allows for permanent installation in the ground and gives the sensor a very long lifetime in comparison to the battery and resistance type sensors. The capacitance value is measured primarily in one of two ways. The first method uses the sensor's electrodes as part of an RC oscillator circuit generating an AC signal whose frequency depends on the sensor's capacitance and therefore the water content of the surrounding soil. Different frequencies will correspond to different levels of soil moisture. The second method measures the capacitance value of the sensor directly by measuring the charge or discharge time which corresponds to the capacitance value of the sensor.
- **Time Domain Sensors:** Time domain reflectometry (TDR) sensors are used to measure soil water content. They have two 12cm long probes which are inserted into the soil. It works on the principle that high electromagnetic waves are passed through the probes and the transport time of those waves being reflected back is calculated. Time depends upon the dielectric constant and it further depends upon the soil water content. Pulse is usually sent thousands of time in a second. Average delay in time across the probes tells about the moisture content. A less expensive alternative are sensors that measure using water content reflectometry (WCR) and time domain transmissometry (TDT). Modern sensor comes with Bluetooth, which usually passes the reading directly to irrigation system. Similarly, Frequency domain reflectometry FDR use oscillator to propagate signal across probes. The difference between wave and return wave frequency is measured to determine soil moisture.
- **pH Sensor**: pH sensor are used to measure the water quality and other parameters present in the soil. It basically measures the concentration of hydrogen ions of water and that ions depend upon the acidic or alkaline of aqueous solution of the soil. Measurement of pH value is obtained by im-

mersing a pair of electrodes (reference and measuring electrodes) into the solution and measure the voltage difference developed across the electrodes.

- **Temperature and Humidity Sensor**: Presence of water vapor in air is measured using humidity sensors and degree of hotness and coolness around soil is measured by temperature sensor. Relative humidity gets changed with change in temperature. Irrigation impacts the temperature and humidity levels as the amount of water droplets in air is increased after irrigation. This causes decrease in temperature which in turn increases the relative humidity of the surroundings. The measurements of related parameters of temperature and humidity are alerted to user from the fields. Farmer can take the required action based on this information.
- **Light Intensity Sensor:** Sunlight is a critical component for the growth of plants and crop. Each plant based on its property and composition reacts differently and also depending upon the nature of soil, it can get dry too early with rise of sunlight or if soil is of clay in nature then it can hold moisture more time. The light sensor detects the presence of light and adjusts the brightness of light to desired level. It uses Light dependent resistor (LDR) where the resistance decreases with increase in light intensity and increases with reduction in light. As absorption of light gives energy to electrons and they become more conductive and current starts flowing in the conduction band, so resistance is reduced with increase in light. Ohmmeter or digital multimeter can be used to measure this resistance. There are several types of light sensors including photo-resistors, photodiodes, and phototransistors. Integrating Light sensors with light systems will enable them to get switched on/off automatically without any human interference (Lakhiar et al. 2018). It can be used in green houses where artificial lighting is achieved by using incandescent lamps, high intensity discharge fluorescent lamps, and LED lights.
- **Fiber Optic Sensors:** They are widely used in today's scenario like communication between inter-satellite, satellite to ground, to find the location of planes from ground surface and in agriculture. It is generally based on the measurement of changes in the optical properties like reflectance and transmittance, change in refractive index, phase shift, polarization and light energy (fluorescence based sensors or Raman based sensors).In this sensor which is shown in Figure 4, LED/Laser transmits the light that propagates along the fiber according to the total internal refection and falls on the soil. Light of different wavelengths is absorbed by soil particles and remaining gets reflected back. Then this reflected light is received by photo-detector which converts it to electrical signal. Further, the signal conditioning circuit consists of buffers, inverting amplifier with variable gain and a subtractor for zero setting desired with op-amp.

Figure 4. Optical sensor



Data from the optical sensors is compared with the threshold values stored in microcontroller and deficient component is predicted. LCD displays the name of the deficient component and the amount required in soil. Thus user can select the fertilizers accordingly and dispense them to the soil. They can also get the information about different soil properties such as clay, organic matter, and moisture content of the soil. Deployment of these sensors is very easy. It can be placed in field, vehicles, drones, aerial platforms, and satellites as shown in Figure 5.

Figure 5. Moveable optical sensor

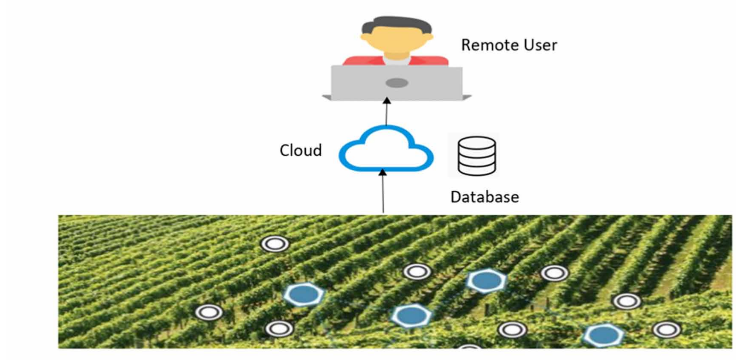
In the Fiber Bragg grating optic sensor (FBGS), optical interrogator sends white light (all colors of the visible spectrum) down to the core of the fiber. It passes through the Fiber Bragg Grating (FBG) which is a series of optical filters. While passing inside it, a specific Bragg grating wavelength is reflected back and rest of spectrum is transmitted. This happens periodically by altering the refractive index of fibers. External factors such as heat and vibration are induced then FBG reacts accordingly causing a proportional phase shift in the reflected Bragg wavelength. These variations are then translated into physical engineering unit such as temperature, strain etc. because all FBG sensors are based on measurement within a selected wavelength range. It is possible to daisy chain multiple sensors on a single optical fiber. FBG sensors are non-conductive, electrically passive, and immune to electromagnetic interference making them safe and reliable unlike conventional electrical sensors. More recently, Actively heated fiber optic (AHFO) and the passive fiber optic (PFO) sensors are used in precision agriculture to measure soil water content.

3. SMART SOIL MONITORING SYSTEM

Communication system transfers information from one point to other using cables as medium or wirelessly without cables, wires or any other medium. As in above section different type of sensors are discussed which collects data about soil and then this data should be transmitted to central server using communication systems for further analysis. There are several wireless technologies being used for communication, each one having specific merits and demerits. For implementation of Smart Soil monitoring systems, different protocols and standards along with different network's technologies that are used such as Arduino board, Raspberry family(García et al. 2020), different types of processors like ATmega328(Balakrishna.K, Nethravathi.S.N, and Krishna 2016), ATmega2560, LPC2148(Varma et al. 2017)etc and communication technologies that are cellular communication (3G,4G/LTE, 5G), Smart Phones, Wireless Personal Area Networks(PAN)/Local Area Network(LAN) (IEEE 802.15.1(Bluetooth), BLE (Bluetooth Low-Energy),WiFi, Zigbee), Radio Frequency Identification(RFID), Low-Power Wide Area Network (LPWAN) with Narrow Band IoT (NB-IoT) and Long Range Wireless area Network (LoRaWAN).

Wireless sensor network (WSN) is the network in which multiple wireless sensors are connected with the sensor nodes. Each node is having a transceiver to transmit data to base station, an electronic circuit to get connected with sensor and a battery as energy source. As shown in Figure 6, these nodes are responsible to collect data. Nodes are further classified as source node and sink node. Sink node receives data from multiple source nodes and source nodes collect data from sensors. Function of sink node is more computational as compared to source node, as it has aggregated data from multiple sources. Computed data from sink node is then sent to central servers for further analysis and usage. Depending upon the complexity of nodes, Cost and size of sensor varies and it results in further constraints on memory, energy, and computational ability. Although with rapid advancement, it is expected that these constraints will be removed and it will become feasible to implement in agriculture(Wang, Zhang, and Wang 2006).

Figure 6. Wireless Sensor Network (WSN) architecture



Communication technologies are crucial for the implementation of IoT devices in agriculture. Depending on application requirements, various communication protocols along with technologies are being used, most common are discussed here:

- **Wireless PAN/LAN:** Wireless PAN/LAN are also used for communications between field sensors and central base stations for short distance range. In this different technologies are used based on the communication range such as Bluetooth, ZigBee and Wi-Fi. In the following brief overview of these technologies:
- **Bluetooth Technology:** Bluetooth standard (IEEE 802.15.1) is a proprietary open wireless technology standard for exchange data between devices, creating personal area networks (PANs) and

operates in the free 2.4GHz ISM (Industrial, Scientific, Medical) microwave band. It is considered as one of the suitable wireless technology for wireless sensor network where the wireless sensor network is made up of less number of sensors over distance range (8m-10m). Data rate can be achieved from 1Mbps-24Mbps.Due to its advantages of consumes battery less, easy to use, free of charge etc this technology is being preferred in smart agriculture, and other applications(Jawad et al. 2017). Further, with the advancement in conventional Bluetooth technology, new technology has been released, known as Bluetooth Low Energy (BLE) technology. In BLE, data rate enhancement, ultra-low power and low cost can be achieved in the same ISM frequency band.

- **Wi-Fi:** It is used frequently in IoT-based agriculture systems for monitoring soil because Wi-Fi is mostly found in different devices like smart phones, laptops, tablets etc. Wi-Fi(wireless fidelity) is a wireless local area network (WLAN) that operates at 2.4 GHz frequency of ISM band with data rate (11Mbps) for communication range in order of 20m to 100m.The Wi-Fi protocol supports IEEE 802.11standard family (IEEE802.11 a/b/g/n).With this technology, all the devices are connected over an ad-hoc network.
- **Zigbee based soil moisture sensor network:** Zigbee is a wireless technology standard that defines a set of communication protocols for short range communication (upto 75m-100m indoor and upto 300 meter outdoor).The objective of this technology is to monitor and control devices. Both Bluetooth and Wi-Fi are not quite suitable for this specific application of wireless communication because they use a lot of power or where the low power consumption is important. It addresses the need of low cost, low power implementation of devices with low data rate (20kbps-250kbps). It is the most commonly open source standard that are used for IoT based application such as home automation, medical data collection, industrial control systems and precision agriculture. Open source protocol makes it cheaper for manufactures to build Zigbee technology because they don't have to pay any license fee. It is designed to support a hundreds of devices in a single network. Three frequency bands (868MHz,915MHz and 2.4GHz) are assigned to Zigbee with star, mesh and tree topology. Mesh topology in Zigbee network is important because if any node fails, data can be re-routed using another path and self healing process. In many Zigbee applications, the devices spend most of its time in power saving mode also known as sleep mode. Zigbee network uses AES cryptographic algorithm for data encryption and data authentication. Main purpose of this is to gather information or perform certain control tasks related to any application. In a Zigbee based soil moisture sensor network, there is a controller in the agriculture with a software application that controls the sensors and made a Zigbee network. This Zigbee network is connected to the internet or farmer with the help of gateway(Roy and Bandyopadhyay 2013).
- **RFID**: This technology works on radio waves which automatically identifies and tracks plants, crops etc. RFID tags get attached to the plant and there is an associated reader, which reads the radio signal feedback sent by RFID tag. Multiple tags can be read and tracked at same time which saves time to get information about whole crop. RFID tags are of three types a) Active tag b) Passive Tag and c) Semi Passive Tag. Both active and Semi Passive tags are heavier than Passive tags as they have their own power supply but Passive tag doesn't have its own power supply and instead use power of RFID reader to transmit signal back to reader. .Semi Passive reader has own power supply but still use reader radio signal to transmit feedback back to reader. Passive ones are cheaper, compact, and lighter, so they are more useful in agriculture but have a range of 10cm. RFID reader is of three components: Microcontroller, Signal generator and Signal detector. RFID tag consists of Transponder (to send/receive signal); Rectifier (to get power from radio waves),

Controller, and memory. A RFID tag as shown in Figure 7 is used to transmit data to the RFID reader, which then converts the radio waves into a practical form of data. This data is then transferred to server via antennas and base station where the data is stored in database and analyzed using several tools. RFID tags can be used to detect any virus or disease information which is affecting the crop. As it is difficult to tag each and every seed but a bundle of crop having similar properties can be tagged together with a single tag. These tags store information about the date of sowing, quality of seed, soil parameters, and ideal time of harvesting. RFID is contact less, has high recognition rate, memory to store data, secured, and can be easily integrated with other systems.

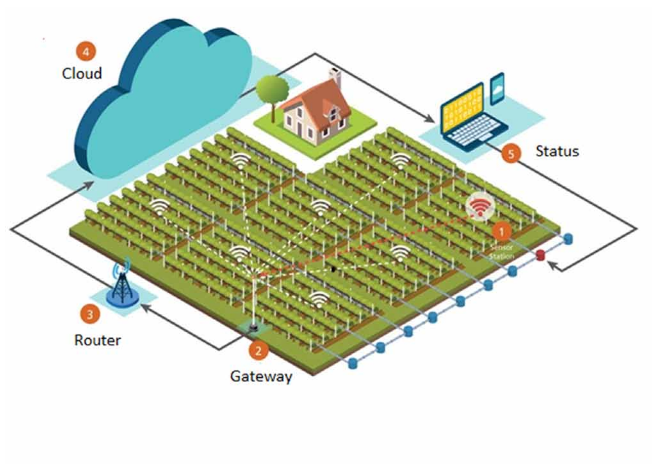
Figure 7. Radio Frequency Identification Soil Monitoring System

- **Smartphone:** Smartphone is actively being used in agriculture for soil monitoring. There are many build-in tools in Smartphone like camera, GPS (Global positioning system), microphone, accelerometer, and gyroscope etc which are used for sensing and identifying an object or substances. Modern Smartphone equipped with advanced cameras are used to get the properties of soil by digital photography. But light detecting sensors of cameras can give different results for different smart phones as they don't produce uniform color response. Also, user need to take care of lighting exposure as image could be blurring in low light and will be overexposed in bright light. So the image need to be recalibrated in case soil color is being used to get soil properties. Color calibration produces a 'true' color image that removes the impact of lighting, light sensor impacts. These images are analyzed to measurement chlorophyll, ripeness level, Leaf Area Index (LAI), soil organic and carbon makeup. GPS provides location for crop mapping, disease/pest location alerts, solar radiation predictions, and fertilizing.

In today scenario, there are many smartphone's apps like Kisan Suvidha, Pusa Krishi, Soil Health Card (SHC), Agri Mobile app, Bhuvan Hailstorm app etc which are designed to get important agricultural data about weather, moisture, technologies, pest attacks, storms, rain, or dry weather etc. These applications are connected with sensors wirelessly using Bluetooth/WiFi etc. The app display soil moisture content, temperature, conductivity, Ph parameters on screen for immediate viewing. Also, farmers can get connected with experts to get the advice for further actions. These apps are extremely useful to get data about other fields and information can be sent from one field to any other part of country for further advice(Oliver 2019).

- **Long Range wide area networks (LoRaWAN):** LoRa is a low power wireless radio network protocol that support long-range (upto 40km in rural areas and up to 3 km in urban areas) communication between the sensors in the field and base station. It is low-cost, energy efficient for IoT and has been integrated into proven solutions for a number of important vertical markets, including smart agriculture. This protocol operates on unlicensed ISM frequencies (415MHz, 868MHz, 915MHz) which vary according to continent to continent. But in GSM, every GSM operators pay a huge amount of money to use the frequency spectrum. LoRaWAN also reduce the power consumption and improves the battery lifetime of connected sensors by more than 10 years. LoRa Technology as given in Figure 8(Semtech White Paper n.d.) has reduced impact on environment, maximized the output and still keeping the cost low.

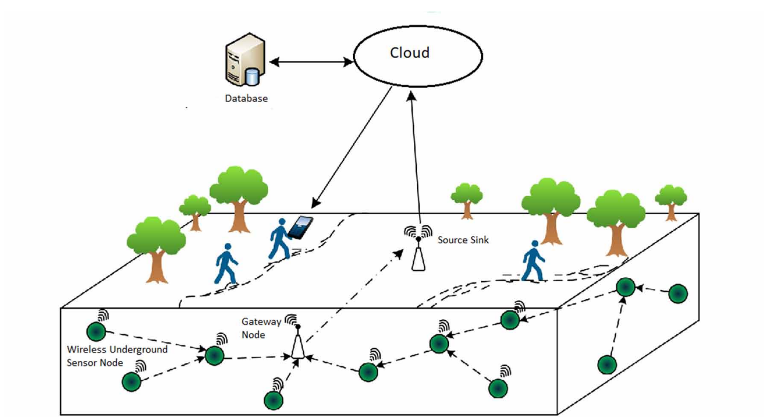
Figure 8. LoRaWAN based Smart Soil Monitoring



- **Terrestrial Wireless Sensor Network:** This network has helped to connect peoples to the internet globally and also used for precision agriculture. In these network wireless sensors nodes are deployed in the field and are connected through radio frequency link of ISM radio bands with gateway. Gateway is placed far away from sensor nodes and is connected through 3G/4G/LTE/5G with cloud network. Thus a remote farmer can monitor the field conditions, and detect when crops need watering, pesticides, or fertilizer. Optimum usage of pesticides and fertilizers will result in healthy crops, maintains soil fertility, and will save the agriculture cost. Healthy crops reduce the overall burden on healthcare systems (Singh, Dixit, & Kaur, 2019). Critical values from the sensors and gateways can be integrated with other systems like irrigation to automatically watering the plants when required. This will save the work force and physical need to switching on/off the pump. Also, smart phones can be used to get the status of field by getting all vital parameters on screen (Ojha, Misra, and Raghuwanshi 2015).

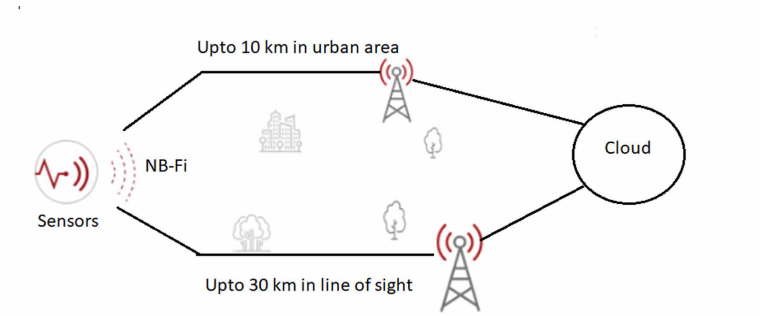
- **Underground Wireless Sensor Network:** The goal is to create underground network that can wirelessly communicates between soil and surface. Soil information such as moisture, temperature etc can be used in a wide variety of other applications like managing golf courses, alerting homeland security to an intruder and even detecting earthquakes (Parasher, Singh, & Kaur, 2019). In this network as shown in Figure 9 sensor nodes are buried inside soil and sends information to underground Gateway wirelessly. As higher frequency signal can get distorted due to presence of soil, so Low frequency signal is used and this leads to requirement of large number of sensors. There will be a single underground gateway that collects data from multiple sensors. Information gathered by underground gateway is transmitted to the surface data logger. Thereafter, data can be transmitted to cloud and will be used by farmers. Thus, underground sensors could significantly reduce water usage without damage the crop and conserve precious resources(Ojha, Misra, and Raghuwanshi 2015).

Figure 9. Underground Wireless Sensor Network



- **LPWAN-Narrow Band:** This technology provides the low –cost low power and wide area coverage needed for robust IoT network. There are number of competing technologies in the LPWAN space such as Narrowband IoT (NB-IoT), Sigfox, LoRa and others. LPWAN technologies may be divided into two groups: wideband and narrowband systems. In wideband systems, one channel typically occupies a frequency band from 100 kHz to several MHz, while in narrowband systems one channel has a bandwidth from 50-100 Hz. Technologies of low-power narrowband radio communication as shown in Figure 10 began rapidly developing in the world on the back of the improvement of quartz oscillators' accuracy, which allowed increasing the duration of signal stability: it became possible to contracted the communication band preserving the signal power limits. Long duration of signal stability in narrowband systems allows transmitting data at a low data rate at distances of 10 kilometers and more without exceeding the power limits in unlicensed bands (typically, from 25 to 100 mW).

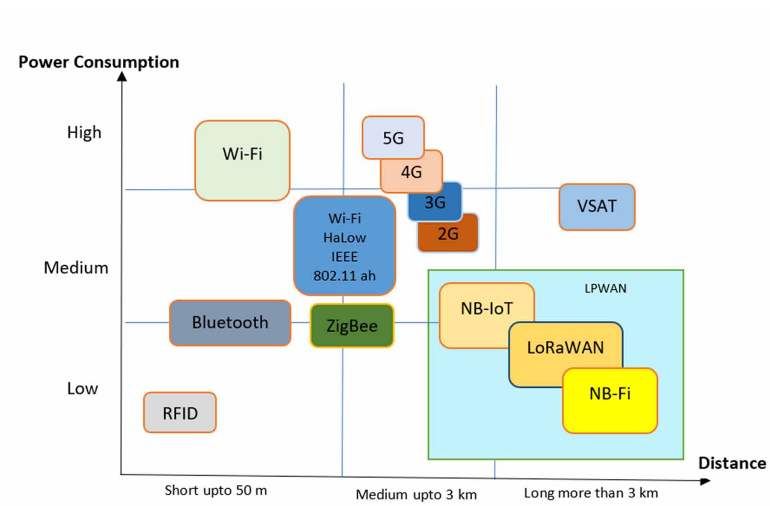
Figure 10. Low power Wide Area Network with Narrow Band



WAVIoT develops low-power consumption of NB-Fi (Narrow Band Fidelity) radio modules ensures autonomous operation of NB-Fi devices for a long period of time, which allows customers to use them in remote locations and with little maintenance costs. With 10+ years of battery life, IoT network along with NB-Fi modules can send data for more than 10 kilometers distances. In LPWAN, NB-Fi devices can collect data from sensors and transmit to gateway with low signal power. Then collected gateway data is handed over to the cloud network.

- **NB-Fi** technology is focused on energy efficiency and extra long battery life of devices, and is designed for solutions that require fast and inexpensive rollout of IoT networks with a 100% data collection rate from the devices. The comparison among NB-Fi and other technologies is shown in Figure 11.

Figure 11. Comparison between different technologies



REFERENCES

Ayaz, M., Ammad-Uddin, M., Sharif, Z., Mansour, A., & Aggoune, E.-H. M. (2019). Internet-of-Things (IoT)-Based Smart Agriculture: Toward Making the Fields Talk. *IEEE Access: Practical Innovations, Open Solutions*, *7*, 129551–129583. doi:10.1109/ACCESS.2019.2932609

Balakrishna, K., Nethravathi, S.N., & Krishna, H. (2016). Real-Time Soil Monitoring System for the Application of Agriculture. *International Journal of Engineering Science and Computing*, *5326*. https://ijesc.org/

García. (2020). IoT-Based Smart Irrigation Systems: An Overview on the Recent Trends on Sensors and Iot Systems for Irrigation in Precision Agriculture. Sensors, 20(4).

Heble, S. (2018). A Low Power IoT Network for Smart Agriculture. *IEEE World Forum on Internet of Things, WF-IoT 2018 – Proceedings*, 609–14. 10.1109/WF-IoT.2018.8355152

Jawad, H. M. (2017). Energy-Efficient Wireless Sensor Networks for Precision Agriculture: A Review. Sensors, 17(8). doi:10.339017081781

Kaur, G., Tomar, P., & Singh, P. (2018). Design of cloud-based green IoT architecture for smart cities. In *Internet of Things and Big Data Analytics Toward Next-Generation Intelligence* (pp. 315–333). Springer. doi:10.1007/978-3-319-60435-0_13

Lakhiar, I. A., Jianmin, G., Syed, T. N., Chandio, F. A., Buttar, N. A., & Qureshi, W. A. (2018). Monitoring and Control Systems in Agriculture Using Intelligent Sensor Techniques: A Review of the Aeroponic System. *Journal of Sensors*, *2018*, 2018. doi:10.1155/2018/8672769

Ojha, Misra, & Raghuwanshi. (2015). *Wireless Sensor Networks for Agriculture : The State-of-the-Art in Practice and Future Challenges.* Academic Press.

Oliver, J. (2019). 済無. *Hilos Tensados*, *1*, 1–476.

Parasher, Y., Singh, P., & Kaur, G. (2019). Green Smart Security System. *Green and Smart Technologies for Smart Cities*, 165-184.

Roy, S., & Bandyopadhyay, S. (2013). A Test-Bed on Real-Time Monitoring of Agricultural Parameters Using Wireless Sensor Networks for Precision Agriculture. *International Conference on Intelligent Infrastructure*.

Singh, P., Dixit, V., & Kaur, J. (2019). Green Healthcare for Smart Cities. *Green and Smart Technologies for Smart Cities*, 91-130.

Sujatha, R., & Anitha Nithya, R. (2017). A Survey on Soil Monitoring and Testing In Smart Farming Using IoT And Cloud Platform. *International Journal of Engineering Research and Applications*, *7*(11), 55–59.

Varma, Mulla, Raut, & Pawar. (2017). Fertigation & Irrigation System for Agricultural Application along with Soil Monitoring Using IoT. *Vishwakarma Journal of Engineering Research, 1*(2), 241–45. www.vjer.in

Vossen, P. (2006). Changing PH in Soil. *University of California Cooperative Extension, 11*, 1–2. https://vric.ucdavis.edu/pdf/Soil/ChangingpHinSoil.pdf

Wang, N., Zhang, N., & Wang, M. (2006). Wireless Sensors in Agriculture and Food Industry - Recent Development and Future Perspective. *Computers and Electronics in Agriculture*, *50*(1), 1–14. doi:10.1016/j.compag.2005.09.003

Chapter 14
Real-Time Crop Monitoring in Agriculture

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ABSTRACT

In many countries like India, farming is done using indigenous methods. Because of lack of proper knowledge in our farmers, the state of the agricultural sector becomes even more critical. Since the farming methodologies rely mostly on weather forecasts and predictions which might not be foolproof, most often the farmers incur huge losses leading to debts and mass farmer suicides. Adequate soil moisture, soil quality, air quality, and proper irrigation play a major role in the yield of crops, and hence, such factors cannot be overlooked. A major concern now is the exploding population due to which the agricultural supplies are not meeting the ever-increasing demand. The world's population is expected to cross nine billion marks by 2050 due to which the agricultural supply should increase at least by 70% to meet the requirement. To achieve this, it's necessary to monitor the plant growth at all stages starting from sowing until cultivation.

1. INTRODUCTION

In many countries, farming is done using indigenous methods. Because of lack of proper knowledge in farmers, the state of the agricultural sector has become even more critical. Adequate soil moisture, soil quality, air quality and proper irrigation play a key role in the crops harvesting and hence such factors cannot be overlooked. A primary concern now is the exploding population due to which the agricultural

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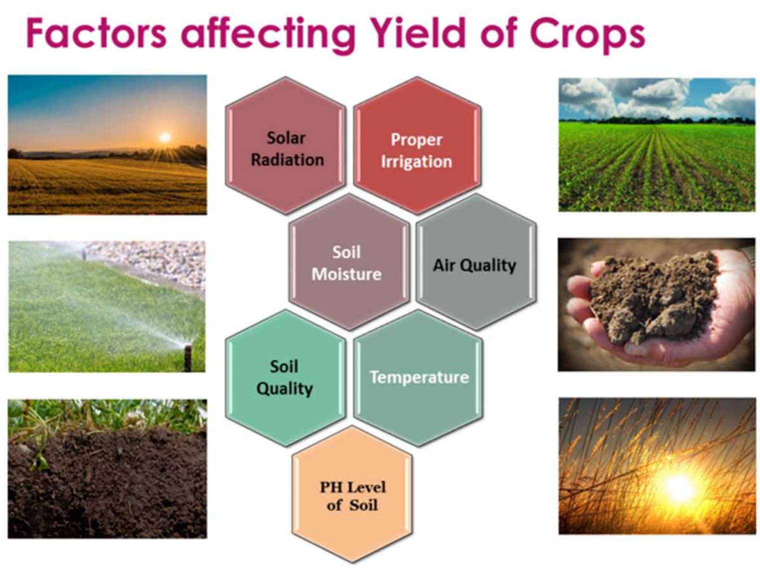
supplies are not meeting the ever-increasing demand (M Suchithra, Asuwini T, Charumathi M C, Ritu N Lal, 2018).

Population of the world's is estimated to cross 9.7 billion by the year 2050 (Le Mouël C., Lattre-Gasquet D., & Mora O, 2018) due to which the agricultural supply should increase at least by 70 percent to meet the requirement (Ranveer Chandra, 2017). To achieve this, it's necessary to monitor the plant growth at all stages starting from sowing till cultivation.

Agriculture experts think about problems of World's food production and the most promising approach is "Data driven agriculture". Data driven agriculture is the ability to map every farm and define it with lots and lots of data. Efficient use of huge data to enhance on farm precision farming is termed as Data driven agriculture. Data driven farming means having the right soil data at the correct time, to conclude the precise decision by the help of which one can improve long term profitability (Brian Hayden, 2015) For example, what remains the soil moisture four inches below the soil in the farm or like what is soil nutrient level throw-out the farm. If one can build a map like this, this could enable technique like precision farming. Precision farming is the ability to do site specific applications. One can understand Precision farming with an example more clearly. Farmers can apply water or pesticides uniformly throw-out the farm, but with Precision farming, can apply it only where it needed. Now farmers will use less water or fewer pesticides and water wastage will be less and also will use fewer pesticides so it will be beneficial for the environment too. Some years before, the implementation of this technology was expensive but with the advancement in technology its cost is lowered significantly (Roy S. & Bandyopadhyay S.,2013). Figure 1 represents the various factors that effects the crops.

Figure 1. Factors affecting the crop.



So, with the advancement in technologies, there is possible practical implementation of "Real time crop monitoring in agriculture". Various activities in field like moisture monitoring, water level monitoring, temperature monitoring, crop state monitoring, weeds monitoring, natural activity monitoring etc. can be monitor by using this system.

Agriculture experts are trying to digitalize farming and related agricultural activities in order to enable the farmers to regularly monitor the plant growth parameters and perform the necessary actions to maximize yield. This innovative idea will be constructive in the agroindustry due to its remote monitoring nature and high dependability. This concept will make agriculture a more reliable and profitable business. But the extent of its deployment mainly depends upon the awareness among agriculturalists and its positive outcomes on agricultural sector.

Not only this idea will replace old fashioned techniques in agriculture but will also contribute to the society by creating new employments. Its sole purpose is to monitor the growth of yield by using digital techniques. Values of various parameters upon which the growth of crop depends can be easily acquired accurately.

1.1 Field Measures by Monitoring System

The information related to crops and farms is measured and displayed by these systems, which are:

1.1.1 The Crops and Field Record

These systems capture all the detailed information related to the fields and crops. It examines and explains the reason behind the change in data over time. The system majorly captures the date of sowing crops, variety of crops planted together, history of the field and other relevant details concerning the quality of soil and crops grown.

1.1.2 The Vegetation Indexes

The real-time monitoring system examines the nature of crops by providing a variation on the different vegetation which is on the farm. This system gives a clear view of how one farm is performing compared to the other farms having the same crop. The information about vegetation given is the average farm vegetation, historical vegetation cover and the non-performing regions of the farm.

1.1.3 The Soil Situations

The real-time monitoring system majorly records the moisture in the soil, temperature, and drainage of soil due to the overflow of water in the field. It also records the optimization results of soil.

1.1.4 Climate and Precipitation Test

Majorly the following tests are performed for the weather: test for dew points, snow cover and also the temperature of air and the soil.

In this digital era, along with the development of technology people are trying to blend the human brain with the artificial brain. These continuous efforts for development have originated a whole new domain of Artificial intelligence. This Real-time monitoring has only become possible because of the advancement in technology.

2. NEED OF REAL TIME CROP MONITORING

Since the farming methodologies rely mostly on weather forecasts and predictions which might not be foolproof, most often the farmers incur huge losses leading to debts and mass farmer suicides. So there is need for crop monitoring system. Other reasons are as follows:

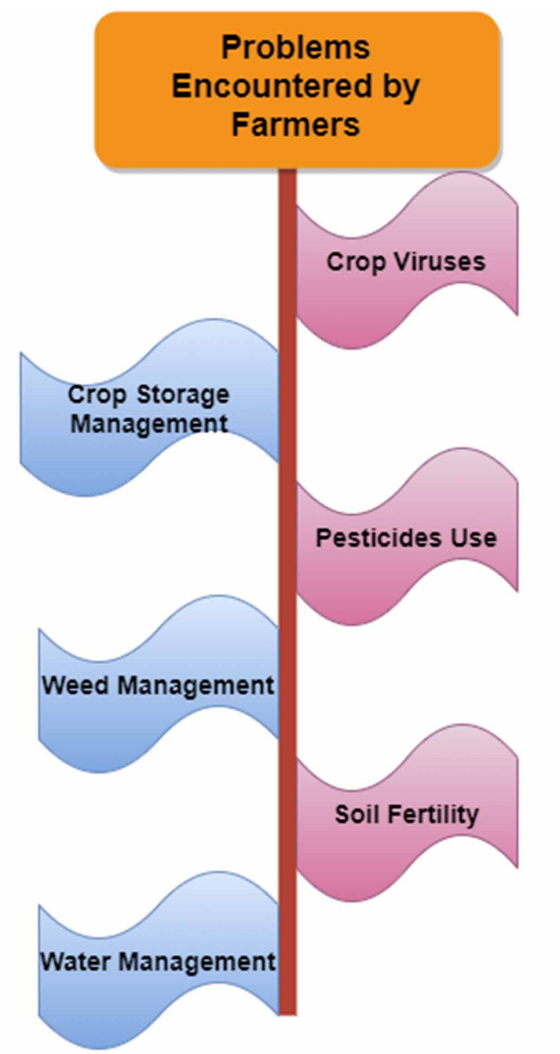
- The farmer can obtain data that could help them to improve their business as most of the monitoring is done remotely.
- Farmers could get information at a high rate with fewer labor requirements.
- There is a continuous requirement of analyzing the water level in fields and crops.
- Monitoring fields remotely will save the efforts in many things like physical efforts and inconvenience of managing sources, wastage of electricity, irregular and highly un-reliable power, going back to check on fields at odd hours, the risk to get shocks from electric circuits, etc.
- These automated systems are so convenient to use that even a physically disabled person can use it easily.
- It helps in managing the scenarios when there is an excess of water is flowing in the field or running of the pump while there is no water in the source.
- Many countries are still not able to meet the need for food supplies though stands at a good position in the world for farming practices because of the drastic increase in population. So, to increase production, there is a desperate need to improve food production techniques.
- There will be a huge economic impact if farmers start using a real-time monitoring system. By this, farmers can identify the current condition of crops during the agricultural season, which is an important matter supporting agricultural policies.
- Various natural calamities like flood, hail storms, cyclone, and earthquakes causes considerable harm to the harvests and the infrastructure of affected areas. Quite a few countries worldwide are prone to some sort of natural disaster. For instance, In India, seaside areas are subjected to the tropical cyclones. In 2018 in India, three hefty cyclones namely Gaja in 16th November 2018, TITLI in 11th October 2018, and Pethai 17th December 2018 damaged cyclic crops such as Coconut, Areca and Rice Nut plants in East coast districts of Tamil Nadu and Andhra Pradesh. Conventional study-based methods calculate loss valuation are labor-intensive and time-taking process. This drawback of the traditional survey can also be resolved by using the same technologies which one can use for real time crop monitoring (Sawant S., Mohite J., Sakkan M., & Pappula S.,2019).

3. REAL-TIME CROP MONITORING SYSTEM

As mentioned above, the world's population has increased drastically in the past few years and expected to reach 9.7 billion in 2050 (Le Mouël C, Lattre-Gasquet D., & Mora O. 2018). So, with the increase in population, the demand for supplies has also increased.

Farmers use the many ways to serve the demand which is not good enough hence they use harmful pesticides in uncontrolled ways that hamper the soil. This leads to the infertility of the field. So, there is a prominent need for different automation techniques. Farmers encounter problems like crop viruses, management of crop storage, use of pesticides, weed management, soil fertility and water management as shown in Figure 2. With fewer efforts, these all above discussed problems can be controlled by various automated techniques like AI, IoT, and ML etc. By using automation in farming practices, soil fertility can be improved and hence the production. That's why the Automation of Agriculture has been developed and has become a major interest amongst countries.

Figure 2. Problems Encountered by Farmers



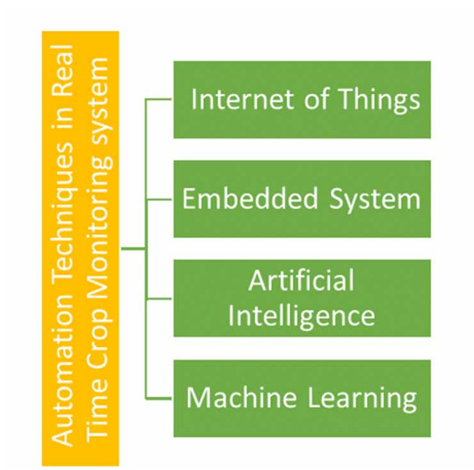
The technology has evolved in the field of farming that improves production and fertility. Nowadays, techniques for real-time monitoring of the crops are available which facilitates recording quick reactions to momentary events. These techniques involve analyzing satellite images (users generally use satellite images but there can be other methods also) of different fields and crops to determine both the negative and positive growth of the crops. By analyzing the various vegetation index of a firm over a while the farmer can conclude if the crops are improving or decaying. From this, the farmer can take remedial actions that may be required on the farm. The crop monitoring system which uses satellite allows a user to observe crops that are in various fields, regions, and areas. After collecting the data, the system analyzes the different fields and interprets the examined data for the different users.

Real time crop monitoring system can be categorized on basis of use of various technologies as:

- AI and ML based crop monitoring system
- Embedded System based crop monitoring system
- IoT based crop monitoring system

Figure 3 represents the automation techniques in real time crop monitoring system, A real time crop monitoring system can be consisting of more than one technology mentioned above.

Figure 3. Automation Techniques in Real Time Crop Monitoring System



3.1 AI and ML Based Crop Monitoring System

As the world population is increasing and land has become limited, people need to be more creative and effective about the farming techniques, they need to learn using less land area how they can yield more crops and increase the fertility of their farms. In this era of advanced technology, human has made intellectual machines which perform various operations by observing the surrounding. AI (Artificial intelligence) comes under the computer discipline that can build the understanding of the surrounding and yield to the maximum results. Through AI (Artificial intelligence), a machine can do work based on prior learning. Certain domains enhance the work done by a machine and support to develop more advanced technology such as deep learning, CNN, ANN, ML. Now a days, AI has been using in various filed like security, finance industry, medical area, agriculture, education field etc. (Jha K., Doshi A., Patel P., & Shah M. 2019).

Now the industries are adopting AI techniques to help in various fields like:

- To grow more potent crops from farm
- To monitor field soil and growing conditions

- Pests control in the farm
- To put farmer's data in a pattern, improvise a range of different farming tasks in the food supply system, and aid to manage the workload.

Various factors like change in climate, food security, and population growth concerns have driven the various industries into looking for more innovative advances ways for the purpose of protecting and improving harvest growth. Because of this, AI is gradually emerging as part of the industry's technical evolution. There is a vital role of "Artificial Intelligence and Machine Learning" in the Agricultural Industry for Real-time crop monitoring in agriculture. The most common forms of Artificial Intelligence in farming seem to fall into the following main types:

Farming Robots

Various Corporations are focusing on the development of these autonomous robots which could handle basic agricultural jobs more effectively than human laborers like harvesting crops at a faster pace and high volume.

Soil and Crop Monitoring

Statistics taken by various drones are using by Companies with the help of AI (Artificial Intelligence) and deep learning algorithms. Companies are using technology (software based) to watch on soil and crop healthiness. A few years ago, the field statistics used to record manually which was time wasting and at the same time was not very precise. Now, with the innovative technologies, the entire field is geo tagged for the purpose of finding the actual field area. The solution one gets helped in weather advisory and remote sensing, monitoring and scheduling field activities (for complete traceability), educating agriculturalists to pick right strategies, helps in supervise overall crop healthiness and crop guess, and signals for the pest in the crops. Advance technologies like Artificial Intelligence can read and understand data to drive the real-time visions.

Small farmers across the world follow conventional farming practices because they are not educated enough to understand the science behind crop lifecycles, quality metrics, pests, and the latest micro fertilizers. These automated systems rely on Image-based resolutions to furnish knowledge on the overall wellbeing of the crops during the budding period and also the end quality of the harvested crops. It provides the following benefits:

- ***Farming Product Grading:*** As fresh products like fruits, vegetables, grains, etc. are distinguished by their color, shape, and size, their analysis and ranking are done based on the images captured by the drones. A farmer uploads image which he has taken with the help of phone and it reads by solution provided by technologies and determines the quality of the goods in real time, without any large efforts.
- ***Alarms on Harvest Infestation:*** Just with a click, a Farmer can understand if there are pests, viruses or foreign plants (weeds) are growing with their crops and also the solution is given by technologies. Crop viruses or pest infestation in the harvests are identified by solution (which uses deep-learning and image-processing and AI). It also provides tips on how that disease can be rectified and stopped from increasing further along with the parameters.

3.1.1 Predictive Analytics Using Machine Learning

Developed (machine learning) ML principles are used for the benefit of trace and foretell various environmental influences like the change in weather conditions during the crop yield. Several tools related to AI (Artificial Intelligence) and ML (machine learning) can anticipate the best time to sow the seeds and notify whenever there is a risk from pest invasions, and more. When to sow crops is a serious problem for farmers, also excess precipitation and drought can be a serious challenge. An App can be made for this purpose that uses machine learning and business intelligence. App can send advice message to related farmers which will show message like 'ideal time to sow'. Framers need not to install any sensors in the farm that saves money. They need only mobile phone for receiving this advice or alert message. Various examples of apps are as follows:

- ***AQUATEK:*** It is an application to help farmers to monitor the health of their farms with the help of their mobile devices which helps them to take action before there is a problem. Instead of installing a costly irrigation management system, farmers can track water usage and set accurate, precise irrigation plans by using app only.
- ***Kisan Yojana:*** "Kisan Yojana" is another famous agriculture app available for free of cost for Android users. Farmers can get info about all Government schemes using this app. It removes the info gap between the rural Government and People. Different states Government schemes can be easily delivered using application.
- ***IFFCO Kisan:*** "IFFCO Kisan" is one of the best apps in out of almost agricultural apps for Farmers. Climate forecast data, agriculture alerts to farmers in (10 Indian languages), latest agriculture guidance and various farming tips can be provided by this android application. They can take help of farming experts in an easy manner using this application. There is also various other projects, one of the Project is "Haritha". It is useful for the purpose of Automated Irrigation System for gardens of home (Anil A., Thampi A. R., John M. P., & Shanthi, K. J., 2012). One can collect historical climate data (for some past years), to calculate the crop-sowing period for the specific area and will do analysis using Artificial Intelligence. MAI is used to find the best sowing period which stands for Moisture Adequacy Index. It's a standard index to assess the level of adequacy of the soil moisture and the rainfall level to meet the essential water requirement of harvests (Microsoft News Center India 2015). Before sowing seeds, the farmers related to the area will wait to get a text message and will receive automated alert voice calls which will alert them whether harvests of their field are at potential hazard of a pest outbreak (on the basis of climate situations) or not and also will the know phase of the harvest.

3.1.2. Supply Chain Efficiencies

Companies make efficient and smart supply chain by using real-time data from the various data sections. These data-streams used to come from different sources. And to ensure a competent and reliable supply chain in various stages of the agriculture, Artificial Intelligence and related technologies are useful. Find a few listed here:

- **Transition Detection:** To obtain high-margin transactions, data scrutiny on multiple data lines with crowd-sourced information taken from buyer/producer markets and transporters with the use of transaction detection algorithm.
- **Quality Maintenance:** To frame up agriculture commodity's international standards to efficiently market across countries, computerized vision and AI-based self-grading and sorting is carried out for fruits and vegetables.
- **Credit Risk Management:** To ensure a very low risk operation, the credit delinquency which is one of the major challenging issues of current supply-chain is overcome by Crowd-sourced data, algorithms and analytics.
- **Agriculture -Mapping:** An agriculture map of supplies and commodities at a resolution of 1 sq. km can be obtained using satellite-based image analysis and crowd-sourced fusion.

As there is enormous possibilities of agriculture in the world, it's essential that the usage of technology should be ensured to a maximum extent to bring best for both consumers and farmers. In agriculture, to make advance technology widely available like AI there are many startups emerging in the country with the help of technological enhancement paired with favorable government policies. As the agricultural sector is heavily dependent on climatic conditions which are often unpredictable, AI comes as a great boon. As a matter of fact, agricultural industry depends upon the climatic conditions to a large extent which is largely unpredictable, AI can bring great benefits. AI is likely to transform the agricultural industry because of the benefits it offers. Artificial Intelligence is becoming more viable, with its computational power increasing and the adoption cost falling, especially for smallholder farmers.

3.1.3 Benefits of Artificial Intelligence and Machine Learning in Real Time Crop Monitoring

There are various benefits of Artificial intelligence and machine learning in real time crop monitoring as shown in Figure 4. Some of them are listed below:

Figure 4. Benefits of Artificial Intelligence in real Time Crop Monitoring System

- ***Artificial Intelligence helping farmer to analyze field data:*** Farms yield thousands of data points in the fields on the daily basis. Artificial Intelligence can help farmers can make better decisions by analyzing temperature, weather conditions, water usage or soil conditions. Artificial Intelligence technologies can assist farmers in making informed decision about the crops, seed choices, and resource utilization.

3.4.2 Precision Agriculture Is Possible by Artificial Intelligence

Precise agriculture makes use of Artificial Intelligence technology to aid in finding diseases in plants, poor plant nutrition, and pests on farms. By using AI, weeds can be detected and targeted which helps in choosing a kind of herbicides and unnecessary herbicides can be avoided to reach our food. This is called as precision agriculture.

3.1.4 Improvement in Agricultural Accuracy and Increase Productivity by Using Artificial Intelligence

To increase productivity and precision or agricultural accuracy using Artificial intelligence farmers can create forecasting system. These models can predict future weather patterns months ahead to aid the farmers' decision. This type of forecasting is particularly beneficial for small farms in some of the developing countries as their knowledge and data can be limited in many ways. Farmers nowadays are also reaching to the sky to analyze the farm in on the top of the ground data. Data captured through drones over fields is processed using deep learning algorithms and Computer vision. To identify problem areas and potential improvements, Artificial Intelligence enabled cameras can capture pictures of the whole field and analyze these pictures in near-real time by using drones. By using these drones one can cover large area of farm in a very less time as compare to human to monitor farm.

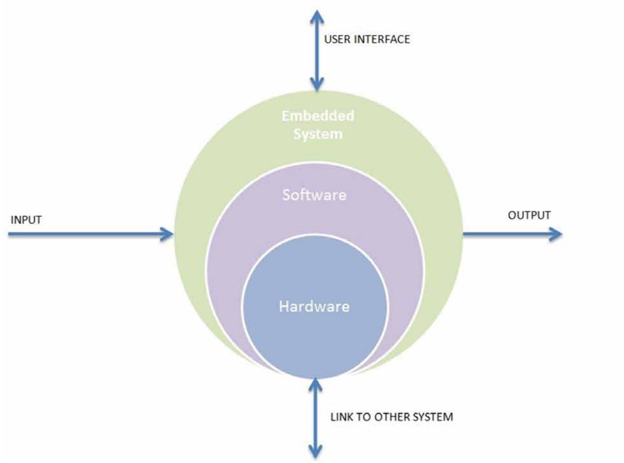
Workforce shortage is one of the biggest challenge most farmers are facing because of less people taking the interest in the farming profession. To harvest crops and keep farms productive, traditionally farms needs large number of workers, mostly seasonal only. Less number of people is able and willing to move to the land areas, as human have gone away from the agricultural societies to now living in cities. To help in this condition with shortage of workers, one of the solutions is Artificial Intelligence agriculture robots. These robots optimize the human workforce to bring the best benefits in the less time. Crops can be harvested in the higher volume and at a faster rate as compared to human workforce by using robots. These robots can more efficiently identify and eradicate weeds, and bring down the costs for farming by having a tendency of working continuously.

3.2 Embedded System Based Crop Monitoring System

Furthermore, AI (Artificial intelligence) and ML (Machine Learning) are mostly theories and data. AI and ML majorly refer to algorithms and programming. There should be a software hardware interface for the purpose of implementation of these logic-based concepts and algorithms. Figure 5 represents the embedded system structure.

The system by which this task can be accomplished is known as "Embedded systems". Hardware systems having chips with customized software programming are referred to as embedded systems. To

Figure 5. Embedded System Structure



implement hardware, we use various sensors like soil moisture sensors, temperature sensing device, humidity sensors, Light sensors etc.

3.3. Internet of Things Based Crop Monitoring System

IoT can be known as a shared pair of things or objects that can interact in between with help of Internet connection. It is very much helpful in farming. Data got from sensors can be sent to web server database using Internet Connection. By using Database server data can encode and process will start. For example, Irrigation will start automatically depending on data got from moisture and temperature sensors and periodically the notification message will go to farmers mobile. Now, Field can be monitored from anywhere (Rajalakshmi P. & Mahalakshmi S. D. 2016).

4. BENEFITS OF REAL TIME CROP MONITORING SYSTEM

By using Real Time Crop Monitoring System, one can monitor and collect data in a farm which will improve crop yield of a farm. Some other benefits are as follows:

- Production rate will increase with proper planting, proper irrigation.
- Water will use only when needed at an appropriate area with help of climate forecasts and various kind of soil moisture sensors.
- Farmers can visualize various parameters such as harvest production rate, moisture of soil, intensity of light etc. in real time and so get help to accelerate decision making process.
- Using Real Time Crop Monitoring System, farmers can decrease resource consumption and also total cost.
- Tools related to farm can be supervised and maintained according to failure prediction production rates, and labor effectiveness.
- Production quality will improve using new technologies.

5. ORGANIZATIONS/PEOPLE TO USE REAL TIME CROP MONITORING SYSTEM

Along with farmers, other people or organization which can get benefits from Real time crop monitoring system are as follows:

- **Agricultural managers and Agronomists:** The crop monitoring system reduces efforts and is very precise. Hence is being very commonly used by the agronomists (expert in soil management and field-crop production) for optimized use of resources.
- **Business owners:** As it counts on large data so, business owners can rely on their predictions for business investments.
- **State organizations:** This system is very useful for state organizations they can rely on this for decisions concerned with food security and ecological problems.

6. APPLICATIONS AND FUTURE OF REAL TIME CROP MONITORING SYSTEM

There are various applications of Real Time crop monitoring system which can help the farmers in future.

- Young farmers are making good investments in comparison to the elder ones for making artificial intelligence technology applicable in farming.
- Now farmers are using many new AI techniques like deep learning to diagnose the type of plant and can also help the farmers in creating the favorable environment for sustainable growth. Which certainly has increased the rate and quality of production.
- The use of artificial intelligence techniques in farming to diagnose the disease and weeds in farms is growing at a very fast speed through CNN, RNN or any other computational network.
- To provide the particular required environment to the plants using greenhouse farming, without human intervention can be done by using IoT, wireless technology, communication protocols and sensors, which are required for weather control and monitoring even without any human presence in the fields.
- Robots are another example of real time monitoring which can be used in every aspect of farming from seeding to harvesting which will usually require near about 25 to 30 workers for the same work.
- One more interesting use of AI technology in farming are drones with cameras, which are used for continuous real time monitoring of farms and collection of data for further analysis.

To self-drive the occasional practices in agriculture or to make Real time crop monitoring system in agriculture there will be need of IoT, machine learning, sensors, and various other advance technologies.

7. CONCLUSION

Because of Machine Learning and Artificial intelligence-based farming applications are making it possible for farmers to gather useful data. Small farmers and large landowners must understand the potential of smart technologies for farming to increase sustainability and competitiveness in their field productions.

As the population increasing rapidly, the demand can be successfully met if small farmers implement digital solutions in an efficient manner in their field.

REFERENCES

Anil, A., Thampi, A. R., John, M. P., & Shanthi, K. J. (2012, December). Project HARITHA-an automated irrigation system for home gardens. In *2012 Annual IEEE India Conference (INDICON)* (pp. 635-639). IEEE. 10.1109/INDCON.2012.6420695

Chandra. (2017). *How data-driven farming could transform agriculture*. https://www.youtube.com/watch?v=dpVylFjT-Cw&feature=youtu.be

Hayden. (nd.). *What Does "Data-Driven Farming" Mean?* https://blog.heatspring.com/what-does-data-driven-farming-mean/(2015)

Jha, K., Doshi, A., Patel, P., & Shah, M. (2019). *A comprehensive review on automation in agriculture using artificial intelligence*. Artificial Intelligence in Agriculture. doi:10.1016/j.aiia.2019.05.004

Le Mouël, C., Lattre-Gasquet, D., & Mora, O. (2018). *Land use and food security in 2050: a narrow road*. Academic Press.

Microsoft News Center India. (2015, May). *Digital Agriculture: Farmers in India are using AI to increase crop yields.* https://news.microsoft.com/en-in/features/ai-agriculture-icrisat-upl-india/

Rajalakshmi, P., & Mahalakshmi, S. D. (2016, January). IoT based crop-field monitoring and irrigation automation. In *2016 10th International Conference on Intelligent Systems and Control (ISCO)* (pp. 1-6). IEEE. 10.1109/ISCO.2016.7726900

Roy, S., & Bandyopadhyay, S. (2013). A Test-bed on real-time monitoring of agricultural parameters using wireless sensor networks for precision agriculture. *First international conference on intelligent infrastructure the 47th annual national convention at computer society of India CSI*.

Sawant, S., Mohite, J., Sakkan, M., & Pappula, S. (2019, July). Near Real Time Crop Loss Estimation using Remote Sensing Observations. In *2019 8th International Conference on Agro-Geoinformatics (Agro-Geoinformatics)* (pp. 1-5). IEEE. 10.1109/Agro-Geoinformatics.2019.8820217

Suchithra, Asuwini, Charumathi, & Lal. (2018). Monitoring Of Agricultural Crops Using Cloud and IoT with Sensor Data Validation. *International Journal of Pure and Applied Mathematics*.

Chapter 15
WSN, APSim, and Communication Model-Based Irrigation Optimization for Horticulture Crops in Real Time

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ABSTRACT

The use of wireless sensor networks, the internet of things, and advanced technologies lead to new direction of research in the agriculture domain called prescriptive agriculture. Prescriptive agriculture is the enforcement of precision agriculture, which is observing, measuring, and responding to inter and intra field variability of farm field. In this chapter, the advent of wireless sensor network, APSim, and communication model spurred a new direction in the farming domain at optimizing irrigation. Sensors are programmed to collect the datasets of climatic parameters such as relative humidity and temperature, where the datasets were forwarded to the server through a GSM module. Datasets collected were analyzed through statistical software for grown crops by considering inter and intra farm field conditions. Finally, information on irrigation is decimated through an algorithm designed by way2SMS and WebHost server.

INTRODUCTION

About 70% of all freshwater is utilized for landscape irrigation in farming around the world. Water plays a critical role in farming in nearly all aspects of determining the productivity of the crop. Even the good seeds and applying sufficient fertilizers fail to achieve their full potential if the plants are not optimally irrigated. Day by day water scarcity rapidly increasing due to a decline in the rainfall and food demand increasing for the consumption of the vast population. Present-day developing requests raising benefit per unit of land to fulfill staple enthusiasm to a tremendous people within lessened developing area zone. Towards accomplishing this objective, ranchers go with the tried and true way of thinking arrangements like trickle water system, satisfactory utilization of preparation, crop design, and so on.

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The development phases of a plant rely upon different variables like ecological conditions, soil quality, and other related boundaries. Water causes the plant to be new, yet also plant's tissue cell assumes a significant function through the assimilation of supplements and photosynthesis (Balakrishna K., and Rao, M. (2019)). The water system is the strategy for applying water remotely to the enhancement of the prerequisite to plants; eventually, plants get water from the sources like raining, dampness content in the air and soil. The satisfactory utilization of the water system helps in the presentation of harvests legitimately as well as by implication by affecting the accessibility of different supplements in taking, the circumstance of the social activity, and so on.

Wireless sensor innovation prodded another heading for the progression of the cultivating through the advanced technology. WSN (Wireless Sensor Network) alludes to spatially dispersed remote organization gadgets that utilization the sensor to screen the physical climate boundaries continuously (Balakrishna K. et al. (2018)). Innovation and arrangements are being applied in this domain to give an ideal choice to accumulate and deal with data to advance the water system through factual programming (Balakrishna K. (2020)). Besides, alarming environmental change and shortage of water demand better than ever techniques for present-day cultivating. APSim is measurable programming, which makes a social model for the inter and intra field inconstancy of the farm fields. Precision Agriculture is one of the encouraging areas in perceiving, estimating and reacting to inter and intra field changeability through a wireless network. A key segment of the precision farming methodology is the utilization of data innovation through a wide cluster of parts, for example, sensors, GSM module, computerized equipment, and programming. Enforcement of exactness precision agriculture choices progressively prompts another space called prescriptive horticulture.

Prescriptive Agriculture is a point by point, site-explicit proposal and understanding to assist ranchers with expanding their yield from the streamlining inputs. This technology captures huge amount of datasets from the farm fields and analyze the datasets based on the plant's condition and helps rancher's in decision making for the management of crops. It influences the site-specific for the ranchers at increasing yields and reducing inputs. Numerical based decision making for the irrigation for artificial intelligence-based for water system is achieved through factual programming software APSim software (Mare Srbinovska et al. 2014). In this paper, another methodology is proposed for the improvement of the water system for cultivation crops dependent on WSN, measurable programming and present-day innovation.

LITERATURE SURVEY

To analyze the work of state-of-art, here discussed relevant work done so far in the improvement of the irrigation system for the selected horticulture crops using advanced technologies.

Balakrishna K (2020) worked on optimizing irrigation for horticulture crops like Okra, Tomato, Bell pepper, Cucumber, and Cabbage. The author programmed a WSN device to gather the temperature and relative humidity of the rancher field for a determinate interval of 6 hours for nearly 50 days from 50 devices, which are deployed within a distance of 300-400 meters. Statistical based software like APSim model designed to optimize the irrigation for the selected crops considering the soil inter and intra variability of the farm fields. The mathematical simulated model shows that around 80 – 90% of water can be saved compared to drip irrigation.

(H. G. C. R. Laksiri et al. 2019) developed an efficient Internet of Things based irrigation system in Srilankan farm field. The researcher designed a low cost-effective and smart based irrigation system. The drip irrigation system based water optimization model is built first based on the soil moisture sensor conditions. Next, for efficient and smart water optimization and manually control the water supply by a remote user, Internet of Things based communication are integrated to provide a better model. The parameters collected such as temperature, relative humidity and raindrop sensors. At long last, a climate forecast calculation is executed to control the water flexibly as per the current climate condition. The proposed savvy water system framework will give a successful technique to inundate rancher's development.

(Y. Yao and Y. Yao. 2019) concentrated on plan and exploration of canny water system dependent on cloud framework innovations, for example, Internet, Cloud processing, Big data and Mobile applications. The smart water system focused around incorporated administration is imagined by amassing and investigating datasets identified with the water system. The related datasets, for example, soil dampness content, meteorological components and plant development stages consolidate with the horticultural specialists and numerical model data through the coding languages. The author suggests that the multiple application subsystem consisting of a primary system gives the comprehensive service of intelligent irrigation.

(J. R. dela Cruz et al. 2017) worked on limiting the water resources for the farmland using a simulation toolbox of MATLAB neural network. The author proposed a model named Smart Farm Automated Irrigation System (SFAIS) incorporating inter and intra related farm fields. The simulation of the model done using the artificial neural network in improving water usage.

(V. Ramachandran et al. 2018) worked on optimizing the water system by integrating the Internet of Things, cloud computing and optimizing tools. The water optimization devices deploy on-farm field consists of soil moisture, soil pH, soil class and environmental parameters. The sensors collected datasets are gathered in the Thingspeak cloud server and transferred to the cloud using a Wi-Fi modem and GSM cellular networks. The precision model is controlled using the solenoid valve of the ARM controller i.e., WEMOS D1. The proposed model is an experiment through a pilot-scale to check the optimization of water utilization.

Advanced from the discussed strategies and models propose that enhancement of the water system is still in infancy. Prescriptive Agriculture innovation is a developing territory propelling the variation of precision farming, which appears to have a great deal of convenience for investigators.

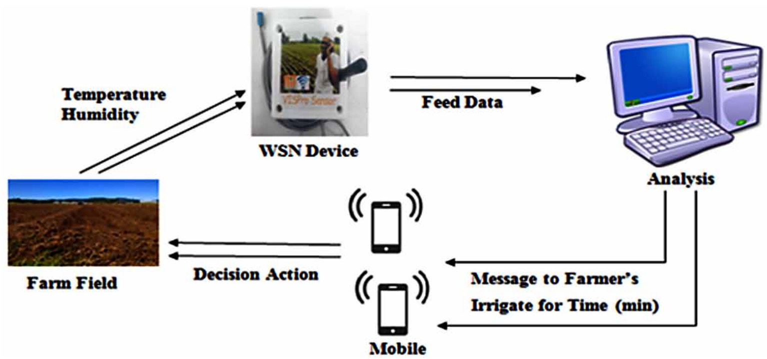
PROPOSED METHODOLOGY

The recommended framework entirety in three phases. From the start stage, the wireless device gathers and advances the temperature and relative dampness datasets from a GSM module to the server. In the second stage, received datasets are analyzed for further processing based on plant growth stages and other parameters. Then at the final stage, the streamlining of the water system for the plant for continuous environmental circumstance dependent on the volumetric water examination model through APSim simulator. The proposed model concept working flow is as shown in Figure 1.

WSN Based Dataset Collection

The temperature and relative dampness of the farm field is gathered with the integrated low power WSN. The design of WSN is as indicated in Figure 2, here temperature and relative dampness are recorded

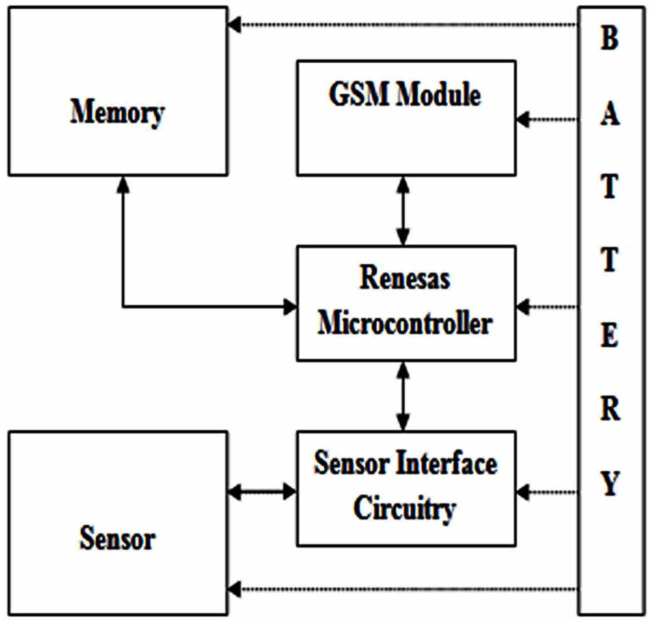
Figure 1. Proposed model working flow for water optimization.



with the DHT11 sensor (Ana Laura Diedrichs et al. 2014). DHT11 sensor temperature ranges from 0 – 50 þC and relative dampness ranges between 20 – 100% with a sampling rate of 1Hz i.e. one reading for every second. Temperature is recorded with NTC (Negative Temperature Coefficient) component having IC on the backside. Relative dampness recorded using the two electrodes and in between that one moisture holding substrate. The variation of the resistance value is correlated with temperature and relative dampness values and processed to the microcontroller through an IC. The variables dht11_rh and dht11_temp sequentially records temperature and relative dampness values and passed over the solitary wire convention with the exact time of every hour to assemble the informational collection. The microcontroller opted for the research work is RL78 (Renesas microcontroller) is associated with a GSM module and DHT11 sensor (Nattapol Kaewmard and Saiyan Saiyod. 2014). The gathered datasets are imparted at the client-server end for analysis through a GSM module, UART signals are used for the communication purpose such as RXD (receive), TXD (transmit) and GND (common ground). To initiate this process, the controller first sends the start pulse to the sensor to activate from low to high to transfer data as appeared in Figure 3. GSM module read and writes functions are controlled with the controller AT commands to forward and receive the datasets from the serial buffer register. A total of 100 wireless devices are plotted for the research work, 50 wireless devices each from two regions such as Varuna locale in Mysore and Pandavapura locale in Mandya. The wireless device is placed above 8-12 feet of height from the ground surface, where the sensor part is kept in a small pipe containing several pores on it for easy inflow and outflow of air. The soil surface is dug for about 8-10 inches and the pipe is placed vertically on that surface, where the sensor is kept inside that pipe to measure the exact values of plant root getting the temperature and relative dampness. In a similar manner placed 100 devices record the dataset's values for each hour for two seasons, each season considered 50 days. Figure 4 shows data received from the ranchers.

An absolute number of datasets of temperature and relative dampness of 35,893 have been gathered for two seasons, where during season 1 from both places 17,929 datasets are gathered (Mysore region of Varuna locale contains 9,147 and Mandya region of Pandavapura locale contains 8,782), during the season 2 from both places 17,964 datasets are gathered (Mysore region of Varuna locale contains 9, and Mandya region of Pandavapura locale contains 8,937).

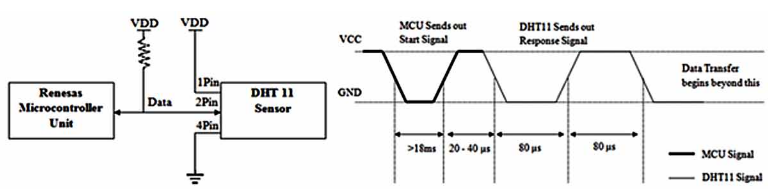
Figure 2. Wireless sensor device architecture



EXPERIMENTATION

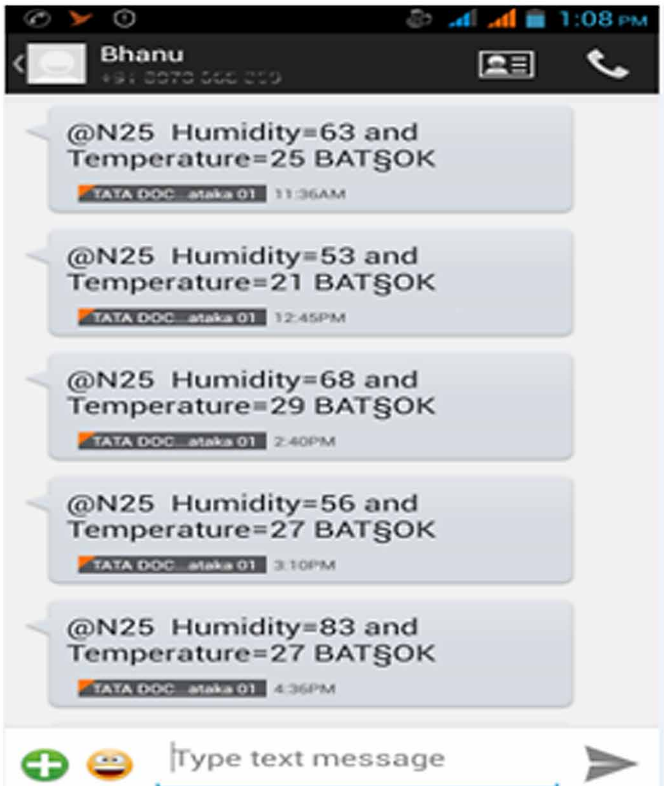
Here evaluated the proposed model for précising the water usage for the selected crops considering its various growth stages of plants. In the primary stage, for the chosen crops accumulated datasets are accomplished to validate the process depending on its growth stages. In the subsequent stage, relying upon the relevant parameters of the farm field enhancement of water utilization is processed. For the principal stage, the gathered datasets are validated through a Symbolic classifier strategy for an acceptance and non-acceptance class for the selected crops has been applied. In the subsequent stage, to optimize the water for crops an APSim based numerical model is carried.

Figure 3. Microcontroller interfacing with DHT11.



Both seasons of two regions such as Varuna and Pandavapura area datasets are considered for this experimentation. Statistical means are taken for a normal estimation of datasets for both the regions. Gathered datasets of 50 WSN devices plotted in the area for every 6 hours are distanced through the Statistical mean. Here Statistical mean applied to check the best harvests that can get for the ranchers

Figure 4. Datasets received at the rancher's end to registered cell through a GSM module.



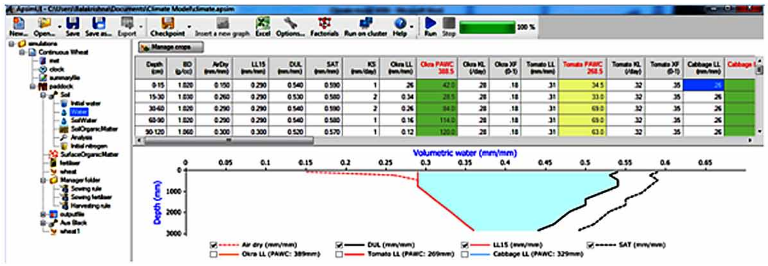
from their farm field considering the whole locale-dependent on the development stages of plant and varied climatic conditions.

For additional analysis, acquired datasets are given to APSim simulator system as follows. The datasets are stored in the ms excel sheet such as temperature and relative dampness, which are gathered from the farm fields for a specific time period. These datasets are given to the simulator to check or validate the acceptance and non-acceptance count. Based on the validation process, the decision model is built to support the ranchers from the assembled datasets. In the following stage, a numerical designed model advanced the water usage efficiency for the selected crops (Hamish E. Earthy colored et al. 2014). It is planned considering the inter and intra farm field variability with plant structure and other related parameters for example, profundity and structure as appeared in Figure 5 (Balakrishna K (2020)).

The computer simulation model designed numerically assesses the water extraction by the plant's root from the potential energy in both soil and water. From our research, we come to know that water has high potential energy in wet conditions, where water is easily flowing and taken from the plants. Then the water has low potential energy at dry condition, here unequivocally limited by the soil grid and plants do not get sufficient water. From Equation 4.1 we can assess the genuine harvest evapotranspiration for chose crops by accepting as 4mm/day for reference evapotranspiration at the two districts.

$$ET_{C,act} = [K_S * K_C + K_E] * ET_O \quad (1)$$

Figure 5. APSim simulation-based volumetric water analysis



Where,

$ET_{C,act}$ = evapotranspiration for actual crop.
K_S = coefficient of water stress.
K_C = coefficient of the basal crop.
K_E = evaporation of soil.
ET_O = reference evapotranspiration.

Table 1. Consumption part for selected crops

Crop	Okra	Tomato	Chilli	Carrot	Watermelon
q	0.45	0.40	0.50	0.35	0.55

Table 1 shows the consumption part (q) for chose crops to be specific okra, tomato, chilli, carrot, and watermelon. The threshold ranges for the selected crops are chosen based on the recommendation of the specialist and scientist from the Department of Agriculture Mysore. Here soil dampness typical variations considered within the range of 0.22 to 0.76 for all crops grown in the farm field. Table 2 shows the coefficient values for the water stress and basal crop based on the development stages of the plant.

$$TAW = 1000\,[\theta_{FC} - \theta_{WP}] * Z_R \qquad (2)$$

Table 2. Range of K_E and K_C

Growth Stages of Plants	K_E (mm)	K_C				
		Okra	Tomato	Chilli	Carrot	Watermelon
1	18	0.50	0.60	0.55	0.60	0.60
2	28	1.05	1.15	1.10	1.05	1.00
3	28	1.05	1.15	1.10	1.05	1.00
4	12	0.90	0.80	0.80	0.90	0.90

Where,

θ_{FC} = water content at field capacity.
θ_{WP} = water content at wilting point.
Z_R = rooting depth.

$$RAW = (p * TAW) \tag{3}$$

Where, p = Consumption part.

Table 3. Growth stage based optimization of water.

Growth Stages		Tomato	Beans	Chilli	Carrot	Watermelon
1	**TAW**	12.25	12.25	12.25	12.25	12.25
	RAW	5.075	5.45	4.056	5.75	5.075
2 & 3	**TAW**	26.25	26.25	26.25	26.25	26.25
	RAW	13.15	11.8	9.10	12.5	13.15
4	**TAW**	41.25	41.25	41.25	41.25	41.25
	RAW	21.225	17.2	13.15	18.25	19.25

From Equation 4.2 to Equation 4.3 the Total Available Water (TAW) and Readily Available Water (RAW) for the selected crops are discovered. The wilting point (θ_{WP}) is taken as 0.09 and water content at field capacity (θ_{FC}) is taken as 0.20. The root depth (Z_R) for a crop is taken with variation, for example, 16 cm (phase 1), 35 cm (phase 2), 35 cm (phase 3) and 50 cm (phase 4). TAW is the aggregate sum of water that the harvest can extricate from the root, where it relies upon the rooting depth and the soil surface of a plant. Some portion of the water being held by soil particles in the plant root zone is in more prominent power. At this stage, the plant feels harder to extract the water from the root zone due to the potential energy. Finally, the plant root zone does not extract any sort of water from its root zone, when a wilting point has arrived. The water uptake for the plant roots will be diminished to easy flow when the wilting point reached accessible to the roots easily. At that point, water supply to the plant will be quicker and ET_C rises to maximum due to the wet soil conditions. Next when the soil becomes dry then the plant's roots encounter pressure inflow of water underneath soil water content falls limit esteems. To avoid the stress for plant's root zone here shown the watering needs to be given for plants considering its growth stages and all shown in Table 3.

$$K_S = \frac{TAW - D_{RZ}}{TAW - RAW} \tag{4}$$

Where,

K_S = stress coefficient of soil water

D_{RZ} = root zone depletion.
TAW = Total available water
RAW = readily available water

$$K_S = 1 \text{ if } D_{RZ} < \text{RAW} \tag{5}$$

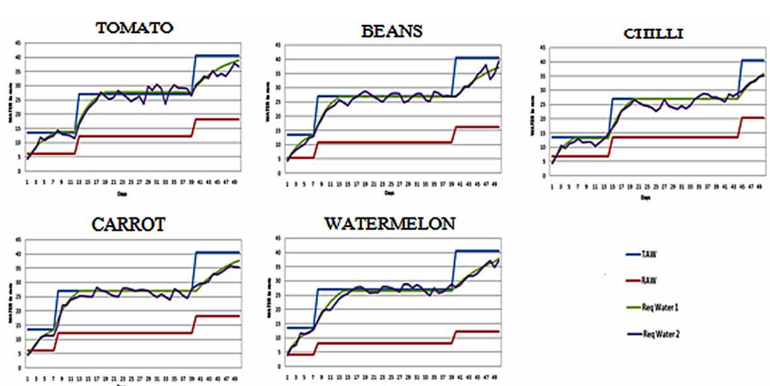
For assessment of the stress coefficient of soil water, the numerical model takes the estimations of TAW, RAW, D_{RZ} and reenacts as in Equation 4. The K_S decides the amount of irrigation needed for plants every day from the root zone of the plant. Equation 5 determines that at this stage, plants do not need any extra water for their normal and healthy growth.

RESULTS

In this segment, the computer simulation model shows that numerical model analyses led to a model dependent on our datasets with the inter and intra farm field parameters. The figure shows that considering the parameters of chosen plants relying upon both the ecological and field boundaries remembering the phases of development of plants, we get TAW, RAW, Required water 1 and Required water 2. The root zone of plants upholds a certain amount of water after the irrigation, this is called TAW. The uptake of water by the plants without suffering water stress is called RAW. The actual water needed for the plants to normal growth for chosen crops is considered as Required water 1, while reenacted water prerequisite for the picked plants is shown as Required water 2. Figure 6 shows relying upon the field atmosphere the water needed for explicit yields for Season 1 at the Varuna area. It assists spare with watering by giving it as needed to the plants considering climatic conditions. From the given in Equation 1 – 5, here the K_C, K_E, K_S, E_T, p, Z_R and D_{RZ} esteem are changed step by step for the stages.

Table 4 shows a performance of water improvement for select yields like tomato, beans, chilli, carrot, and watermelon. Computer simulated numerical model analyses are carried for the chosen five crops for both seasons of Varuna and Pandavapura Locale. The requirement water 1 and requirement water 2

Figure 6. Varuna Locale water requirement for season 1.



shows from the above figure to check the performance analysis of the irrigation of the farm field. This outcome has been contrasted with the extreme squandering of water in Indian cultivating and has accomplished irrigation as given in Table 4 (Department of Agr, GOK, 2013). The two seasons datasets of two locale regions of both temperature and relative dampness range up to 35,893 in numbers. When contrasted with all past work, parameters of inter and intra farm field consideration are larger, datasets gathered were also too larger.

Table 4. Water saved through advanced technology.

Crops	Varuna		Pandavapura	
	Season 1 Savings in Water %	Season 2 Savings in Water %	Season 1 Savings in Water %	Season 2 Savings in Water %
Tomato	60.52	62.84	59.14	60.84
Beans	53.68	58.37	57.45	57.29
Chilli	59.57	64.40	58.53	57.27
Carrot	54.27	54.17	49.17	51.38
Watermelon	52.56	54.27	51.05	56.23

The theoretical outline for the data decimation is as appeared in Figure 7, where the Way2SMS gateway protocol forwards the information to the rancher's end for further actions to take.

Figure 7. Theoretical diagram for automating the decimation information

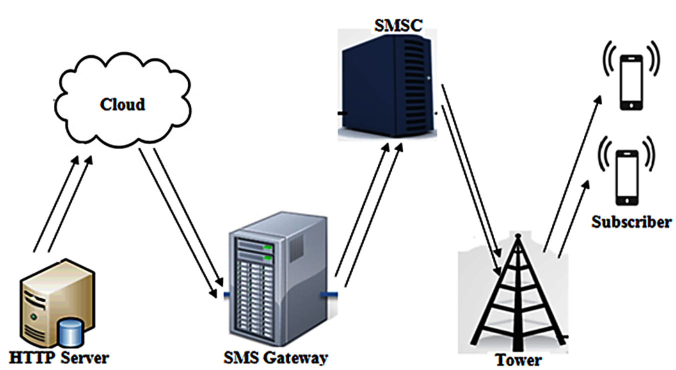
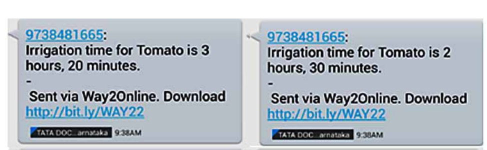


Figure 8. Decimated information given to the rancher's



The automation of the information to the ranchers end is completed using the integration of a way2sms with a web host server deals. Information forwarded like duration of irrigation to precise the irrigation at the farm field. Figure 8 gives some example messages which have been sent to the ranchers to demonstrate

CONCLUSION

In this work, an advancement of the irrigation is achieved from the computer based numerical model using the APsim and Matlab Software. Before the analysis, the datasets are gathered through the wireless devices placed in the farm field are sends the information to the server through a GSM module. The numerical model has created for chosen crops like tomato, beans, chilli, carrot, and watermelon which were appeared to streamline the water utilization. Water advancement accomplished in the two locales for the picked crops has been with varieties going around 70.38-82.18% with water investment funds ranges around 40.18-54.30%.

REFERENCES

Balakrishna, K., & Rao, M. (2019). Tomato Plant Leaves Disease Classification Using KNN and PNN. International Journal of Computer Vision and Image Processing, 9(1), 51–63. doi:10.4018/IJCVIP.2019010104 doi:10.4018/IJCVIP.2019010104

Balakrishna, K. (2020). Fusion Approach-Based Horticulture Plant Diseases Identification Using Image Processing. In S. Chakraborty & K. Mali (Eds.), Applications of Advanced Machine Intelligence in Computer Vision and Object Recognition: Emerging Research and Opportunities (pp. 119–132). IGI Global. doi:10.4018/978-1-7998-2736-8.ch005 doi:10.4018/978-1-7998-2736-8.ch005

Balakrishna, K. (2020). WSN-Based Information Dissemination for Optimizing Irrigation Through Prescriptive Farming. International Journal of Agricultural and Environmental Information Systems, 11(4), 41–54. doi:10.4018/IJAEIS.2020100103 doi:10.4018/IJAEIS.2020100103

Balakrishna, Rao, & Kumar. (2018). A WSN Application to Optimize the Irrigation for Horticulture Crops in Real-time using Climatic Parameters. *Elsevier Scopus Journal of Advanced Research in Dynamic and Control Systems, 10*(12), 199-207.

dela Cruz, J. R., Baldovino, R. G., Bandala, A. A., & Dadios, E. P. (2017). Water usage optimization of Smart Farm Automated Irrigation System using artificial neural network. *2017 5th International Conference on Information and Communication Technology (ICoIC7)*, 1-5. doi:10.1109/ICoICT.2017.807466810.1109/ICoICT.2017.8074668

Diedrichs. (2014). Low-Power Wireless Sensor Network for Frost Monitoring in Agriculture Research. IEEE.

Government of Agriculture. (2013). State of Indian Agriculture 2012-13. Ministry of Agriculture Department of Agriculture & Cooperation New Delhi.

Hamish, Brown, Huth, Holzworth, Teixeira, Zyskowski, Hargreaves, & Moot. (2014). Plant modeling framework: Software for building and running crop models on the APSIM platform. Journal Environmental Modeling and Software, 385-398.

Kaewmard & Saiyod. (2014). Sensor Data Collection and Irrigation Control on Vegetable Crop using Smart Phone and Wireless Sensor Networks for Smart Farm. IEEE.

Laksiri, H. G. C. R., Dharmagunawardhana, H. A. C., & Wijayakulasooriya, J. V. (2019). Design and Optimization of IoT Based Smart Irrigation System in Sri Lanka. *2019 14th Conference on Industrial and Information Systems (ICIIS)*, 198-202.

Ramachandran, V., Ramalakshmi, R., & Srinivasan, S. (2018). An Automated Irrigation System for Smart Agriculture Using the Internet of Things. *2018 15th International Conference on Control, Automation, Robotics and Vision (ICARCV)*, 210-215. doi:10.1109/ICARCV.2018.858122110.1109/ICARCV.2018.8581221

Srbinovska, Gavrovski, Dimcev, Krkoleva, & Borozan. (2014). *Environmental parameters monitoring in precision agriculture using wireless sensor networks*. Elsevier.

Yao, Y., & Yao, Y. (2019). Design and Research of Intelligent Irrigation Things Cloud System. *2019 International Conference on Information Technology and Computer Application (ITCA)*, 167-170. doi:10.1109/ITCA49981.2019.0004310.1109/ITCA49981.2019.00043

Chapter 16
Using Drones in Smart Farming

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ABSTRACT

Smart farming is the one area that has dependably been entrusted with giving nourishment to the world. With the consistently expanding populace, the horticultural segment needs to ensure that it copes with technology in order to build the measure of yield to meet the nourishment prerequisites of the world. To build the produce from farming, every single agrarian partner needs to accordingly get rid of customary rural practices and grasp current horticultural practices that will upset the field of agribusiness. One of these innovations that are intended to alter the field of agribusiness is the fuse of drones into cultivating. Drones can help famers in a range of tasks from analysis and planning to the real planting of yields and the ensuing observing of fields to find out wellbeing and development. This aim of this chapter is to provide an overview of how drones can help take agriculture to new sustainability heights.

INTRODUCTION

Smart Farming speaks to the utilization of present day Information and Communication Technologies (ICT) into agribusiness, prompting what can be known as a Third Green Revolution. Smart Farming has a genuine potential to convey a progressively gainful and maintainable horticultural creation, in view of an increasingly exact and asset proficient methodology. If we see from farmer's point of view, Smart Farming equip the farmer with an extra incentive as better basic leadership and the executives. Based on these, smart farming is emphatically related, to 3 interconnected innovation fields:

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1. **Management Information Systems:** Arranged frameworks for gathering, handling, putting away, and spreading information in the structure expected to do a farm's tasks and capacities
2. **Precision Farming: Precision agriculture** (**PA**), **satellite farming** or **site specific crop management** (**SSCM**) is a farming management idea based on perceiving, computing and acknowledging to inter and intra-field variability in yields. The ultimate aim of of precision agriculture research is to describe a decision support system (DSS) for the entire farm management along with the objective of optimizing returns on inputs while preserving resources.
3. **Agricultural automation and robotics:** The procedure of applying, robotics, automatic control and artificial intelligence techniques at all dimensions of horticultural creation, including farmbots and farmdrones

An **agricultural drone** is an unmanned aerial vehicle connected to cultivating so as to help increment crop creation and screen crop development. Sensors and computerized imaging abilities can give farmers a more extravagant image of their fields. This data may prove helpful in improving harvest yields and farm productivity. As farms become bigger and progressively effective to satisfy this raising need, drones will demonstrate precious in accurately dealing with a farm's crucial activities. (Stehr, Nikki J., 2015)

With advances, for example, computerization and GPS direction that have officially changed the cultivating business, drones are currently ready to modernize it indeed. Here are a few ways by which drones can satisfy various jobs to help farmers all through the yield cycle.

- Soil and Field Analysis
- Crop Monitoring
- Irrigation
- Health Assessment

Also, the drones can review the harvests for the farmer periodically to their preference.

Every week, every day, or even hourly, pictures can display the modifications in the yields after some time, along with this it also shows possible "inconvenience spots ". Having perceived these bother identifies, farmers can attempt to improve crop the board and creation

AGRICULTURAL DRONES: WHAT FARMERS NEED TO KNOW

Using drones for agribusiness is an interesting issue nowadays, and all things considered. These UAVs, as they are in some cases called, are rapidly turning into a main apparatus in a farmer's precision hardware blend. The present farmers need to manage progressively complex concerns. For example issues like water which considers both quality and amount, changes in the environment, glyphosate-safe weeds, quality of the soil, unsure item costs, and increasing input prices.

Farm land is isolated using Precision Farming into zones which is exclusively made do with a scope of precision machinery equipped with GPS. Innovation empowers farmers to gather, cache, join and examine the levels of information which manage precision nutrient and irrigation management.

Farmers uses the assortments of sources to construct these information layers. Yield screens, soil test results, moisture and nutrient sensors, and climate bolsters are for the most part valuable information sources. Notwithstanding these chronicled informational indexes, new innovations, similar to rambles, can give a perspective on the present state of the in-field crop.

Piloted unmanned drone flying machine is quick turning into an industry standard inside the rural and cultivating parts. Among the numerous utilizations drones give, maybe the most pivotal is their capacity to gather fundamentally indispensable data to advise and teach users, notwithstanding easily supplanting a great part of the man-controlled work required on high-land activities.

In the present current society, cultivating is never again the crude element of years past. Or maybe, cultivating has been in walk with the remainder of society as an aggregate entire, sharing in and fusing cutting edge innovation into generation tasks to accomplish a large number of objectives.

As the cultivating business keeps on developing at a quick flame pace, makers have turned out to be vigorously put resources into staying informed concerning "brilliant" gadgets, for example, drones to redesign old cultivating strategies and lift production in a significant way.

Inarguably, drone farming innovation is viewed as the most imperative advancement as of late for the agricultural domain, with countless seen by means of drones use in everyday farming and production operations.

Ways for Gathering the "What's Happening Right Now" Data Layer

Entire agricultural land, in-season, flow condition information is a standout amongst the profitable snippets of data in a precision farming. With the help of this information a farmer can find the issues in advance and quickly pick suitable intercessions. Spot-checking, which is the well-known strategy for getting this data today, this does not precisely catch conditions over a whole farm.

Infrared cameras also called NDVI cameras is used by Manned surveillance satellites and the most necessary information hotspots for entire farm condition appraisal are RGB cameras. These data's are most appropriate for looking over a huge number of sections of land at once, where the time and assets required scheduling and examine by these methods legitimizes cost and multifaceted nature.

A new method to infer information related to the farmland is represented by Agricultural drones. The persuading reason behind the usage of drones is the outcomes produced are on-demand; at whatever point, wherever place required, the drone is feasible and can be passed on quickly. A farmer can have their drone in the back part of the truck so that the farmland data will be received by the next day or sooner. It's hard to beat the promptness and solace of masterminding the strategic, the data, and drawing near consistent results; just drones offer these favourable circumstances

Drones are basically sensible, it requires a capital endeavour when appeared differently in relation to most cultivate equipment. Action is respectably fundamental, and getting less difficult with each new time of flight gear. They are secured and solid, but difficult to incorporate into the yield exploring work process; while visiting a field to check for ground issues, the drones can be passed on to assemble aeronautical data. Be that as it may, the veritable central purposes of automatons are not about the gear; the regard is in the settlement, quality and utility of the last information item. (Tom McKinnon, 2016)

Drone-enabled scouting is a helpful method to gather the "what's going on this moment" information. There are 3 principle components to utilizing an UAV successfully to do this:

1. getting the sensors over the field,
2. the sensors themselves, and
3. the data analysis

At long last, these are the administrative and business angles to consider

Drone Capabilities

Crop Data Collection

Drone aircraft gather fundamentally essential on-request, constant data with accuracy results that can be promptly depended on.

The particularly exact information gathered from drones can be utilized to support high-effectiveness planting and developing by investigating crop improvement by means of on-going checking, inside and out examining and consistent measuring

Data given by drones help makers and farmers to extraordinarily diminish costs and to diminish pesticide conditions that are perilous to human wellbeing.

Analysis of Soil and Fields

Piloted drones utilize incorporated three-dimensional, thermal imagery to evaluate and figure by and large soil and field wellbeing to decide whether upgrades are required before planting

Robbery and Burglary Concerns Farmers have encountered burglary of products, property, and animals since the early beginnings of the business.

Subsequently, farmers have energetically grasped drone technology because of its capacity to give 24/7 observing of fields, property, products, domesticated animals and more.

Drone Mapping and Surveying

Drones help farmers in mapping out substantial spreads of real esatate to deliberately develop their harvests in the most valuable design.

State-of-the-art flight arranging projects can be effectively introduced into drones to help farmers in illustration and mapping their zones of inclusion for ideal cultivating and production.

Exactitude

Precision agriculture is vigorously dependent upon drone-powered technology. Cultivating systems of days gone by were to a great extent dependent upon labor and mirrored a nonattendance of exactness information accumulation. Then again, cultivating today is overseen in a ultra-exact style through automaton air ship went for accomplishing the most abnormal amounts of viability with respect to profitability, amount, quality, yield, and generally speaking advantages.

Operation and Reliability

Quickly advancing drone technology has brought about refined drone aircraft promptly accessible on the present market that highlights superior power, simplicity of activity, and a vigorous dimension of unwavering quality. Technological progressions have rendered drones surprisingly simple to incorporate with farm operations and work process to promptly help profitability and make benefits.

Diversity of Abilities

Producers within the agricultural and cultivating fields are unhesitatingly putting resources into unmanned drone aircrafts each day. The pack of drone-related advantages effectively influence buy choices for purchasers as they make very instructed, all around educated choices perceptive of the decent variety of advantages drones give, from yield crop-dusting and spraying to providing real-time field-level surveillance, and substantially more

Ease of Operation

Piloting unmanned drone aircraft requires instruction and preliminary measures.

Notwithstanding the requirement for informed background in drone operation, the obligatory instruction measures are superficial in nature and once accumulated clients can without much of a stretch and effectively pilot drone aircrafts.

Evolving technology has rendered drone airplane basic, safe, and truly dependable with operational estimates that are ending up progressively instinctive and easy to use. The consistent mix of drones alongside their simplicity of activity have altered the manner in which agricultural producers and farmers develop yields and gather land and field information to guarantee by and large terrain health.

Manpower and Health Conditions

The present drone aircraft can assume the challenging undertakings of spraying and crop dusting. With dronestaking control over these troublesome assignments, workers never again need to persevere through delayed presentation times to pesticides, dust, and different perilous airborne components.

Undeniably more exact than less innovatively propelled hardware, for example, tractors, drones can administer a very explicit amount of fluid to crops, along these lines decreasing waste and expenses to farmers.

Return on Investments and Financial Considerations

Drone investments are a significant choice requiring a lot of research and thought. Return on Investment. Farmers reluctant to incorporate drone technology inside their activities might just be mitigated by the learning that putting resources into drone aircraft has been demonstrated to give astounding degrees of profitability and give a wide scope of advantages that basically can't be accomplished by some other methods. Much like costly farm equipment, drones are a necessary piece of any feasible and present day farm task and should be viewed as a fundamental apparatus for continuous achievement. (Jeremy Jensen, 2019)

HOW DO DRONES HELP FARMERS?

Precision Agriculture or smart farming relies on the utilization of cutting edge methods in the administration of harvests to expand the farm yield without trading off the quality of the product. Commercial drones are sufficiently enormous to convey remote discovering innovation which requires satellite network or the utilization of kept an eye on air ship.

In Agriculture, a vital use for UAV's is thermal imaging. Multi- spectral sensors are mounted on a drone, this helps farmers an important picture of how their harvests will be, explicitly crop shade, perform under various developing strategies. Imaging information from a drone is a decent pointer of crop vigor and canopy stress..

UAV'S imagery would help the farmer to screen what's happening in his farm, without the need of reviewing the farm independent from anyone else or procuring individuals for it. The farmer would get the exact thought that on which zones he should concentrate more, where to dispense more assets, and whether the zone is appropriate for a specific harvest or not, and what might be the likelihood of a high return. (Len Calderone, 2017)

This would surely engage the farmers and moderate vulnerability and defenselessness that dependably float over the farming division. It isn't that only the big farmers would profit by drone technology. As governments put more accentuation on boosting the appropriation of this innovation and drones would be broadly utilized in farming, later on, they would be generally utilized as basic machines for cultivation.

Multi- spectral sensors enable a farmer to accurately apply required water, manures, or pesticides just where they are required as opposed to applying similar sums over the whole land. Multi- spectral sensors procure imagery in bands which can detect herbage wellbeing and recognize territories in the lands which are nitrogen insufficient via a procedure known as Normalized Difference Vegetation Index. Farmers need to assess yield wellbeing and spot out bacterial or parasitic diseases. By checking a harvest utilizing both near infrared light and visible, UAV's conveyed gadgets can distinguish which crops reflect diverse measures of green light and NIR light. This information can produce a multi-spectral picture which follow some changes in plants and uncovers their wellbeing.

Yield Spraying with a UAV (ramble) sprayer needn't bother with a runway; the automaton can take off and land vertically. Flying at the low stature of a few yards, the harvest sprinkling can be controlled. Automatons are sensible for a wide scope of complex scene, harvests and plantings of shifting statures. Definite and exact harvest splashing ensures the best incorporation and utilization of manures or pesticides.

Aerial application—crop cleaning — incorporates showering crops with crop insurance things from an agricultural aircraft. Until rambles followed along, a farmer required a specific rural airplane to play out this movement, which was exorbitant and not outstandingly correct. By and by, a rancher can cut costs with their own one of a kind UAV Sprayer

THE PROS AND CONS OF DRONES IN AGRICULTURE

Pros

1. Review

Automatons could be used for soil and field assessment. They can be used to convey careful 3-D maps that can be used to lead soil examination on soil property, dampness substance, and soil disintegration. This is basic in orchestrating seed planting structures. In reality, even in the wake of planting, such information is important for both water framework and the organization of the nitrogen level in the environment.

2.Sowing

Despite the fact that not exactly predominant at this time, a few manufacturers have thought of frameworks ready to shoot pods which contains seeds and plant nutrients into the effectively arranged soil. It significantly diminishes the cost of the sowing..

3. Monitoring

The biggest impediment in cultivating is deficient crop monitoring of vast lands. This test is exacerbated by the ascent of unusual climate designs which leads to the expanded dangers and maintenance costs. Drones can be utilized to create time series animations to indicate exact harvest advancement which uncovers production wasteful aspects thus better better crop management.

4. Drones for Agriculture Spraying

Using ultrasonic resounding and lasers, automatons can change tallness with an alteration in geology and topography. Their ability to inspect and adjust its good ways from the most punctual stage empowers them to sprinkle the correct proportion of the perfect liquid similarly logically. This results in extended efficiency since the proportion of water going into groundwater is restricted. Sprinkling using meanders aimlessly has furthermore wound up being speedier than other standard systems.

5. Irrigation

Automatons outfitted with warm, hyper-unearthly, or warm sensors can recognize the bits of the field have ended up being dry. Along these lines the recognized territories can be taken care of promptly making water system exact and timely.

6. Health Assessment

A couple of automatons are prepared for separating crops using obvious and close to infrared light. Onboard light preparing gadgets are then prepared to perceive the proportions of green and close infrared light reflected by the plants. For outlining the plant wellbeing these data is used to make multi-ghastly pictures. (Vikram Puri, Anand Nayyar & Linesh Raja, 2017)

7. Easier to Deploy

Prior to the utilization of drones, farmers who needed to direct aerial surveys of their farms for multispectral imaging had no real option except to do them utilizing kept an eye on air ship. In addition to the fact that flying is kept an eye on airplane progressively costly, yet it is likewise more strategically muddled. Between searching for a pilot fit for flying the flying machine, verifying consent from air traffic, and taking off from a sizable airfield, working a kept an eye on flying machine takes a ton of time, exertion, and labor. (Laurent Probst, Bertrand Pedersen & Lauriane Dakkak-Arnoux, 2018)

Cons

1. Flight Time and Flight Range

There are a couple of issues with automatons in farming. Larger drones have short flight time with the range of 20 minutes to an hour. This time period controls the land that it can cover for each charge. The flight goes in like manner limits the breadth that can be spread in the midst of each flight time. Automatons that are costlier always offer longer flight time and longer range.

2. Initial Cost of Purchase

Automatons with the features that qualify them for use in the agribusiness are over the top expensive. This is by and large so for fixed wing rambles which could cost up to $25000 (PrecisionHawk's Lancaster). For specific automatons, the staggering cost is complete of hardware, programming, mechanical assemblies and imaging sensors.

Obtaining drones that doesn't come furnished with the significant equipment could be more affordable. Regardless, the perfect cameras and the getting ready writing computer programs are over the top making it similarly capital concentrated. Acquiring drones arranged for use in agribusiness could show excessive in the short run anyway advantageous as time goes on.

3. Federal Laws

The usage of automatons for farming purposes behind existing is seen as business. This infers the ranchers needs to encounter FAA overseer planning to acquire a remote pilot support or agreement a director with such capacities.

4. Interference Within the Airspace

Agricultural drones share a similar airspace with physically kept an eye on airplane. Henceforth they are inclined to obstruction.

5. Connectivity

A huge segment of the arable farmlands in the US have no online consideration expecting any. This infers any rancher intending to use rambles needs to place assets into system or buy an automaton prepared for getting and taking care of data locally in a game plan that can later be dealt with

6. Knowledge and Skill

. The photos require examination by a talented and capable staff for them to interpret any important information. This infers an average rancher without these capacities may require getting ready or may be constrained to utilize a talented faculty familiar with the examination programming to help with the image processing.

Automaton innovation keeps improving day by day. As many drone makers enter into the business, the cost of the automatons will be reduced.

7. Licensing Requirements

Choosing to utilize and rones for agribusiness isn't as basic as purchasing an drone and flying it when you're in the farm. Utilizing androne to improve farm the board is viewed as a business drone application, and all business drone pilots should be affirmed under the FAA's Part 107 principles. The procedure of accreditation includes taking and passing a 60-thing different decision information test, which will set you back in any event $150. The test is very exhaustive and will cover a few subjects concerning drone flight, for example, the impact of meteorological conditions, airspace orders, and interpreting sectional chart

DRONES HELP INCREASE PROFITS AND YIELDS

Studies have appeared if UAVs are created by 2025; it will be an $82 billion industry, with 80% of the advantages found in agribusiness. This is more vital now than any other time in recent memory, with the worldwide populace proceeding to develop at a high pace, it is fundamental to upgrade the utilization of water assets and to increment agricultural productionwith a need of nourishing 8 billion people by 2030. The objective is to improve farmer's benefits and collect yields while lessening the negative effects of cultivating on the condition that originate from over-utilization of synthetics.

Here are three hints for utilizing drones to support returns and increment benefits:

1. Fly early, fly often.

Exploring fields utilizing drones spares time contrasted and exploring the field from the beginning. In 20-25 minutes, an AgribotixEnduro™ quad drone can cover 160 sections of land. It's simple and cost-productive to investigate a recently planted seedbed, replant if vital, and check again to confirm development. Fly after climate occasions to scout for harvest harm. Fly intermittently all through the developing season to check weed or vermin issues from the beginning and to advise choices about exactness input application and water system.

2. Make decisions based on data, not hunches.

Drones catch field-level insights concerning crops that basically can't be coordinated by conventional spot checks. Drones empowered pictures transferred to the FarmLens™ investigation stage are prepared in only hours. The on-going data can be utilized to make quick move inside a basic fateful opening. The FarmLens platform can be utilized to compute stand thickness, distinguish ailment and bug invasions, find water system issues, and give information to precision agricultureequipment.

3. Maximize the capabilities of your equipment.

Exactness gear gives the capacity to optimize inputs and to drive down expenses. Agribotixsolutions are basic devices in any precision program. Drones empowered agricultural intelligence is the information that drives exactness agriculturepractices, with solid degree of profitability. From precision fertilizer application to help yield, to advancing contribution to decrease costs, to staying away from harvest misfortunes through early distinguishing proof and exactness mediation, cultivators can hope to see expanded benefits at gather time. All the way, our prescribed work process for utilizing adrone to design a precision application is as per the following:

- Identify focal points in your field utilizing the FarmLens Field Health Report.
- If important, visit the field to evaluate local conditions.
- Download the Shape file from your Farm Lens Professional administration and import it into your picked agricultural management software.
- Combine with some other information layers, decide proper application rates and relegate them to scopes of the shape document's framework esteems.
- Use the subsequent document to drive the variable rate application.

FARMING ACTIVITY AND SCHEDULE THAT CAN DEPLOY DRONES

Agricultural Farmers can utilize drones combined with a MultiSpectral sensor and the correct Agronomist to catch exact information for the wellbeing of their plantations, water dispersion and pesticide plans required into the present precision farming. The usage of drones in the agricultural division will build yield and diminish expenses to help combat water deficiencies and over splashing of pesticides.

Farming drone stages can be altered to suit an assortment of requirements, so it is fitting for farmers to have a few drones for various purposes. Drones work by method for a few propellers which lift them into the air, with the height, speed, and direction being constrained by a usable on the ground by means of remote control.

Drones can be utilized to screen domesticated animals, evaluate crop health, survey dry spell conditions, and even to apply pesticides. The key is to have the correct drone accessories for the activity that you expect to complete. For instance, a superior quality camera will give clear, succinct film, while warm imaging programming will enable you to get territories of warmth over your harvests and domesticated animals.

Farmers normally require UAVs to be pre-modified for flight, utilizing the ground station programming to request that the flight way is contained inside their flying height and property line, making a confined box around the property. While working along these lines, every steers check would then be able to be a piece of a routine comprising of auto-propelling the framework for flight, and furthermore observing the live video feed on screen. Since all video is recorded by the framework's ground station programming, there is no genuine need to stress when cows pass the perspective rapidly.

Usage of Drones in Sowing

Ranchers can meld the different features available in developing cultivating automatons to ensure that the seeding and planting structures are a triumph. Automatons are fitted with top quality cameras that take both 2-D and 3-D pictures and accounts of the ranch that is being mulled over. These 2-D and 3-D pictures and accounts can later be considered by the rancher to get information related to the geography of the land, the earth plan in various bits of the homestead similarly as the weed transcendence in the homestead

In the wake of getting information related to these perspectives the rancher can thusly make significant move for the homestead before the individual being referred to gets to the genuine reason for seeding or planting. With respect to topography, the rancher will understand the advancement to be used in the midst of planting especially in conditions where the geography is intense and changed starting with one point of the homestead then onto the next point.

On issues related to the dirt synthesis, the rancher can make any fundamental move so as to ensure that the dirt is fit for planting. In conditions and conditions where the dirt is missing of explicit enhancements, the rancher should continue to apply these enhancements on the dirt before the period of planting and seeding comes. This is planned to ensure that when the rancher finds the opportunity to plant all of the supplements required by the harvests will be open for the yields.

In the midst of the veritable planting, rambles enable the rancher to consider planting plan and models that are fit to their homestead. This will thusly ensure the seeds planted in a particular ranch are the ideal whole for that homestead. This will likewise ensure that the rancher uses less resource for get perfect yield.

Usage of Drones in Crop Spraying

Automatons enable a rancher to manage the weeds and bugs in their homestead in a reasonable and beneficial way. By the usage of a drone a rancher can choose the proportion of weed and annoyance inescapability in their homestead ahead of time. In the wake of getting familiar with the proportion of weed and disturbance inescapability in the farm from the photos and chronicles taken by the cultivating rambles, a rancher is then prepared to think about a showering plan that engages the individual being referred to change the proportion of herbicide that is sprinkled on the field. For domains with high weed normality a rancher ought to adjust the device to regulate more herbicide while for zones with low weed inescapability the rancher should have allocate less herbicide.

The use of automaton in crop showering is advantageous to the rancher since it enables the rancher to as an issue of first significance choose the proportion of weed transcendence in the homestead before applying pesticide. This will engage the rancher to get a good deal on the herbicide since the individual won't use the uniform herbicide application on the cultivate anyway rather seek after the readied showering schedule to spray the land.

Usage of Drones for Farm Monitoring

Farming Drones are fitted with incredible cameras and accordingly these drones can be used by the farmer to screen and watch out for various zones and parts of the farm. The profitable piece about these automatons is that the farmer can change the separation that the automaton is flying starting from the earliest stage guaranteeing that they don't collide with hindrances during the time spent observing the farm.. Farm drones can be used by both the yield and domesticated animals farmers for reconnaissance.

Cultivating Drones are fitted with mind blowing cameras and in like manner these automatons can be utilized by the rancher to screen and watch out for different zones and parts of the homestead. The productive piece about these robots is that the rancher can change the partition that the machine is flying beginning from the soonest organize ensuring that they don't crash into impediments during the time spent watching the homestead.. Homestead automatons can be utilized by both the yield and trained animals ranchers for surveillance

For the harvest ranchers, the automatons can be used to be careful with the quantity of occupants in the yields in the field, mind the green shade of the plants to choose if the yields are sound or not among various points related to the yields. From this observation a farmer can make vital move in the wake of examining the pictures and recordings caught by the drone.

For the livestock farmers, particularly those farmers with expansive crowds of domesticated animals, the drones can be utilized to distinguish wiped out and harmed creatures in order to empower the farmer to make fundamental move before misfortunes happen. In the wake of recognizing the wiped out or harmed creatures, the composer at that point proceeds to guarantee that they are dealt with. After treatment, the drones can likewise be utilized to screen the mending procedure of these specific creatures.

Land automatons can similarly be used in the homestead for perception suggested for security purposes. A rancher can use the automatons to screen their homestead to check whether there indicate interpolers. The use of these automatons thusly engages ranchers to keep up wellbeing and security in their homestead. (Jeremy Jensen, 2019)

LIST OF DRONES AND ITS USAGES

Drones are structured with the abilities to fly in air without the help of a pilot. Their developments are primarily constrained by a remote unit in the majority of the cases while couple of profoundly propelled plans are worked from PCs. There are such a significant number of assortments of drones that you can without much of a stretch find in world and every one of them are functioning for various real time applications so it is difficult to characterize any set criteria for their characterization. Contingent based on the need or based on the applications, they can have variable size and structure. Here we will discuss about different kinds of drones and for easy understanding they are sorted into 4 fundamental areas: Numbers of propellers utilized inside, their size, flying extent and types of gear.

Fixed wing drones have an essential good position working for them: they can fly longer and more inaccessible than rotational automatons. Many like planes, the intentionally fabricated condition of the wings of fixed wing rambles make lift as they push ahead. This suggests the propeller motors of a fixed wing ramble simply need to give progress ahead. Ordinary fixed wing automatons can fly for 30 to 40 minutes, any more extended than the 15 to 25 minutes normally cultivated using pivoting drones.

Notwithstanding having a more extended energy life, this can likewise move quicker. This empowers them to cover huge locales, up to 60 hectares in a lone battery cycle. With the use of a fixed wing model, a country automaton can accumulate data on a homestead that will assume control more than seven days at whatever point done physically. The wing structure enable them to skim easily towards a protected landing spot should they come up short on batteries.

In any case, the high speeds of fixed wing rambles likewise end up being an impediment. Here, there is no alternative for drone pilot to drift or back off to an adequately low speed to catch high goals pictures. As they are commonly larger than rotational drones, making them less compact and badly designed to bear

Then again, turning drones have the benefit of predominant mobility. Besides having the capacity to make vertical departures, revolving drones can drift, moderate down, and roll out extremely sharp improvements in course. This permits a drone pilot to make an extremely tight flight way. The more slow speed that turning automatons can achieve can construct the spread pace of raised pictures got, making more significant standards replicated models that are in like manner progressively precise.

The short battery life is the real detriment. A turning drone's propellers are in charge of both drive and lift, which needs a powerful yield. Indeed, even top of the line revolving drone models are just fit for a energy life of half an hour or less. For extensive lands, finishing a thorough overview will take visit come back to-home outings for energy substitution.

One main thing to recollect is, regardless of whether you pick a rotary drone or fixed wing drone, is that farming drone can be pricey. All things are considered, as these are proficient evaluation drones furnished with automated flight alternatives and a camera which can catch close infrared light. You will likewise require a product or application for review arranging and post-handling of information. Every one of these highlights put agricultural automatons at a value extend that is route outside of what easy going clients can manage.

DIFFERENT TYPES OF DRONES (LIZA BROWN, 2019)

1. Number of Propellers

Rotory Drones

Single and Multi Rotor Drone

As it names, it employs only a single rotor (may be the tail unit in very few cases) which often generate thrust more systematically than their multi-rotor counterparts. This makes them to be ideal for a longer flight times. It costs a lot as it is designed with single blade combined with gas powered.

Multiple rotors have numerous rotors situated at key focuses on the specialty. These additional rotors can make it simpler for the specialty to keep up its equalization and continue drifting. Likewise, most kinds of multi-rotor drones can't convey a substantial payload, as this would disturb the parity kept up by its balancing rotors.

Tricopter

There are 3 particular sorts of astounding motors inside a tricopter, 3 controllers, 4 gyros and only a solitary servo. A tricopter can stay offset on its way as it is furnished with such colossal quantities of commendable sensors and electronic stuff itself

Quadcopter

Exactly when a multirotor is organized with 4 rotor forefronts then it advances toward turning out to be quad copter. These devices are typically compelled by exceptionally organized brushless sort DC motors. Two of these motors used to move clockwise way however other 2 continue running counter clockwise way. It picks a protected landing for quadcopter. The wellspring of battery for such contraptions uses to be a lithium polymer battery.

Hexacopter

Hexacopter will work for some inherent applications with its 6 engine mechanism where 3 of them works away at clockwise bearing and other 3 will carry in anti-clock direction. Subsequently, these gadgets can increase higher lifting power when contrasted with quadcopters.

Octocopter

Octo implies 8; so octocopter is going to function with its ground-breaking 8 engines and this send its capacity to 8 practical propellers. The main speciality is it normally has high flying capacities when contrasted with units examined above and are additionally exceptionally steady. It benefits a steady film recording with octocopters at any elevation. It discover application in the realm of expert photography. (Vikram Puri, Anand Nayyar & Linesh Raja, 2017)

Fixed Wing Drone

Here the classification is is completely extraordinary from every above unit. Fixed wing drone designs are very extraordinary when contrasted with normally utilized multi rotor type drones. A wing is discovered on them and the wing seems like conventional planes. It is not ready to stand steady in air as they are very little amazing to battle in opposition to gravitational power. They discover their uses in development associated to chronicle to which they can push ahead according to abilities provided by their inbuilt energy framework.

2. Classification of Size

Very Small Drones

It is structured with a typical **typical measurement** range differing from a huge measured creepy crawly to a 50 cm long unit. The two regular plans in these classes are: Mini Drones and Nano/Micro Drones. Nano drones are comprehensively utilized in light of their minor structure and light weight improvement as they work like key weapons for spying

Mini Drones

Mini drones have a size minimal greater then miniaturized scale drones which implies, it will go over 50 cm however it will have at most extreme 2m measurement. A large portion of this mini drone is structured with fixed wing type development while a few can have rotational wings. They need more power as their size is little.

Medium Drones

These type drones are lighter and smaller when compared to airship yet it presents a larger units. It has a normal flying limit with the range of 5km to 10 km and it projects weights up to the 200kgs.. UK watchkeeper the most famous standout amongst this classification.

Large Drones

These drones are identical in size for flying machine and it is most likely to be used in military applications. These drones capture the places which are not secured with ordinary drones. They are principle gadget for reconnaissance applications. Clients can likewise characterize them further into various classifications relying on their flying capacities and range.

3. Classification on Range

Very Close Range Drones

It acts like a most loved toy for the children. It can fly up to 5 Km with fly time of 20 to 45 minutes when outfitted with amazing batteries. Raven and Dragon Eye are most utilized units in this class.

Close Range Drones

Close Range drones flies up to the range of 50 Km with a energy reinforcement of 1 to 6 hours. These drones can function for longer life spans and can easily cover far separations so they discover their usages in observation missions

Short Range Drones

Short Range is minimal better as thought about than short proximity drones so these are regularly used for military applications. They can venture out up to most extreme separation of 150 Km which implies inclusion is practically 100Km high when compared to that of short proximity drones. The assessed flight time for these drones is 8 to 12 hours so these are helpful for observation and detective use.

Mid-Range Drones

Mid-range drones is much amazing when contrasted with all the drones discussed above. Mid-range are notable as fast drones which cover zone up to 650 Km. These drones are usually utilized for monitoring applications and few essential sort, under this class it functions for gathering meteorological information .

Endurance

Endurance is the best accumulation of drones which has very high time flight time of 36 hours and it can go up to the most extreme tallness of above 3000 feet ocean level effectively. These are mainstream for top of the line reconnaissance applications.

DRONES HELPS AGRICULTURE TO NEW SUSTAINABILITY

In spite of the way that drone innovation is so far changing creation to assemble ease of use and lower costs, these machines starting at now can go far towards improving ranchers' principle concerns – and the earth. Here are 3 key focal points of automaton use in cultivating:

1. More information, less time

Drones have the capability to scout ranchers fields

One of the significant advantages of drones is their capacity to scout ranch fields both promptly and proficiently. This new method enables farmers to enrich quick learning regarding the status of their farmlands in short time period.. This information can be accessed wherever they need.

2. Improving health and efficiency of the Plant

New automaton innovation is feasible at social event data to empower ranchers to improve crop wellbeing. Outfitted with sensors, rambles flying over a field can assemble plant stature estimations by get-together run information from the plant cover and the ground underneath.

Drones also make satellite maps that can empower ranchers to choose decisions about manure – an essential stress of ranchers, as compost addresses up to 50 percent of data costs.

3. Water efficiency and other environmental benefits

. Thermal cameras can distinguish cooler, especially watered field territories similarly as dry hot patches. These data are used by the ranchers to change farm land water framework which helps in saving wasting excess water. This ability to manufacture water improvement is particularly significant in drought stricken areas, for instance, California. (Stephanie Businelli, 2015)

AGRICULTURAL APPLICATIONS OF DRONE

Ranchers and agriculturists are constantly looking for shabby and successful strategies to routinely screen their harvests. The infrared sensors present in drones can be tuned to distinguish crop prosperity, enabling ranchers to react and improve crop conditions locally, with commitments of manure or bug splashes. In the following couple of years, practically 80% of the horticultural market will include rambles. Power and pipeline survey: Many structures, for instance, electrical links, wind turbines, and pipelines can be checked by rambles. (Michal Mazur, 2016)

Soil and Field Analysis

At the beginning of the crop cycle drones are instrumental. Drones provide definite 3-D maps which helps in early examination for soil, supportive in seed planting structures.

Planting

Drone planting systems achieve a take-up pace of 75% along with a decreasing planting costs by 85%. These systems shoot cases with seeds and plant supplements into the dirt, giving the plant the entire supplements imperative to proceed with life.

Crop Spraying

Drones helps in checking the ground level for sprinkling the correct proportion of liquid. The result extended capability with a reduction of in the proportion of synthetics invading into groundwater. In reality, pros check that elevated showering can be done up to various occasions snappier with rambles than with standard equipment.

Irrigation

Automatons with hyper-terrible, multispectral, or warm sensors can recognize which parts of a field are dry or need upgrades. Besides, when the collect is creating, rambles grant the figuring of the vegetation record, which portrays the relative thickness and sufficiency of the yield, and show the warmth signature, the proportion of vitality or warmth the yield exudes.

CONCLUSION

At start of 21st century, individuals anticipated new thousand years. Nobody could envision what sort of new innovation occurs. In that manner, Agricultural drone is an astonishing development innovation, which is turning into an apparatus like any agricultural equipment. Behind this there are different reasons, as nearly modest agricultural drone with cutting edge imaging abilities and sensor are giving explicit information to the farmer. By utilizing these information, farmers can expand crop yields and diminish crop harm. In addition, less utilization of pesticides lessens natural harms. The market for Drones is expanding step by step from the most recent two decades and they have gained a basic disturbed the area of Industry, Military, Agriculture and some more. This examination explored the significance of drones in Agriculture and has featured the different drones accessible for various agribusiness applications alongside specialized details. In any case, Farming is an info yield issue. With utilizing of drones, farmers can lessen inputs – water and pesticides and keeping up same yield, it will be conquering the sustenance lack. Agricultural drone changes farmer's capacity to screen and deal with the key part of farm business that is difficult to continue in remote spot. Convincingly, we can say Drone, which began as a military innovation may finish up also called a green-tech innovation. This chapter is viewed as eye-opener for Industry and Farming for advancement and incorporation of more drones for making Farming tasks better and thus yielding best harvest quality in close future.

REFERENCES

Costa, F., Ueyama, J., Braun, T., Pessin, G., Osorio, F., & Vargas, P. (2012). The use of unmanned aerial vehicles and wireless sensor network in agricultural applications. *IEEE conference on Geoscience and Remote Sensing Symposium (IGARSS-2012)*, 5045–5048. 10.1109/IGARSS.2012.6352477

Devi & Kumari. (2013). Real-Time Automation and Monitoring System for Modernized Agriculture. *International Journal of Review and Research in Applied Sciences and Engineering, 3*(1), 7-12.

Eisenbeiss, H. (2004). A mini unmanned aerial vehicle (UAV): system overview and image acquisition. International Archives of Photogrammetry. *Remote Sensing and Spatial Information Sciences, 36*(5).

Grenzdörffer, G. J., Engel, A., & Teichert, B. (2008). The photogrammetric potential of low-cost UAVs in forestry and agriculture. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *31*(B3), 1207–1214.

Gutiérrez, Villa-Medina, Nieto-Garibay, & Porta-Gándara. (2013). Automated Irrigation System Using a Wireless Sensor Network and GPRS Module. *IEEE Transactions on Instrumentation and Measurement*.

Kim, Y., Evans, R., & Iversen, W. (2008). Remote Sensing and Control of an Irrigation System Using a Distributed Wireless Sensor Network. *IEEE Transactions on Instrumentation and Measurement*, 1379–1387.

Nandurkar, T., & Thool. (2014). Design and Development of Precision Agriculture System Using Wireless Sensor Network. *IEEE International Conference on Automation, Control, Energy and Systems (ACES)*.

(n.d.). Puri, Nayyar, & [Agriculture drones: A modern breakthrough in precision agriculture. *Journal of Statistics and Management Systems*.]. *Raja.*

Stehr, N. J. (2015). Drones: The Newest Technology for Precision Agriculture. *Natural Sciences Education*, *44*(1), 89–91. doi:10.4195/nse2015.04.0772

Wang, Q., Terzis, A., & Szalay, A. (2010). A Novel Soil Measuring Wireless Sensor Network. *IEEE Transactions on Instrumentation and Measurement*, 412–415.

Wang, X., & Liu, N. (2014). The application of internet of things in agricultural means of production supply chain management. *Journal of Chemical and Pharmaceutical Research, 6*(7), 2304-2310.

Yoo, S., Kim, J., Kim, T., Ahn, S., Sung, J., & Kim, D. (2007). A2S: Automated agriculture system based on WSN. In *ISCE 2007. IEEE International Symposium on Consumer Electronics*. https://agribotix.com/wp-content/uploads/2016/04/WhatFarmersNeedToKnow_web.pdf

Chapter 17
Disease Monitoring of Cucumber in Polyhouse Through IoT-Based Mobile Application

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ABSTRACT

Most countries have an economy that is dependent on agriculture—either in a magnificent or small way, from employment generation to national income contribution—implying that agriculture is inevitable. Polyhouse farming is a new and widely accepted method of farming in the present days. The polyhouse is made in such a way that it can provide water and fertilizers in required amounts in a controlled manner, which can result in high yields. Polyhouse requires severe monitoring of crops as stagnant air, and lack of air circulation will lead to breeding of insects and materialistic loss. Hence, this chapter proposes an IoT-based disease-monitoring prototype for an agricultural/polyhouse application. The prototype is designed and tested to identify the disease onset in cucumbers. This work initially focuses on recognizing the critical cucumber diseases in polyhouse using NodeMCU and Raspberry-Pi-based hardware model. The decisions to be made and the major changes in the sensed parameters if any will be intimated to the farmers using a specifically designed mobile application.

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INTRODUCTION

Agriculture is the primary support for our country's economy; it contributes around 26% of India's GDP, and provides employment to about 60% population. Recently, Indian agriculture has been greatly influenced by the global climatic variations. These variations in the climatic conditions has led to an increase in the temperature of about 2-3°C which impacts the agricultural process and practices. On the other hand, crops are being affected by diseases due to pests. The losses due to weeds, diseases and pests have been estimated to be around 40% in the tropics and semi tropics. Similar conditions prevail in other parts of the world too, but with varying intensity levels. These problems necessitate an efficient technology so that the crop productivity, sustainability of farming and profitability can be considerably improved under varying environmental conditions. One such emerging technology is the polyhouse technology.

Polyhouse technology is an approach that helps the plants to experience a suitable environment enabling reasonable non hindering growth. It is indispensable to safeguard the crops from undesirable environmental circumstances that are caused due to variations in wind, rainfall, coldness, extreme temperature, excessive radiation, diseases and insects. Thus, crop cultivation in a polyhouse is a suitable choice which also allows precision farming and overcomes the limitations of space and disadvantages of climate change. Crops to be cultivated in the polyhouse are carefully chosen based on of the size of the polyhouse structure, crop production economics and income generated (profit). To be region specific, the high value vegetable crops viz., tomato, capsicum, brinjal and chilli have been more popular for cultivation in polyhouse in Tamil Nadu, India. They are also cultivating hybrid variety of cucumber and flower crop of marigold in large scale.

Cucumber (Cucumis sativus) is a plant belonging to the Cucurbitaceae family, which is cultivated widely in India. Diseases in polyhouse cultivated cucumber varieties have the characteristics of high disease rate, fast and frequent infection (Tian et al., 2008). The onset of disease will reduce the crop cultivation and degrade the quality of product. It is practically difficult to detect or classify various plant diseases through naked eye even by experts. Moreover, manual inspection also demands regular observation of the crops by skilled persons. This will be tedious and costly while done in large scale farms. Hence, there is a crucial need for the development of a disease monitoring system to detect the changes in the environmental parameters and identify the onset of plant diseases.

Recently, Precision farming is evolving which is capable of handling disparities in productivity within a field and maximizing financial returns. This is accomplished by the use of automatically programmed data collection followed by documentation and finally utilizing the collected data to carry out strategic decisions for farm management by means of sensing and communication technology. IoT enabled Wireless sensor networks play a major role in precision farming with the following advantages:

- Ability to control weather, nutrient supply and irrigation in an economical way so as to yield the best crop condition, strengthen the efficiency of production while at the same time reducing the cost and furnishing the real time information.
- Prospective potential for inspecting a larger area with better sampling intensities.
- Capability of forming a well automated agriculture system with improved resolution.

Hence cost effective user friendly IoT based solutions for polyhouse cultivation has a wider scope. This work initially focuses on recognizing the environmental conditions and symptoms that leads to the major cucumber diseases namely Red Spider Mites, White Flies, Aphids, and Potassium deficiency.

The disease onset can be predicted based on tracking the suitable environmental conditions, which will trigger them. Moreover, the external physical symptoms can also be monitored to discover the disease infection. The favourable ranges of such environmental parameters for different diseases are provided in Table 1.

Table 1. Favourable range of environmental parameters for various diseases

Parameters	Diseases				
	Red Spider Mites	White Flies	Aphids	Boron Deficiency	Potassium Deficiency
Temperature	28.65°C	22-25°C	22-27°C	25°C	28°C
pH	5.2-5.5	3.5-4.3	3.5-4.3	< 5.4	< 5.2
Humidity	76.85%	98%	63-86%	89-95%	92-98%
EC	3.2 dS/m	3.5-4.3 dS/m	3.0 - 3.4 dS/m	2.6 dS/m	2.2 - 3.0 dS/m
Light Intensity	11.5% (D)	>10% (D)	12% (D)	9% (D)	10.5% (D)

The initial physical symptoms of various diseases can be identified by processing the images of a plant. Early diagnosis will avoid further spreading and the related huge loss. Sample infected images are shown in Figure 1 and Figure 2.

Figure 1. Sample images of disease infected cucumber a) Red Spider Mites b) White Flies c) Aphids

a) b) c)

Figure 2. Sample images of disease infected cucumber a) Boron deficiency b) Potassium deficiency

a) b)

- **Red Spider Mites** - Mottled foliage and early leaf fall. Fine pale mottling on the upper leaf surface. Foliage takes on a discoloured look, pale, and sometimes bronze.
- **White Flies -** Occurrence of adult whiteflies and nymphs on younger leaves particularly in its lower surface causing deformation, wilts and loss of leaves. Presence of honeydew and black sooty mould fungus.
- **Aphids -** Plants look yellow in color and weak. Buds of flower and young fruits will fall. Mold bacteria are grown in the affected area, region appears black and young shoots die.
- **Boron deficiency** - Distortion of newer leaves .The appearance of a broad yellow border at the margins of the oldest leaves. Mature fruits include stunted development and mottled yellow longitudinal streaks.
- **Potassium deficiency** – Deficiencies in potassium are initially characterized by reduction in growth, shoot die-back and weak stem structures. Some of the possible symptoms on leaves include
  - Faded bluish-green appearance, predominantly in the interveinal regions of the leaves.
  - Leaf tips and margins show dull general chlorosis.
  - Tip burning and marginal scorch found on the matured leaves with leaves curling downwards or upwards.

The design of an automated system to identify the diseases includes the data acquisition, processing, analysis and decision making. Sensors are used to monitor the vital parameters such as humidity, temperature, light intensity, pH, soil moisture, and electrical conductivity. Moreover, due to the advent of digital technology and the availability of low-cost cameras, image-based surveillance of the agricultural fields is also feasible. Monitoring these parameters will help in efficient farming, by providing an indication to supply water, pesticides, and nutrients at the right time. In addition, detection of plant disease through image processing is advantageous as it lessens the labour involved in monitoring large farms of crops and helps to discover the diseases beforehand. In this work, the analog sensors are interfaced with NodeMCU and the camera is interfaced with Raspberry Pi. The images are processed and analyzed to identify the appropriate symptoms and the associated diseases. The sensed data and the extracted findings are ported into the cloud by means of an Internet of Things (IoT) gateway (ThingSpeak), which facilitates visualization of the real time data. IoT is nothing but a system of interconnected physical objects such as sensors or devices, which can talk to each other using cloud and internet (Jeyalakshmi & Radha, 2017). IoT gateway enables communication via the internet among the physical devices like microprocessors, microcontrollers, sensors and actuators. (Jaishetty & Patil, 2016). The inferences and the remedial solutions from ThingSpeak will be sent to farmers by using MIT App Developer2.

This chapter includes the following sections: Section I includes the introduction. Section II provides the necessary background details. Section III presents the proposed approach for disease detection. Section IV deals with the system implementation and portrays the associated simulation results. Section V elucidates the possible future work and the final section concludes this chapter.

BACKGROUND

In more than 50 countries of the world, the cultivation of crops is undertaken under cover on a commercial scale. United States of America holds a total area comprising of almost 4000 ha under polyhouses primarily used for floriculture. Besides, provides an additional turnover contribution of 2.8 billion US dollars per year and the area under the polyhouses is also expected to increase considerably. In Spain, the polyhouses are established in an area of 25,000 ha and in Italy it is about 18,500 ha, which are mostly used for cultivating vegetable plants such as tomato, capsicum, watermelon, strawberry, cucumber and bean varieties. In Spain, polyhouses are constructed using simple tunnel structures without any complex equipment for environmental control and it mostly uses UV stabilised polyethylene film for its cladding. The polyhouse industry found in Canada is established both for flowers and off season vegetable markets. Canadian polyhouses grow capsicum, tomato and cucumber as main vegetable crops.

Vegetables and flowers that are grown in polybouses established in Netherlands are exported all over the world. Dutch has the most advanced polyhouse industry built in an area of about 89,600 ha. Dutch polyhouses are constructed using glass frames so as to cope up with heavy cloudy conditions which is prevalent round the year. The most important crops in Saudi Arabia are cucumbers and tomatoes which contribute to about 94% of the total country's production. Israel with an area of 15,000 ha and Turkey with 10,000 ha also covers a wide range of cut flowers and vegetables under its polyhouses and Israel is a largest exporter of cut flowers. All of these have evaporative cooling as the most popular cooling method for them. Polyhouses in Egypt are constructed mainly using plastic covered tunnel like structures in about 1000 ha which mainly. Natural ventilation arrangements are made to regulate the temperature and humidity conditions. Some of the main crops that are grown in these polyhouses are cucumbers, tomatoes, melons and kinds of nursery plants. China and Japan are the largest users of polyhouses in Asia. In China, polyhouse technology has been developed at a very faster rate than in any other country. In addition to vegerables, fruits such as mango, grapes, Japanese persimmon, cherry, fig, loquot and lemon are also cultivated in their polyhouses. China uses straw mats to withstand the heat and most of the Chinese polyhouses are said to be unheated. Japan has polyhouses established in more than 40,000 ha area in which cultivation of fruit orchad is done in about 7500 ha. Japan used to grow vegetables and flowers widely in their Polyhouses and most of the vegetable demands are met from their polyhouse produce. Even countries like South Korea have more than 21,000 ha area under polyhouses for cultivating fruits and flowers. Polyhouses are suitable for crop production under extreme weather conditions. Countries like Canada and Russia have extreme winter and countries like UAE, Kuwait and Israel have extreme intolerable summer, where polyhouses are the best choice for crop production. In Philiphines where the rainfall is excess, polyhouses are built to grow plants and crops. Polyhouses are also practiced in several countries where the climatic conditions are moderate. In essence, it is evident that polyhouse cultivation is being practiced globally and in all possible kinds of weather and climatic conditions whereas decision support systems for such environment are emerging.

There are several contributions related to development of decision support system for agricultural applications. Two different Wireless Sensor Network (WSN) for farming applications were developed in the State of Washington. First WSN design is focused on location specific applications such as weather networks and the second design is for on-field applications that include temperature sensing to avoid frost. The designs namely AgWeatherNet for the first and AgFrost-Net for the second were successful in their implementation to serve the planned applications (Pierce & Elliott, 2008). In Portugal, (Morais et al. 2005) WSN based design was implemented for wireless data acquisition and collection of several weather parameters along with soil moisture to ensure planned watering of plants. Improvement in irrigation efficiency has been achieved by deploying many wireless data acquiring systems powered by sunlight for the soil moisture measurements.

Cugati et al. (2003) developed an automated fertilizer applying unit to standardize the fertilizer amount and the rate of applying it. It senses environmental parameters through the input module, and sends it to the decision support system to estimate the fertilizer quantity and decide the spreading pattern. The decision is made by analyzing the sensed real-time data.

A multi-hop WSN system consisting of 65 nodes was developed and implemented in a vineyard by (Beckwith et al. 2004) for a period of six months. The information collected by the system was utilized to consolidate the heat and frost damage in manufacturing wine. It had also been used to overcome the problems caused by fungus and pest. Aline Baggio (2010) formulated a scheme to handle a type of potato crop disease named Phytophtora. The effect of this disease is reduced using their system by continuously monitoring the humidity and temperature. Kolokotsa et al. (2005) devised a polyhouse system with suitable procedures to deal with the environmental changes and ensure proper energy utilization. It was used to monitor the indoor luminance, relative humidity, outside temperature and CO_2 concentration.

A decision driven system was developed for polyhouse seedling generation. It included the growth monitoring model to achieve suitable dry weight of the seedlings while relocating it. This was achieved by continuously monitoring the temperature, light conditions and also taking temperature based decisions on a day to day basis. It helped in managing and controlling the conditions within the polyhouse to achieve the expected sapling growth in the stipulated time period. (Manoj Kumar et al., 2010) & (Vyas et.al, 2016).

In India, an AgriSense distributed system used to monitor the comprising temperature, relative humidity, leaf wetness, and soil moisture was developed by Tripathy et al., 2013. The primary objective of this project was to detect the Bud Necrosis Virus disease that spreads in groundnut crop. Ravi Kishore & Nisheeth, 2013 developed a WSN system using eKo nodes to monitor the amount of moisture content existing in the soil in mango farms.

Many polyhouses are also constructed in Ladakh to extend the suitable season for growing vegetables from three to eight months. In the Northern plain regions, both vegetable and flower seedlings are being raised in the polyhouses so as to capture the early markets as well as to improve the seedling quality. Moreover, polyhouses will also play a major role in bringing profits in floriculture projects.

Though several advancements are prevailing in the other parts of the world, there is a huge scope for development and deployment of such systems in India. Moreover, IoT enabled systems are need of the hour. Hence, this work concentrates on detecting the diseases from the environmental conditions and the symptoms prevailing on the leaves through an IoT based Mobile App.

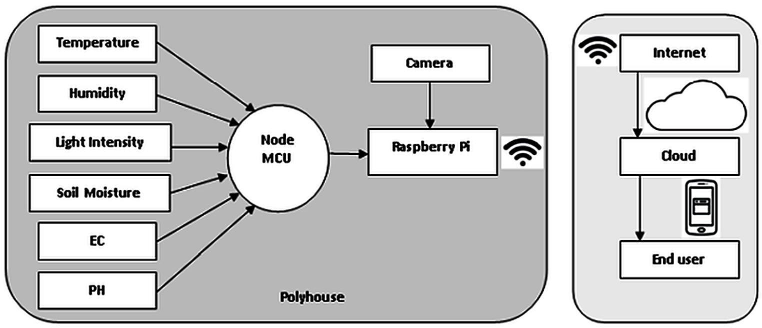
DISEASE DETECTION SYSTEM

The proposed disease detection system senses the field using various sensors and camera, to retrieve the environmental parameters and images, processes it. The disease onset, type of diseases, and pests that cause infections are identified appropriately through two phases. The first phase includes the acquisition of environmental parameter values, effective field coverage through sensors and exporting the acquired data to the cloud. The second phase includes data processing, analysis and decision making at the server, based on the data extracted from the cloud. The proposed system is shown Figure 3.

Data Acquisition

Environmental Parameters

Figure 3. Block Diagram of Disease Detection System



The environmental parameters are acquired using a novel IoT sensor network which is affordable and consumes lesser power. The collected data is stored at the server. The system architecture consists of certain sensors (temperature, humidity, soil moisture, light intensity, pH and electrical conductivity) interfaced with NodeMCU, which are installed in the agriculture field. They accumulate the physical parameters captured from the surroundings. This data is transferred to the cloud through a secured IoT hub. This enables flexible data visualization and understanding.

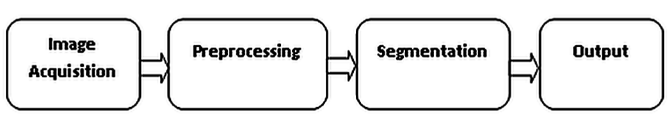
Images

Image Acquisition is an act of retrieving an image from hardware based source for processing (Pooja et al., 2016). In this work, it is done through the digital camera interfaced with Raspberry Pi. The captured data is transmitted to the cloud through Raspberry Pi.

Data Processing

The sensed environmental parameters are send out to the cloud through Raspberry Pi. However, the images are processed and the features are extracted and transferred to the cloud. The image processing procedure is illustrated in Figure.4.

Figure 4. Image Processing Steps



Preprocessing

The pre-processing of image includes image resizing (Manisha & Hingoliwala, 2015). It also includes colour transformation or colour space conversion. The red, green and blue colors in color image processing were not sufficient for visualizing the color differences as exactly as human visual system. Hence, RGB is converted into the HSI (Hue, Saturation and Intensity) color space. HSI helps in indicating the percentage of disease infection in leaves.

Segmentation

Image segmentation is a method of segregating the image into its constituent sub parts, which will have similarity in certain characteristics or property. The pixels with the same property will be labeled identically to extract the object details or the associated information from the digital images. The resultant will be a set of contours that combined will represent the full image. The similarity can be accounted in terms of the color, intensity, or texture. In this work, K-means Clustering is applied to partition the images based on the features.

K-Means Clustering

K-Means is an approach that produces clusters with well defined physical boundaries. In K-Means clustering algorithm the n elements $e_1, e_2, e_3 \ldots\ldots e_n$ are separated into K groups with initial centroids. The K-Means objective function is given by,

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| e_i - G_j \right\|$$

where K is the number of clusters, G is the group centroid and e is the object element. The procedure for K-Means technique is provided.

1. Initialize the centroid.
2. Determine the distance between object element and centroid.
3. Allot the object elements to the group whose distance is minimum.
4. Calculate the new mean of the group.
5. Repeat steps 2-4 until a threshold level is reached.

The function used to perform K-means clustering is shown below (pyscript).

```
def centroid_histogram (clt):
# grab the number of different clusters and create a histogram
# based on the number of pixels assigned to each cluster
numLabels = np.arrange(0, len(np.unique(clt.labels_)) + 1)
(hist, _) = np.histogram(clt.labels_, bins = numLabels)
# normalize the histogram, such that it sums to one
```

```
hist = hist.astype("float")
hist /= hist.sum()
# return the histogram
return hist
```

Cloud Storage

The sensor data and detected features are collected and then uploaded in ThingSpeak (a cloud platform) using Lua Script and Python respectively. ThingSpeak is a freely available Internet of things application. It is also an application programming interface that helps to store and retrieve the data using the HTTP protocol over the internet. The uploaded values can be viewed as graphical notations. This facilitates the efficient representation of the time series data acquired from the field (Ravi Kishore & Snehashish, 2016).

ThingSpeak activity has provision for including channels, which contains data fields, location fields, and a status field. The sensed data can be written on the channel, processed and viewed with MATLAB code, and discrepancies could be responded with tweets and other alerts. The channel has private, public views, channel setting, API keys and data import/export tabs. Channel ID and the read/write API are essential for posting the sensed data from the nodes on-field.

Data Analysis and Decision Making

Segmented data is retrieved from the cloud and further classification is done based on thresholding. The colour values of the clusters are extracted and compared with a threshold. The threshold is meticulously set (after several trials over various images) to identify the diseases appropriately as shown in Table 2. The decision is made based on the analysis and the countermeasures are intimated to the end-users (farmers) via a mobile app. The App is developed by MIT App Developer2 (Ghassan & Saman, 2015). It is a block-based programming tool used to build Android applications in an easier way.

Table 2. Threshold range for different diseases

Diseases	Threshold Range		
	Hue	Saturation	Intensity
Red spider mites	≥ 201	80-142	30-61
White Flies	≥ 228	≥ 225	≥ 224
Aphids	200-210	208-215	85-93
Potassium Deficiency	200-210	185-210	65-115

SYSTEM IMPLEMENTATION AND RESULTS

The entire prototype is developed and tested in a poly house near Thiruporur Sipcot, Payyanur. The overall experimental set up is shown in the figure 5.

Figure 5. Overall Experimental Set up

Sensor Data

The sensor data are uploaded on the thingSpeak cloud platform. The figure 6 shows output values for sensors(Humidity, Soil Moisture, Temperature, EC, pH, Light Intensity) interfaced with NodeMCU using ArduinoIDE displayed in Com port.

Users can also analyze the output in the thingspeak, which will give the graphical notations of temperature, light, soil moisture, humidity, pH and electrical conductivity values. The graphs shown in the

Figure 6. Sensor Data acquisition using Node MCU in Arduino IDE

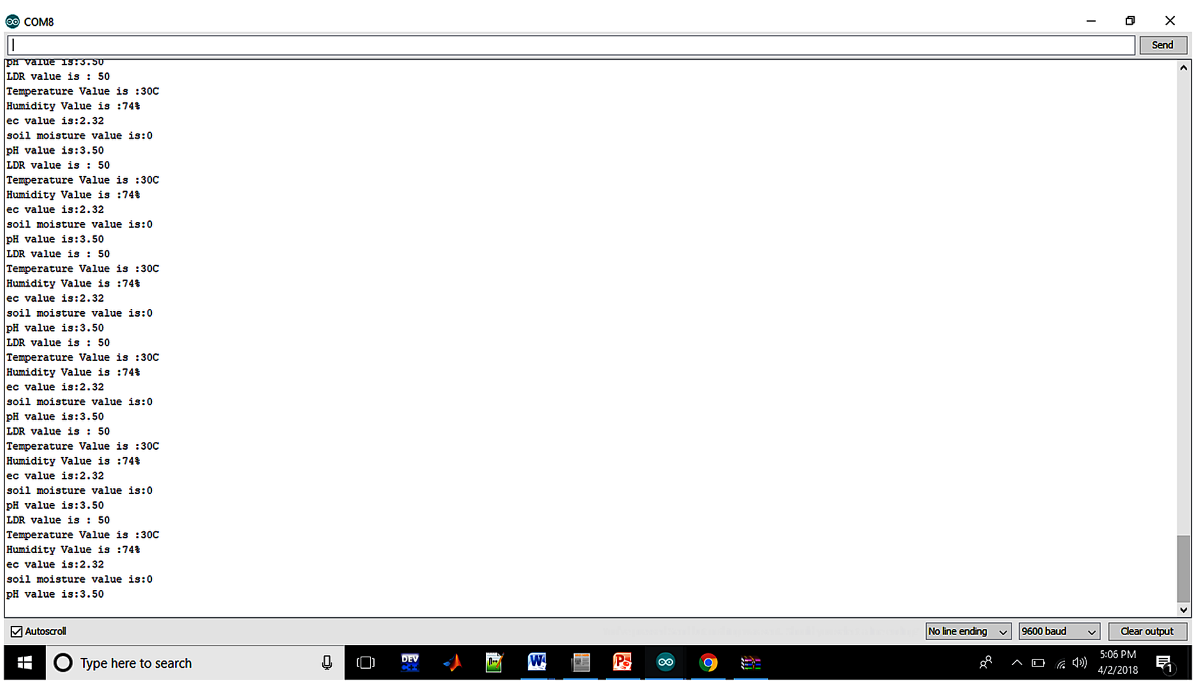


figure 7, figure 8, figure 9, and figure 10 represents parametric values of various sensors and the decision made on disease infection.

Figure 7. Sensed Parameters - a)Temperature b) Humidity

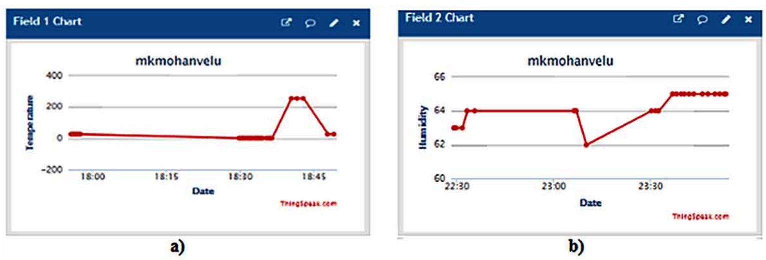


Figure 8. Sensed Parameters – a)Soil Moisture b) pH

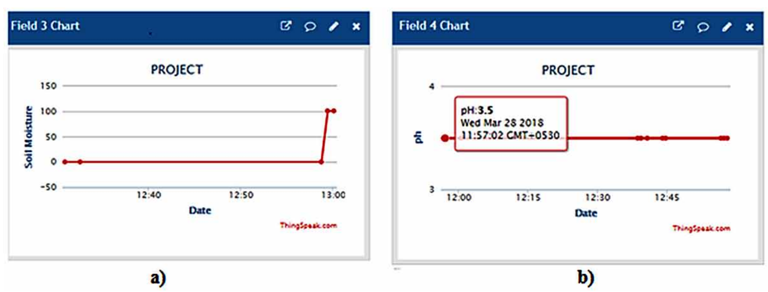
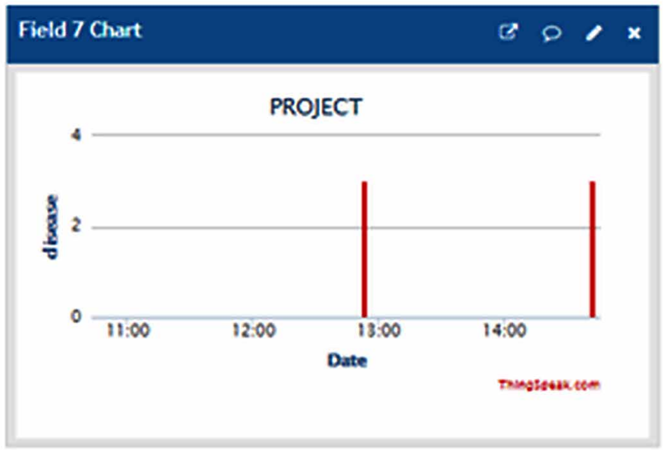


Figure 9. Sensed Parameters - a) LDR b) EC

Image Analysis

The figure 11 and figure 12 shows the segmented image which is used to identify five diseases of cucumber namely, Redspider mites (red), White flies (white), Aphids (whitish yellow), and potassium deficiency (yellow) disease.

Figure 10. Decision on disease infection



Mobile Application

The sensed parametric values and the identified disease details are displayed in the Android application. Data displayed in mobile app is fetched from ThingSpeak. The snapshot of the mobile screen indicating

Figure 11. Segmented images with classification results a) Redspider mites, b) White flies (white)

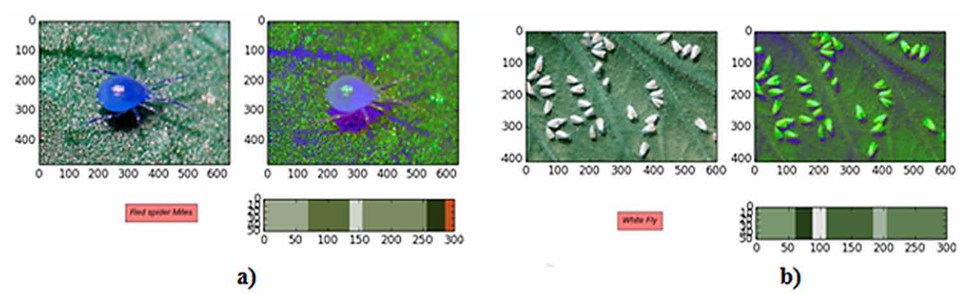


Figure 12. Segmented images with classification results a) Aphids (whitish yellow), b) potassium deficiency (yellow)

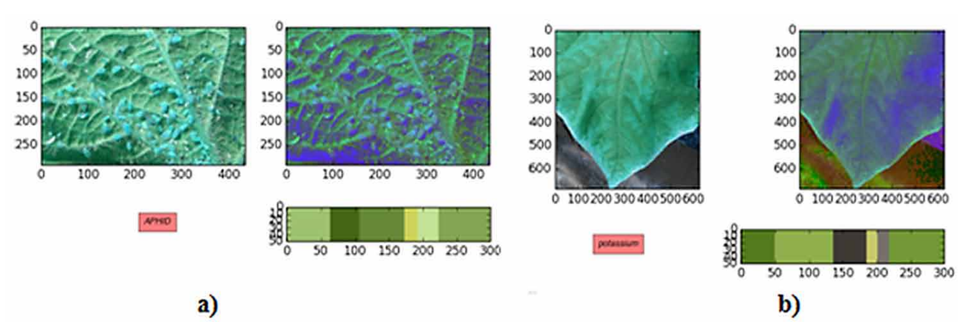
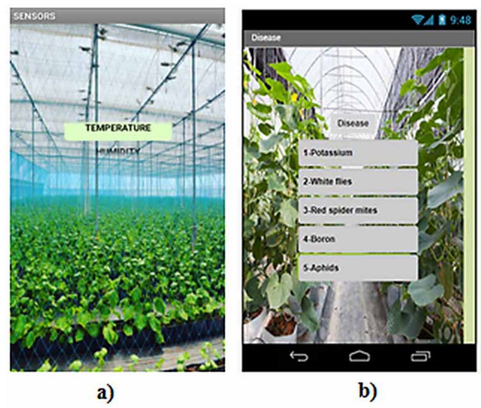


Figure 13. Snapshots of Mobile App display



the available options are shown in figure 13.

FUTURE RESEARCH DIRECTIONS

The developed on-field disease detection system will help in avoiding the misjudgments made by farmers in specific cases. Moreover, it can also reduce their dependency on local chemical agents and save their cost involved in crop production. The system can also pave way for organic cultivation, by eradicating the use of pesticides through other precautionary methods. Further system upgradation can be done by improvising the segmentation procedure, using machine learning and extending the ability of the system to detect all possible diseases of the Cucumber plant. Moreover, the system can be customized to any other critical plants too. Further advancements can be made in this module by making it a movable drone to capture all images in every nook and corner of the field. Such solutions will be the heart of the upcoming smart cities, which enhances the quality of our staple food.

CONCLUSION

The proposed system enables the early identification of disease in polyhouse cucumber. The efficient analysis is enabled through measurement of sensor parameters, image acquisition, real time realization and analysis of data through IoT based architecture. The environmental parameters such as temperature, humidity, soil moisture, pH, EC and light intensity are measured and uploaded to cloud using NodeMCU via ESP8266. The visual details are captured by cameras interfaced to Raspberry Pi and segmented using K-means clustering. The segmented results are uploaded to cloud. Further classification is done based on thresholding strategy. The collected data are displayed by the specifically designed application in end users mobile for efficient monitoring and counter react accordingly in Polyhouse. The prototype of the system is developed and tested in real field.

REFERENCES

Baggio, A. (2005). *Wireless sensor networks in precision agriculture*, Paper presented at the ACM Workshop on Real-World Wireless Sensor Networks, Stockholm, Sweden.

Beckwith, R., Teibel, D., & Bowen, P. (2004). *Report from the field: results from an agricultural wireless sensor network*. Paper presented at the 29th Annual IEEE International Conference on Local Computer Networks, Tampa, FL. 10.1109/LCN.2004.105

Cugati, S., Miller, W., & Schueller, J. (2003). *Automation concepts for the variable rate fertilizer applicator for tree farming*. Paper presented at the 4th European Conference in Precision Agriculture, Berlin, Germany.

Ghassan, B., & Saman, Z. (2015). *Teaching Cyber-Physical Systems using MIT App Inventer2*. Paper presented at the 2nd International Conference on Education and Social Sciences, Istanbul, Turkey.

Jaishetty, S. A., & Patil, R. (2016). IoT Sensor Network Based Approach for Agri-Cultural Field Monitoring and ConTrol. *International Journal of Research in Engineering and Technology*, *2*, 45–48.

Jeyalakshmi, S., & Radha, R. (2017). A Review on Diagnosis of Nutrient Deficiency Symptoms in plant leaf image using Digital Image Processing. *ICTACT Journal on Image and Video Processing*, *7*(4), 1515–1524. doi:10.21917/ijivp.2017.0216

Kolokotsa, D., Saridakis, G., Dalamagkidis, K., Dolianitis, S., & Kaliakatsos, I. (2010). Development of an intelligent indoor environment and energy management system for greenhouses. *Energy Conversion and Management*, *51*(1), 155–168. doi:10.1016/j.enconman.2009.09.007

Manisha, B., & Hingoliwala, H. A. (2015). Smart Farming: Pomegranate Disease Detection Using Image Processing. *Procedia Computer Science*, *58*, 280–288. doi:10.1016/j.procs.2015.08.022

Manoj Kumar, G., Samuel, D. V. K., & Sirohi, N. P. S. (2010). Decision support system for greenhouse seedling production. *Computers and Electronics in Agriculture*, *73*(2), 133–145. doi:10.1016/j.compag.2010.05.009

Morais, R., Valente, A., & Serôdio, C. (2005). *A wireless sensor network for smart irrigation and environmental monitoring*. Paper presented at the EFITA/WCCA Joint Congress on IT in Agriculture, Portugal.

Panchard, J., Rao, S., & Prabhakar, T.V., Hubaux, J.-P., & Jamadagni, H.S. (2007). COMMONSense Net: A wireless sensor network for resource-poor agriculture in the semiarid areas of developing countries. *Information Technologies and International Development*, *4*(1), 51–67. doi:10.1162/itid.2007.4.1.51

Pierce, F. J., & Elliott, T. V. (2008). Regional and on-farm wireless sensor networks for agricultural systems in Eastern Washington. *Computers and Electronics in Agriculture*, *6*(1), 32–43. doi:10.1016/j.compag.2007.05.007

Pooja, P., Varsha, T., & Pravin, P. (2016). *Cucumber disease detection using artificial neural network*. Paper presented at the International Conference on Inventive Computation Technologies, Coimbatore, India.

Ravi Kishore, K., & Nisheeth, R. (2013). *Wireless sensor network in Mango Farming*. Paper presented at the Nirma University International Conference on Engineering, Ahmedabad, India.

Ravi Kishore, K., & Snehashish, M. (2016). *IoT Based Weather Station*. Paper presented at the International Conference on Control, Instrumentation, Communication and Computational Technologies, Kumarakoil, India.

Tian, Y., Li, T., & Niu, Y. (2008). The Recognition of Cucumber Disease Based on Image Processing and Support Vector Machine. *Congress on Image and Signal Processing*, *2*, 262–267.

Tripathy, A. K., Adinarayana, J., Merchant, S. N., & Desai, U. B. (2013). *Data mining and wireless sensor network for groundnut pest/disease precision protection*. Paper presented at the National Conference on Parallel Computing Technologies, Bangalore, India. 10.1109/ParCompTech.2013.6621399

Tripathy, A. K., Adinarayana, J., Sudharsan, D., Vijayalakshmi, K., Merchant, S. N., & Desai, U. B. (2013). Data mining and wireless sensor network for groundnut pest/disease interaction and predictions – a preliminary study. *Int. J. Comput. Inform. Syst. Ind. Manage. Appl.*, *5*, 427–436.

Vyas, D., Borole, A., & Singh, S. (2016). Smart Agriculture Monitoring and Data Acquisition System. *International Research Journal of Engineering and Technology*, *3*(3), 1823–1826.

ADDITIONAL READING

Dong, X., Vuran, M. C., & Irmak, S. (2013). Autonomous precision agriculture through integration of wireless underground sensor networks with center pivot irrigation systems. *Ad Hoc Networks*, *11*(7), 1975–1987. doi:10.1016/j.adhoc.2012.06.012

Hong, L., Shuying, L., Qun, D., & Weibin, L. (2018). Application of Multi-Sensor Image Fusion of Internet of Things in Image Processing. *IEEE Access: Practical Innovations, Open Solutions*, *6*, 50776–50787. doi:10.1109/ACCESS.2018.2868227

Mat, I., Kassim, M. R. M., Harun, A. N., & Yusoff, I. M. (2016). *IoT in Precision Agriculture applications using Wireless Moisture Sensor Network. Paper presented in the IEEE conference on open systems*. ICOS.

Nurzaman, A., Debashis, D., & Iftekhar, H. (2018). Internet of Things (IoT) for Smart Precision Agriculture and Farming in Rural Areas. *IEEE Internet of Things Journal*, *5*(6), 4890–4899. doi:10.1109/JIOT.2018.2879579

Sethi, P., & Sarangi, S. R. (2017). Internet of Things: Architectures, protocols, and applications. *Journal of Electrical and Computer Engineering*, *2017*, 1–25. Advance online publication. doi:10.1155/2017/9324035

Singh, V., & Misra, A. K. (2016). Detection of plant leaf diseases using image segmentation and soft computingtechniques. *Information Processing in Agriculture*, *4*(1), 41–49. doi:10.1016/j.inpa.2016.10.005

KEY TERMS AND DEFINITIONS

Clustering: The task of grouping a set of objects into a group (based on some attribute), in such a way that they are more similar within them than to those in other groups.

Data Analysis: It is a process of inspecting, refining, transforming, and modeling data with the aim of extracting useful information, deducing conclusions, and enabling decision-making.

IoT: Interconnection of sensing and actuating devices to share information across platforms through a unified framework.

NodeMCU: An open-source firmware used to prototype IOT applications.

Polyhouse: Polyhouse or a greenhouse is a house or a structure made of translucent material like glass or polyethylene where the plants grow and develop under controlled climatic conditions.

Precision Farming: The belief that family is central to wellbeing and that family members and family issues take precedence over other aspects of life.

Raspberry Pi: Small single board computer used to enhance programming skills.

Segmentation: It is the process of partitioning a digital image into multiple segments and makes it more understandable.

Chapter 18
Artificial Intelligence in Integrated Pest Management

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ABSTRACT

Climate change, the increase in the international exchange of infested materials, and pest control problems cause unpredictable pest outbreaks faced by farmers. To overcome these problems, a sustainable pest control tactic, integrated pest management (IPM), which is providing the effective use of natural resources, is needed. IPM is an ecologically based control management strategy that considers all factors (i.e., natural enemies, economic thresholds, plant susceptibility and breeding factors, pest biology, and climatic conditions). In IPM, expert staff constitutes the essential element. The expert plays a role in system design, monitoring ecological factors, and decision-making mechanisms. For sustainable pest management, it is possible to perform the routine processes such as monitoring biological and environmental components and choosing the appropriate time and method through artificial intelligence. In this chapter, the use of artificial intelligence in IPM and information about algorithms, tools, methods used in artificial intelligence will be explained.

INTRODUCTION

Today, modern agriculture is facing great difficulties. Agricultural manufacturing has now become a competitive and globalized industry where farmers and other actors providing input into agriculture have to consider climatic and geographical differences as well as global economic and political factors. In order to ensure nutrition demand of the growing world population, food production needs to be increased from year to year, but the world's arable areas are limited (FAO, 2014; Quarcoo et al., 2014). While the use of

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agricultural products for bioenergy creates additional pressures on the world's food requirement, housing as well as transportation problems narrow down the world's arable lands considerably (Boserup, 2017). In recent decades, the changes in global climate has led to an increase in unexpected precipitations, global warming, droughts and the frequency of extreme weather events (Piao et al, 2010). These unfavorable conditions lead to endangering traditional production areas and bringing new risks and uncertainties for world agriculture. Because of climate change, the outbreaks of existing pests are increasing or they become the main pests in areas where they did not cause problems before (Scherm, 2004). An increase in the international exchanges of infested material (seed, plant and soil) is caused by unpredictable pest problems faced by farmers (Dent et al., 1995). In addition to all these global problems, issues related to pests such as pesticide resistance, secondary pest outbreaks and breakdown in host plant resistance, have increased the magnitude of the agricultural production problem (Weller et al., 2014). To cope with these challenges, a continuous and sustainable increase in productivity in all agricultural production areas is needed, while water, energy, pesticides and fertilizers, etc. should be used diligently and efficiently.

Consequently, agriculture needs help to eliminate these problems and uncertainties and requires new solutions for all aspects of agricultural production, from better and predictable product planning to precision agriculture and optimized resource implementation. Nowadays, the most popular and sustainable approach to controlling pests is Integrated Pest Management (IPM) (Flint and Bosh, 1981). However, this approach is quite sophisticated and requires a lot of knowledge, expertise, and observation. In practice, it is necessary to monitor the pest in the field, determine the most sensitive stage of pests, decide on the most appropriate control tactic (pesticide or other alternative methods) and apply it in the best time (Flint and Bosh, 1981). Consequently, IPM requires intensive field observation, trained staff, and data mining. In this context, it has emerged that the use of artificial intelligence (AI) algorithms is a necessity for controlling, tracking, and using these agricultural inputs at the optimal times (Azfar et al., 2015). In this chapter, we will examine the impact and the historical development of Industry 4.0 on modern agriculture and the innovations in IPM in concerning information technologies.

BACKGROUND

Industry 4.0 in Agriculture

Industry 4.0 is defined as the intelligent production period in which all live and inanimate objects with a particular economic value can communicate and interact with other objects through internet connection along with developments in many fields of technology (e.g., AI, 3D printers, robotics, biotechnology, and nanotechnology) (Lasi et al., 2014). In order to increase the added value of economic production, developed countries are preparing for a new industrial revolution in almost every sector, including agricultural production, and many businesses have been or are being integrated into this new industrial revolution. In this period of digitalization in production, virtual and physical systems are being integrated and the objects connected to the internet will, therefore, become intelligent in the production system (Aksoy, 2017).

One of the important places where the transformation has been realized under Industry 4.0 is the factories equipped with "smart" technology. These factories are called dark (lights out) factories because no people work there (Alkan, 2016). These smart systems, which are used extensively in industry, have even entered our daily lives (such as electricity, water, fire alarm and intervention systems in smart homes). Similarly, it is possible to use similar "smart factories" in agricultural production. Thus, sensor supported intervention systems have started to be used extensively to determine the need for water, humidity, temperature, and light in greenhouses. However, the system can switch on/off the equipment automatically or can warn the authorized personal depending on needs such as water, humidity, light, and ventilation (Kürklü and Çağlayan, 2005).

Agriculture is based on production in high amounts in large areas, and the use of labor in production never meets the food demand of our world. For this reason, today's technology provides a benefit for the machinery and equipment used for agricultural production. Therefore, to feed the rapidly growing world population, mechanization in agriculture is defined as the first revolution of the agriculture industry. The use of synthetic fertilizers and pesticides is described as industry 2.0 in agriculture, and the emergence of biotechnological products is called industry 3.0 in agriculture. In the future, industry 4.0 in agriculture will probably be realized by integrating AI into production. It seems the concept of "Modern Agriculture" that was born with the effects of Industry 4.0 should be adopted to benefit from its advantages. The agriculture conversion from traditional to modern production led to the use of modern production factors such as science, technology, and capital and to increase the use of agricultural machinery (Finney, 1996). The increases in innovative technologies in agriculture, agricultural production, and management activities gradually specialized and increased the productivity obtained from the unit area (Binswanger, 1986). In the last two decades computer science and space programs developed technologies such as computers, satellites and remote sensing systems which have now been combined with agriculture (Baogang, 2006). In other words, Modern Agriculture is the transformation of agricultural production methods from manual tools to machine use, then from manual machinery to automatic one (Agarwal and Goel, 1981). With the use of agriculture machinery, while the work efficiency obtained from a unit area has increased considerably, the use of synthetic fertilizers, hormones, and pesticides has enhanced the agricultural yield in a unit area. As a negative reflection of modern agriculture, the use of intensive chemicals has triggered an increase in populations and epidemics of pests. The intensive use of these chemicals in agriculture has unfortunately caused poisoning of non-target organisms or heavy environmental pollution. To overcome these problems of Modern Agriculture, a new concept, "Good Agricultural Practices" should be utilized for today's agriculture and to contribute to the sustainability of agriculture.

Good Agricultural Practices in Modern Agriculture

The developments of quality hybrid varieties, biotechnology, chemical additives, and information technology in agriculture, has considerably improved the potential of agriculture production. The model of good agricultural practices has been adopted in developed countries and has brought agriculture to the next level. Modern agriculture started with the use of chemicals and it has also caused extraordinary problems such as the destruction of resources and environmental pollution. In recent years, countries around the world have paid more attention to the management and conservation of the ecological environment in agricultural development, considering the conservation and efficiency of production resources such as soil, fertilizer, water, pesticide. In this context, new models such as "Good Agricultural Practices" were born in sustainable agriculture (Swanson, 2008).

The essential component of good agricultural practices is IPM (Sabir et al. 2010). In this method, there are significant improvements such as the correct identification of the pest, the control of pests at the right time, the use of less synthetic chemicals and environmentally friendly alternative pest control tools, reducing chemical residues on foods and environmental pollution, the occupational safety for agricultural workers. It is clear that all this advanced information is based on intensive scientific works and practical applications. Although numerous studies have been carried out on IPM, the processing, analysis and practical application of this information require IPM specialists. The most critical challenge is that a small number of specialists reach agriculture producers and make the information available. Therefore, it is possible to process the existing and developing data in the IPM into software and then to analyze them and to deliver the right advice to the agricultural producer by an AI technology. After this section of our chapter, the description of IPM and the use of AI in IPM will be discussed.

PEST CONTROL STRATEGIES

It is expected that 60% of the existing production in agricultural production will be lost if no action is taken against pests (Popp et al., 2013). For example, if the olive fly [*Bactrocera oleae* (Gmelin) (Diptera: Tephritidae)] is not controlled, damages may incur up to 15-30% in average years and 70% in outbreak years (Anonymous 2008). If codling moth [(*Cydia pomonella* L. (Lepidoptera: Tortricidae)], one of the main pests of apples, are not controlled, damage may incur up to 60% or even 100% (Anonymous 2008; Aydar et al., 2010). Grain, which is essential in human nutrition, is considered as food security in much of the world. Grain products cover 50% of cultivated areas in Turkey (Koçak, 2006; Gökdoğan, 2015). Such a yield loss in wheat, which is the most important raw material of human nutrition, is reflected directly as an increase in the rate of hunger in the world. In this part, we will mention pest control methods used and the impact of the use of technology on the success of control. There are many pest control methods against agricultural pests (Table 1). When we classify control methods, these are cultural practices, physical & mechanical, chemical, biological, biotechnological and genetic controls. Among these methods, the most preferred pest control tactic is chemical control (pesticides) because these are quick acting, cheap, highly effective and easy to apply (FAO, 2014; Kumral et al., 2017). Chemical control destroys pests with chemical substances contained in their composition. The reason for this is that pesticides usually consist of toxic substances. Therefore, when the chemicals were used intensively, they cause severe hazards to non-target organisms and humans. More than that, the intense and incorrect use of these chemicals cause many ecological problems and environmental damages (Simon, 2014). Also, mistimed and high dose usages of the compounds can cause pesticide residues on crops. However, careless and negligence in the handling of pesticides, lack of information and / or training can be a severe health risk for farmers (Damalas et al., 2006).

Because of these adverse effects of chemical pesticides on non-target organisms, the tendency is towards highly specific alternative control methods. First of all, within the scope of cultural practices, general cultivation techniques should be used for growing plants which are healthy and resistant to a pest. Also, the use of biotechnological and physical control tools or biological agents specific to target organisms is another alternative. The methods, such as biotechnological and biological control, are provided to keep their pest populations under the threshold of economic damage. In recent years, some biotechnological methods, such as mating disruption with pheromones, releasing genetically sterile organisms, growing genetically modified plants, have been significant developments in pest control (Anonymous, 2014; Singh et al., 2006).

Scientists have been developing new and different pest control methods since determining the hazardous effects of pesticides. In recent decades, a comprehensive approach to pest control, namely

Table 1. Pest Control Methods

Pest Control Methods	→	Cultural Practices
		Physical and Mechanical Control
		Chemical Control
		Biological Control
		Bio-technological Control
		Genetic Control

Integrated Pest Management (IPM), has been developed against main pests around the world. IPM is an ecologically based control management strategy that considers natural factors, i.e., natural enemy pressure and climatic conditions. Existing IPM programs, consider factors such as pest and natural enemy populations, economic thresholds, plant susceptibility, plant breeding factors and pest biology. In IPM programs, two or more compatible methods are combined, and the potential interactions among these methods are evaluated. Under IPM programs, cultural practices, resistance crops, biological (predator, parasitoid, pathogens) and biotechnical (messenger chemicals) methods should be a priority. Pesticides should have specific effects on pests and no-side effects on natural enemies and other wildlife (Flint and Bosh, 1981). Consequently, IPM is a form of control that aims to solve agricultural pest problems by using multiple combat methods instead of a single method and uses a combination of methods suitable for economic, ecological and toxicological demands that prioritize natural factors in the fight against harmful organisms (Kogan, 1998). An IPM program is comprised of six essential elements: (1) people: system developer and manager; (2) knowledge and information: biological and ecological information needed for creating a program; (3) monitoring: determination of pest, natural enemies and other abiotic and biotic factors as numerical data; (4) decision making levels: the pest population level required to start pest control; (5) methods: which control tactics are combined for reducing pest populations; (6) Agents and materials: the tools of pest control (Flint and Bosh, 1981).

INTEGRATED PEST MANAGEMENT WITH ARTIFICIAL INTELLIGENCE

As stated in the previous section, the most crucial element is IPM specialist. But, except as system designer, as well as the expertise plays a role to perform the routine processes (such as monitoring, choosing the appropriate time and method). Despite improving many specific products that can be used in control against agricultural pests, the person who decides which method is appropriate constitutes a critical factor as decision-maker. In IPM, results that can achieve success in pest control can be obtained with the combination of many systems. Firstly, the identification of the pest must be made correctly by using a suitable technique. With advances in electronics and information technologies, it has been developed with various pest detection systems. The oncoming section will explain some techniques and tools which can be used to determine diagnose and density of pests. It is imperative that information such as instant changes in plant phenology as well as pest population level is acquired in a timely and accurate manner. Also, the climate data from the environment in which the plant and pest live must be taken in order to predict the development of the organism using mathematical prediction models. With these techniques and their combination, the integration of AI could maximize the success of control. The most important aspect feature of this stage is the immediate transferring of instant data with a wireless sensor network. All these technological benefits can be considered within the scope of IPM, and a successful pest control strategy can be implemented. This integration increases the effectiveness of pest control, while the costs of material and labor are decreased (Azfar et al., 2015). Due to the recent developments in technology and the impact of Industry 4.0 on agriculture, AI algorithms are being used, and successful results are being obtained within the scope of IPM (Table 2). We will explain these techniques and studies and their usage of AI in IPM.

Table 2. Pest Control Methods

Pest Control Methods	Cost	Environment Friendly	Product Quality	Labor Saving	Effectiveness
Chemical Control	Low	Low	Low	Low	High
Biological	Medium	High	High	Medium	Medium
Genetic	High	Medium	High	High	High
IPM with AI	Medium	High	High	Medium	High

Pest Detection and Monitoring Systems

In remote sensing the detection of plant pests, wireless sensors and some highly sensitive motion/vibration sensors have been using in recent years. The acoustic sensors, which can record some specific frequencies produced by pests, are available. However, pest populations in the entire area are challenging to detect using these sensors. At least, it is possible to point out the presence of some insects in a particular part of our area. Image processing and optical sensor technologies combined with pheromone traps are also available for direct identification of pests (Wang et al., 2006; Lee et al., 2010). Accurate detection of pests is vital when implementing an IPM strategy. Today, to determine diagnose and density of pests are possible with acoustic, ultrasonic and optical sensor technologies which are specific to pest species.

Acoustic Sensors

Sensitive acoustic technology has been used since the early 20th century to detect hidden insect infestation in soil, trees, and plants (Brain, 1924). The development of modern computer technology has made possible the digital signal processing techniques that facilitate the separation of insect sounds from background noise and provide the driving force for research on new acoustic vehicles to detect and monitor the invasion of underground insect pests. Recently acoustic technology has been adapted to detect insects in feeding areas (Brandhorst-Hubbard et al. 2001, Zhang et al. 2000). Insect species can be usually detected through low sounds (0.5 - 150 kHz) that they produce when they are flying, feeding or calling their opposite sex. Eliopoulos et al. (2015), used acoustic sensors for the detection of insects in stored wheat and they found that the method could be used to estimate population density in the area.

Fleurat-Lessard et al. (2006) used a computer program that matches the data from acoustic sensors and sensors to detect pests in a wheat pile, and they stated that this technology is useful for early pest detection in grain storage facilities. Mankin et al. (2004) usedacoustic sensors for the pest *Cephus cinctus* Norton (Hymenoptera: Cephidae) in wheat and stated that the movement and feeding activities in the plant could be detected by these sensors (Mankin et al., 2004). In addition, Potamitis et al. (2009) used acoustic sensors to detect and automatically diagnose acoustic emissions from typical behaviors such as the location and feeding of pests of *Rhynchophorus ferrugineus* Olivier (Coleoptera: Curculionidae) and *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) and they stated that the results were gave an accurate detection with a rate of 99.1%.

Ultrasonic Sensors

Insects that are hidden in seed, wood and some other fibrous plant materials can be detected by ultrasonic signals emitted during feeding activities. A pest detection system with ultrasonic sensors contains components such as an ultrasonic transducer, a low-noise narrow-band amplifier, a signal conditioner, and an output display device. In a system containing these components, the wave sent from the ultrasonic sensor bounces back after it hits the insects and it sends them to the machine capable of processing digital signals. Thus, the movement direction and actual position of the insects in the area can be estimated in real time (Shade et al., 1989). But so far, this system has not been able to run consistency different environments. It is still unclear what results it will produce in places where the usual background noise is high and how it will deal with the detection of insects of more than one species. In order to develop an intelligent, portable ultrasonic device for monitoring pests in the field, such studies, i.e., more research and development projects are needed (Shade et al., 1990). The absence of a new study since 1990 is an indication of this judgment.

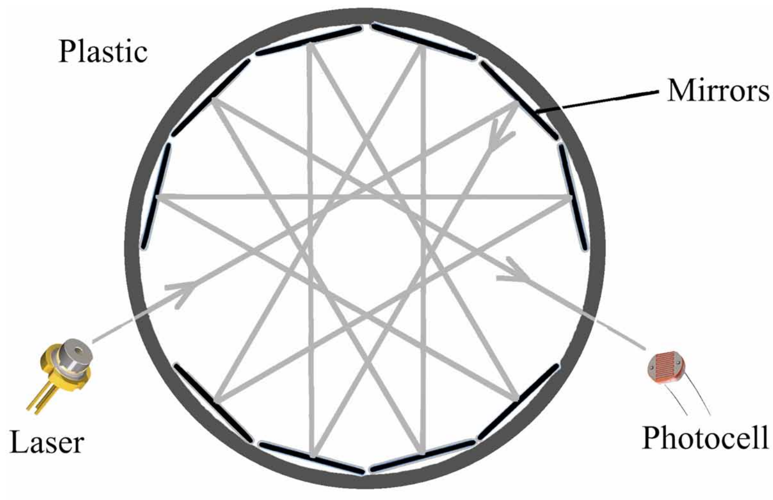
Optical Sensors

This system, which is prepared using sensors such as infrared rays, is placed in the entrance of pest traps combined with an attractant (pheromone, light or bait), and keeps track of how many times the pest enters to the trap. The optical sensors send rays to the entrance of the trap, and this ray cuts its path when the targeted pest enters the trap containing the attractive objects. This motion causes voltage fluctuation in the system controlling the sensor. This fluctuation is the signal of the entry of the pest into the trap. The determination of the date and population density when pests are first caught in traps plays an essential role in the IPM. For accurate detection, attractants which are specific to each species must be used.

Ozcan et al. (2014) developed an optical trap to determine bark beetles *Dendroctonus, Ips* and *Scolytus* species (Coleoptera: Scoltyidae) (Fig. 1). By placing optical sensors into the entrance of this trap, they have developed a system that detects the date of the pest's entrance in minutes-hours-days and stores the data on an SD card. With using this system, they emphasized it could be developed for effective IPM strategies against bark beetles.

Red Palm Weevil (*R. ferrugineus)* is feeds on palm trees, and if not detected, causes very serious damage. If the pest is detected in time, the damage can be minimized with proper control methods (Giblin-Davis et al., 2013). For this reason, pheromone traps are used to monitor the pest. However, the manual counting of these pheromone traps is particularly tricky in the Mediterranean basin and in areas not easily accessible for reasons including long distance. To solve this problem, Potamitis et al. (2015)

Figure 1. Design of laser scanning application



describe a new monitoring solution for the Red Palm Weevil. They have used an optical sensor to detect the fall of the insect into the trap. The electronic circuits connected to the sensor count the pests and send the results as SMS to a predetermined phone using the GSM network. Thanks to this system, labor costs were reduced, and it was possible to monitor the pest population and emergence around larger areas. When we look at all these studies, optical sensors provide a significant advantage in counting pests. However, it has the disadvantage of not being able to detect the pest species in the traps when not using a specific attractant to species and inefficient functioning under artificial light. Studies show that more research on identifying species with a high precision is needed.

Image Processing Systems for Insect Pests

The effective use of different IPM techniques is possible with monitoring pest populations. With data obtained from various pest traps, there is an opportunity to obtain more information about the flight and emergence of pests. These data relate to what is the number of pest individuals captured using traps and whether this number exceeds the economic damage threshold. For example, in the apple orchards in the Emilia Romagna region (Italy), the control for codling moth begins with the identification of two male moths caught per trap in two consecutive days (Anonymous, 2011). In order to achieve this condition, at least two pheromone traps must be hung in a one hectare-sized fruit orchard and checked each day until males have been captured. To provide this data, the traps should be checked periodically, the number of individuals trapped should be recorded, and these procedures should be performed throughout the season. All these tasks require intensive labor and cause a loss of time and energy. As with the optical sensor systems mentioned in the previous section, if a species-specific attractant is not used in the traps, it is not possible to accurately detect the pest species entering the trap. Also, it is not possible to find an attractant specific to every pest species. To solve this problem, successful results on remote trap tracking systems could be obtained by performing automatic pest counting with a camera placed in the trap and the image processing techniques in the image taken by this camera. An exemplary system view is shown in Fig. 2-3.

Figure 2. Remote pest monitoring system

Shimoda et al. (2006), to count diamondback moth *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) individuals, they used a pheromone trap with an image processing technique. In the method, they have used a smartphone to capture the images of the trap periodically and transmitted the images to a computer using the wireless LAN system. They stated that this technique has a success rate of 91% (Shimoda et al., 2006). Similarly, Boissard et al. (2008) indicated that they were able to diagnose the pest whitefly adults on rose leaves with image processing and emphasized that these methods can be used in the context of integrated control and the early diagnosis of pests. This method of Boissard et al. (2008) may be easily adapted to the yellow sticky traps which are an attractant for whiteflies. Tirelli et al. (2011) have developed a system to automate the count of insect pests in the roseus plant, *Vinca catharantus*. They have created a system that captures images at regular intervals and sends them to the host via the wireless network connection and uses the background separation technique to determine the number of pests (Tirelli et al., 2011). Similarly, Fukatsu et al. (2012) developed a system to automate the pest count of pheromone traps used for *Leptocorisa chinensis* Dallas (Hemiptera: Alydidae) (rice beetle) pests. They set up a physical server on the field and sent the images captured in the pheromone trap by the camera via wireless LAN. They demonstrated a successfully counted trap by using the image processing software based on background separation technique on the land server with 89.1% success compared to the manual technique (Fukatsu et al., 2012). Facello and Cavallo (2013) have developed a system that allows data to be stored on a server at fixed time intervals by placing a temperature-humidity and an IP camera on pheromone traps to monitor fruit and vineyard pests. They used the solar panel for energy, and they can be accessed from any device with an internet connection by sending data to the central server with WiFi connection. A sample image processing output is shown in (Table 3). These studies above enable remote sensing traps to obtain data about the pest monitoring, the diagnosis of pests, the number of trapped pests and their flight periods, which are frequently used in the IPM. However, in determining the control timing, it constitutes only one input for the decision-making mechanism. These data must be integrated with other biological, physical and environmental parameters.

Figure 3. Example of image processing output for olive moth

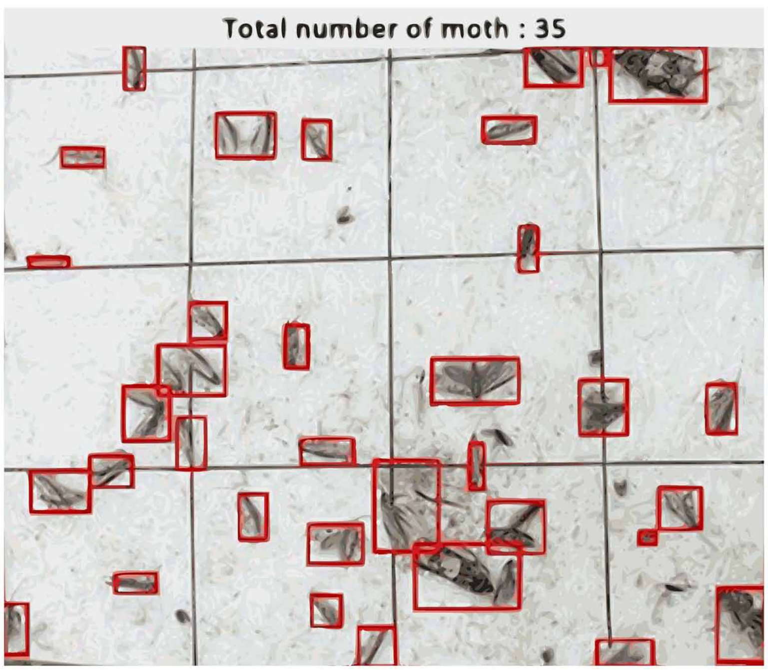


Image Processing Systems for Plant Disease

Plant diseases cause significant economic losses in the agricultural industry. Early detection of the pathogen by monitoring the plant for the purpose of controlling against these diseases is an effective method to prevent disease outbreaks. This control is provided by a human and expert knowledge is required to diagnose the disease. Besides common observation for disease symptoms, DNA-based and serological methods provide the necessary tools for the accurate diagnosis of plant disease. Although DNA-based and serological methods have revolutionized the detection of plant disease, the analysis requires at least 1-2 days. This process takes time to determine the disease diagnosis and control strategy (Martinelli et al., 2015). In order to speed up this process and to diagnose the disease momentarily, the disease can be diagnosed by image processing on the diseased leaf image (Khirade and Patil, 2015). In this section, various image processing methods for the detection of plant diseases are discussed. In an example, diseased leaf image, i.e. RGB (Red Green Blue) image, was used to identify the disease (Fig. 4). After applying the K-means clustering techniques, the green pixels were defined, and then the variable threshold value was obtained using the Otsu method (Otsu, 1979). The color matching method was used for feature extraction. The RGB image was converted to a HIS (Hue-saturation-intensity) version. The SGDM (Spatial Gray-level Dependence Matrices) matrix was generated for the calculation of texture statistics, and the results were calculated using the GLCM (Gray-level Co-occurrence Matrix) function (Al-Hiary et al, 2011). Huang et al. (2014), developed new spectral indices to identify wheat diseases. In their work, they used three different plant pests and diseases (powdery mildew, yellow rust, and aphids) in winter wheat. The most and least detected wavelengths for different diseases were obtained using the RELIEF-F algorithm. The classification accuracy of these new indices was in plants with powdery mildew, yellow rust and a healthy one. Jhuria et al. (2013), used image processing techniques for the detection of fruit diseases. They used an artificial neural network to detect the disease. They created two separate databases, one for the training of currently stored disease images and one for the application of query images. They focused on three different parameters: color, texture, and morphology. In their experiments, they found out that the morphological features produced better results compared to the other two features.

Table 3. Basic steps for plant disease detection and classification

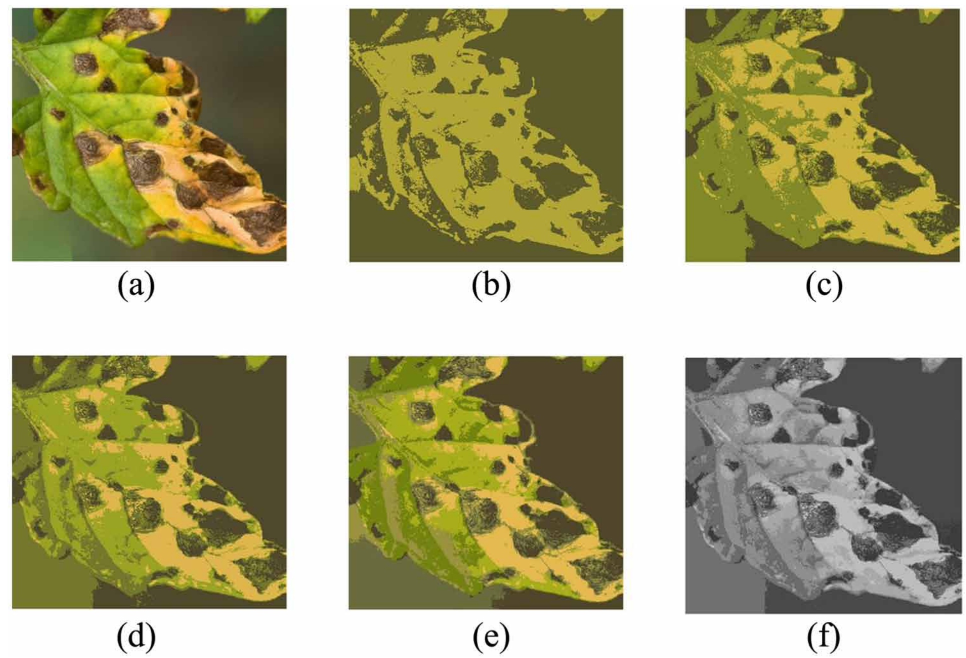
1- Image acquisition
↓
2- Image pre-processing
↓
3- Image segmentation
↓
4- Feature extraction in image
↓
5- Detection and classification of plant disease

Husin et al. (2012), used image processing techniques to diagnose disease in leaf images of the pepper plant. This study aimed to ensure that chemicals are applied only to diseased peppers. They used image processing with Fourier filtering, edge detection, and morphological processes on MATLAB for classification and image recognition in their studies. Phadikar and Sil (2008) used image recognition techniques to identify rice disease and developed a software prototype for virus identification in rice plants. They used the HIS model to segment the image on the diseased plant image. Then they made the boundary and point detection to determine the infected part of the leaf. As a result, these studies showed that accurate identification and classification of plant disease could be done using image processing.

Monitoring Remote Climate Data

Weather data is an essential input for many agricultural models, both at the individual farm level and at the regional or basin levels. The data that constitutes the input to these models is the climate data such as

Figure 4. An example of the output of K-Means clustering for a leaf that is infected with early scorch disease. (a) The infected leaf picture. (b, c, d, e) the pixels of the first, second, the third and the fourth clusters. (e) a single gray-scale image with the pixels colored based on their cluster index



wind direction, wind speed, temperature, humidity, precipitation, leaf wetness, solar radiation, and soil moisture. Weather data was introduced in agricultural models in the early 1970s. Since the 1980s, with the development of microcomputers and microprocessors, weather-based models have been created using personal computers (Welch, 1984). From the late 1980s to the mid-1990s, PC-based systems became relatively widespread, and during this period, crop modelling software "Decision Support System for Agrotechnology Transfer" (DSSAT) was developed (Jones et al. 1994; Demirel et al. 2018]. After 2000, with software products developed or marketed by meteorological station producers such as ADCON and METOS have helped farmers gain access to weather data recorded on or near their lands (Anonymous, 2000; Anonymous, 2019a). In recent years, with the Internet becoming widespread, it is possible to deliver weather-based models to users. Thanks to internet technology, the use of weather stations is widespread. The communication between producers and weather data providers is provided by GPRS technology and a universal interface that can preview this data (Fig. 5). Patil and Kale (2016) proposed a smart agriculture model as real-time monitoring parameters like temperature and moisture in soil and air conditions. To implement decision support advisory models in a Pest&Disease forecasting, they designed a system using both real-time climate condition data and plant disease identification system. They claimed that the system could control various operations of the field remotely from anywhere, anytime by mobile as well as through a web application. The proposed system has three modules — Farm side, Server side, and Client side. The paper proposes a wise agricultural model in integration with ICT. ICT has always mattered in the Agriculture domain. Village farmers may have planted the "same" crop for centuries, but over a long period, weather patterns, soil conditions, epidemics of pests and diseases changed. By using the proposed approach, received updated information allows the farmers to cope with and even benefit from these changes. It is a challenging task to provide such knowledge because of the highly localized nature of agriculture information specific to distinct conditions. The complete real-time and historical environment information is expected to help to achieve efficient management and utilization of resources. Their system consists of six methods as follows:

1. Sensing local agricultural parameters.
2. Identification of the location of sensor and data collection.
3. Transferring data from crop fields for decision making.
4. Decision support and early warming based on data analysis, domain knowledge and history generated.
5. Actuation and control based on a decision.
6. Crop monitoring via camera module.

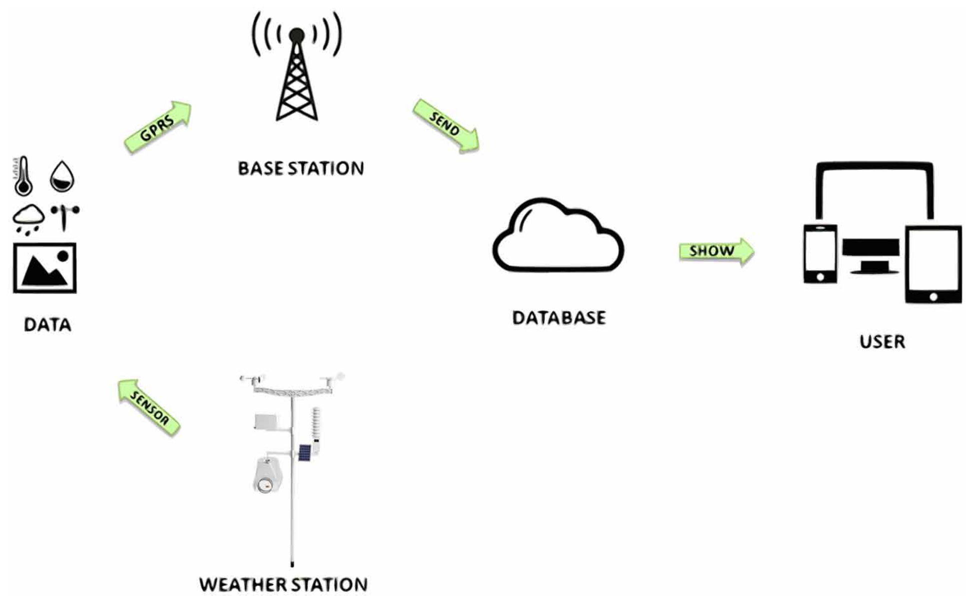
Dan et al. (2015) developed a remote real-time monitoring and control system for greenhouses. They also claimed that the system could implement scientific management methods and prevent crop outbreaks. They designed some sensors for collecting information about the climate of the greenhouse like temperature, pressure, light, humidity, and CO_2. They demonstrated that the system could decide the action of air fans, curtain controls for protecting the direct sunlight and sun heat and sprinkler to maintain humidity. This design can realize remote intelligent monitoring and control of greenhouse for both plant growing and pest control and can be helpful to farms for the scientific and rational planting crops. It is clear that this design would be particularly valuable and popular for farmers. This technology can provide farmers with direct access to weather data and models steadily and cost-effectively. GRPS-based rural meteorological stations can provide region-specific weather forecasts, planning of land-based spraying and fertilization works, determining pest outputs by creating inputs to DD models. However, for AI algorithms, which are used to decide the time of controlling pests in IPM, it is not enough to have climate data alone. The biological activity of the pest and the output of the DD models should be evaluated together.

Degree-Day Models

Agricultural pests are cold-blooded organisms and need specific temperature values for their development. This temperature value is called the development threshold, and although organisms start their physiological activities on the development threshold, specific temperature accumulations are required for some activities. These physiological activities can be predicted by the collection of degree-days (DD) between high and low-temperature thresholds during the entire development period of the insect. The date when the DD begin to be collected is known as the biofix date, and this date is linked to the biological activity of the pest. Birgücü and Karsavuran (2009) researched DD models and their opportunities to use in plant protection and emphasized in their studies that the determination of spraying time is crucial to prevent unnecessary pesticide use and to minimize the adverse effects of pesticides (Birgücü ve Karsavuran, 2009). In general, DD can be calculated using a simple formula for the average daily temperature, calculated from the daily maximum and minimum temperatures.

DD = [(daily maximum temperature + daily minimum temperature)/2] – baseline temperature

Figure 5. Operating mechanism of weather stations



For example, a day where the high is 22.2˚C and the low is 5.8˚C would accumulate 4 DD using 10˚C as the baseline:

Example 1:

$$DD = \left(\frac{22.2 + 5.8}{2}\right) - 10$$

When temperatures do not exceed 10˚C, zero DD have accumulated. This calculation method is the simplest and least precise. Let us examine the example of how to determine the biological periods of a codling moth pest using this calculation method:

Codling moth is the most common pest of apple trees. The larvae, which are directly harmful to the fruit, drill the fruits, open galleries in them, eat the flesh and the core house and leave dirt inside. As a result, they cause the fruit to fall, or they cause the degradation of quality and quantity of fruits that can remain on the tree without spilling. Thus, they lead to a decrease in the market value of the apple. The damage in uncontrolled areas can be up to 60% or even 100%. There is a fight in all the apple production regions in our country (Anonymous, 1995). Producers are often impatient in using chemicals. Unfortunately, they believe that the amount of chemical used is proportional to the high yield and quality. For this reason, calendar-based spraying is often applied. Of course, if a chemical control option is to be used in controlling a pest, it is crucial to determine its timing. This is a critical way to prevent unnecessary and ineffective insecticide use and to minimize the negative effects of insecticides. For this reason, in order to get the most effective results using the minimum number of insecticides, many studies have been carried out on forecasting and warning in the codling moth (Birgücü and Karsavuran 2009). Pheromone traps are hung onto the area to detect the first adult flights of the codling moth. The traps are hung near the center of the orchard to find out if the moths come from outside lands or overwinter in the orchard.

Traps are checked every 1-2 days until the first moth is caught. It is entered as a biofix date on the DD model when at least 1 moth is seen on consecutive days. The codling moth grows at intervals above 10°C and below 31.1°C (Alston et al., 2010). Accordingly, the calculation of DD is done according to the following formula:

$$DD = \int_{t0}^{t} (T - Th).dt$$

DD = degree-days, t=Date, t0= Biofix date, T=Average daily temperature, Th= Lower development threshold

As stated in table 4, in a successful control against codling moth, insecticide control should be applied for the 1st generation in 50-75 DD, 100-200 DD and 200-250 DD for early and newly hatched larvae. For the 2nd generation, insecticide applications should be continued at 1000-1050 DD and 1100 DD. For the control of the 3rd generation, the apples should be checked at the time of 2160 DD and the time between insecticide application and harvest should be taken into consideration. With the use of these

Table 4. Major events in a codling moth management program, based on accumulated degree-days (DD)

DD	%Adults Emerged	%Egg Hatch	Management Event
100*	0	0	· Place traps in orchards
150-200	First moth excepted	0	· Check traps every 1-2 days until biofix is determined
First Generation			
0 (biofix)	First consistent catch	0	· Reset DD to 0
50-75	5-9	0	· First eggs are laid · Apply insecticides that need to be present before egg-laying
100-200	15-40	0	· Early egg-laying period · Apply insecticides that target early egg-laying period
220-250	45-50	1-3	· Beginning of egg hatch · Apply insecticides that target newly hatched larvae
340-640	67-98	12-80	· Critical period for control, high rate of egg hatch · Important to keep fruit protected during this period
920	100	99	· End of egg hatch for 1st generation
Second Generation			
1000-1050	5-8	0	· First eggs of 2nd generation are laid · Apply insecticides to target early egg-laying
1100	13	1	· Beginning of egg hatch · Apply insecticides that target newly hatched larvae
1320-1720	46-93	11-71	· Critical period for control, high rate of egg hatch
2100	100	99	· End of egg hatch for 2nd generation
Third Generation			
2160	1	15	· Beginning of egg hatch · Keep fruit protected through September 15 · Check pre-harvest interval of material used to ensure that final spray is not too near harvest.

(Alston et al., 2010)

DD models, the success in controlling against codling moth increases significantly. As noted in Table 5, DD model studies have also been conducted on many major pests. The most significant factor in the use of DD is to obtain the correct temperature values. If the position of a thermometer or weather station does not represent the environment in which the target insect occurs, the resulting DD do not reflect the actual insect development. Besides, temperatures in a region may not reflect conditions in another region within a few kilometers. This is an indication of the fact that mountains, lakes, and deserts lead to a wide variety of microclimates.

Table 5. A partial list of insect pests that has temperature thresholds

Target Insect		Lower Threshold (C)	Upper Threshold (C)
Common Name	**Scientific Name**		
Alfalfa weevil	*Hypera postica*	-12.2	30.5
Armyworm	*Pseudaletia unipuncta*	-12.2	28.8
Black cutworm	*Agrotis ipsilon*	-12.2	30
Cabbage maggot	*Delia radicum*	4.4	30
Codling moth	*Cydia pomonella*	-12.2	31.1
Corn earworm	*Helicoverpa zea*	12.7	33.3
European pine shoot moth	*Rhyacionia bouliana*	-2.2	---
European red mite	*Panonychus ulmi*	10.5	---
Lilac/ash borer	*Podosesia syringae*	-12.2	---
Obliquebanded leafroller	*Choristoneura rosaceana*	6.1	29.4
Peach twig borer	*Anarsia lineatella*	-12.2	31.1

(Murray, 2008).

Kumral et al. (2005) examined the population density using pheromone traps and temperature values against olive moths in Bursa province, Turkey. As a result of the study, they proved that these two relationships could be used as a predicting method for accurate timing in insecticide applications against olive moth larvae (Kumral et al., 2005). Again, Kumral et al. (2008) have conducted a study to determine the hatching time of olive psyllid larvae [*Euphyllura phillyreae* Foerster (Homoptera: Aphalaridae] using effective temperatures. As a result of the study, they found that insecticide applications against larvae at the right time could also be used as a prediction method (Kumral et al., 2008). Gallardo et al. (2009) have used a 12-year data for DD modelling of *Lobesia botrana* (Den.&Schiff.) (Lepidoptera: Tortricidae) and stated that their model could be a useful tool for improving the effectiveness of IPM strategies (Gallardo et al., 2009). As stated in the conducted studies, biofix date and DD models are used in the prediction and early warning studies in IPM method. Codling moth *Cydia pomonella* L. (Lepidoptera: Tortricidae) adults lay eggs when evening temperatures reach 15° C and above. For this reason, in prediction and warning studies spraying is started when the total of effective temperature reaches 100 DD as of January 1st, as well as when evening temperatures reach 15° C and above (Öncüer, 2004). As a result of these studies, positive results were obtained from three sprayings, the first in the first offspring larvae outflow, the second in 20 days after the first one and the third in the second offspring larvae outflow. However, the numbers of spraying vary from year to year and from an orchard to orchard depending on the duration of effect, moth flight time and intensity of the pesticides (Kıroğlu et al. 1992; Gürses et al., 1985). At this point, sexual pheromone traps should be used together with DD models for moth population determinations, and biofix date should be taken as the date of the first biological activity determined by pheromone trap instead of 1 January. However, a combined strategy should be implemented using a pheromone trap with DD models to determine the time of the control in the integrated control. Using DD models in forecasting systems, the aim is to evaluate all factors that are effective in changing the pest population and to determine whether the pest can reach the economic loss threshold or not. If all indicators are positive, the system can predict the timing and warn the manufacturers. Thus, natural equilibrium and environmental health will be highly protected using timely and correctly implemented methods.

Use of Artificial Intelligence in IPM where All Technological Methods Are Integrated

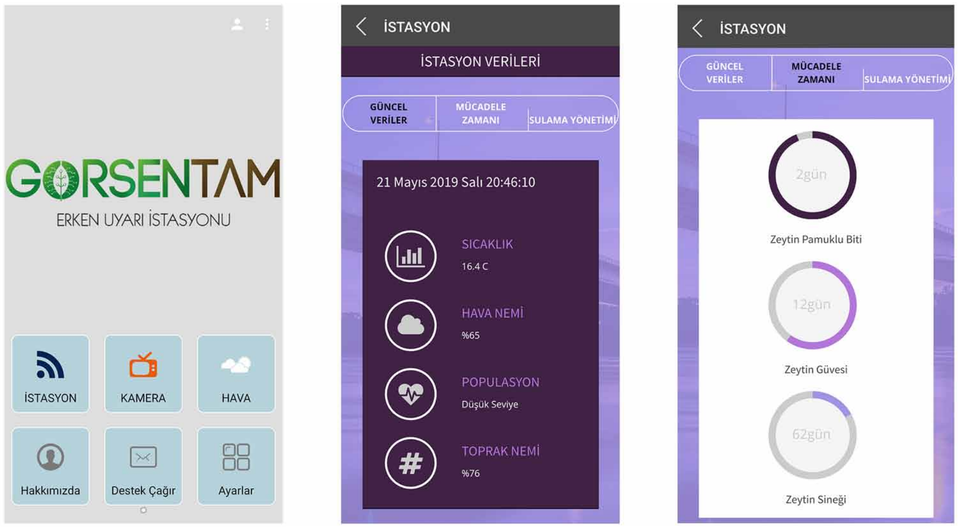
The technologies and techniques used in IPM are beneficial in determining the time of remote monitoring of climate data, remote pheromone trap monitoring, and DD models. However, these techniques require intensive physical labor and costs of labor both to farms that use traditional production and enterprises that operate in large areas. In this context, the need arises for a system that provides a high level of control timing with an AI algorithm that uses the data obtained from these techniques.

In the anticipated system:

1. The system should immediately identify any biological period of the pest in the field (using data such as color, pattern, and width-length, etc. and diagnosing with image processing technology),
2. The system should periodically monitor the number of pests with the same image processing system.
3. The system should collect important climate data (temperature, humidity) that affect the biology of the pest from the environment where the pest lives with high sensitivity.
4. The system should have a mathematical model in which it can evaluate instant climate data with a specific systematic,
5. The system should be able to process the data received from the image processing system and sensors according to the model and immediately evaluate the probability of pest's outflow or outbreak and send the information to the expert or manufacturer via web-based instant message,
6. The system should be viewed or intercepted by smartphones or tablets with an Android or iOS-based application (Fig. 6).
7. In this software, the system should be able to recommend the most appropriate licensed (pesticides and/or biotechnological) product according to the critical biological period of this pest from a current official source (Anonymous, 2019b).

Infrastructure studies have been carried out on this designated system and a project called "GÖRSENTAM: Intelligent Agricultural Control System Supported with Image Processing and Sensor" has been developed [Fig. 6]. The system contains all the technical aspects and details mentioned above and is used within the scope of IPM with its image processing and AI algorithms. GÖRSENTAM was used against olive psyllid in an olive garden in Gemlik, Bursa and successful results were obtained (Demirel et al., 2018).

Figure 6. Screenshots of GORSENTAM mobile application



FUTURE RESEARCH DIRECTIONS

The use of AI algorithms in IPM is a vast and impressive area. More research and development activities should be carried out on this topic. Today, topics such as phytosanitary, good agricultural practices and sustainable agriculture have become very popular and, in some countries, entrepreneurship activities on this topic are supported. For entrepreneurs, the way to follow should be:

1. Selection of an agricultural pest to work on
2. Determination of the development thresholds of this pest (e.g., min:6.4°C, max:40.2°.)
3. Establishing the system to collect data from the field
4. Development of pest-specific DD models
5. Development of tools to track biological activity in the field (e.g., pheromone trap system with a camera)
6. Development of software to automatically track the identification, count and biological activity of the pest (e.g., image processing algorithm)
7. Development of an AI algorithm that interprets all these data and makes logical decisions
8. Development of mobile application or web interface for current monitoring of data
9. Validation of the system
10. Continuation of research and development activities by adding new agricultural pests to the system

CONCLUSION

Successful results can be obtained by using AI algorithms for IPM, but more research and development activities are needed on this topic. Since agricultural pests are cold-blooded organisms, their biological activities progress according to the climate data in their environment. The places where these pests live can be the soil, the surface of a plant and the inside of a fruit. For pests that live in fruit, the development of the pest will be directly related to the climate data in the environment in which it lives. In this context, the suitability and sensitivity of the sensors which collect the climatic data in the environment where the pest is present during the DD modeling are extremely important. Specific agricultural sensors should be developed in order to increase the accuracy of the data that will generate input to AI algorithms on this topic.

On the other hand, AI algorithms need to be developed for hundreds of different species to be applicable for all pests. For example, let us suppose that there are approximately 150 main pests in Turkey. Intensive work is needed to determine the development thresholds of these pests and to develop algorithms for diagnosis and counting of pests with DD modeling and image processing. In this regard, computer science and agricultural science must carry out an interdisciplinary study together. To implement effective IPM, pest monitoring systems and tools that are used to obtain supportive information for decision making should be developed to track pest populations in the field.

Although there are many pesticides licensed today, expert knowledge is required for their effective use. The lethal effect of pesticides differs according to the pest and its phenology. Choosing the right pesticide at the right time requires expert knowledge. In this context, apart from determining the time of control, the algorithms' reporting of the right pesticide recommendation will also raise the level of success for the control. The algorithm should screen the licensed pesticide list of the country in which it will be used and recommend it to the user by selecting pesticides that are suitable for phenology of the pest.

The data from the field and the results of the algorithm IPM should be followed up using a mobile application or interface. This mobile application or interface must be accessible via the Internet for use anywhere and should notify the user by sending a notification at any time.

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REFERENCES

Agarwal, M. C., & Goel, A. C. (1981). Effect of field levelling quality on irrigation efficiency and crop yield. *Agricultural Water Management*, *4*(4), 457–464. doi:10.1016/0378-3774(81)90033-0

Aksoy, S. (2017). Değişen teknolojiler ve endüstri 4.0: Endüstri 4.0'ı anlamaya dair bir giriş. *SAV Katkı*, *4*, 34–4.

Al-Hiary, H., Bani-Ahmad, S., Reyalat, M., Braik, M., & ALRahamneh, Z. (2011). Fast and accurate detection and classification of plant diseases. *International Journal of Computers and Applications*, *17*(1), 31–38. doi:10.5120/2183-2754

Alkan, M. A. (2016). *Karanlık fabrikalar ile insansız üretim.* Retrieved from http://www.endustri40.com/karanlik-fabrikalar-ile-insansiz-uretim

Alston, D., Murray, M., & Reding, M. (2010). *Codling Moth (Cydia pomonella).* Utah State University Extension and Utah Plant Pest Diagnostic Laboratory publicatios. Retrieved from https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1879&context=extension_curall

Anonymous. (1995). Zirai Mücadele Teknik Talimatları. Cilt III. T.C. Tarım ve Orman Bakanlığı, Koruma Kontrol Genel Müdürlüğü, Ankara.

Anonymous. (2000). *Pessl Instruments. Product page on Metos.* Retrieved from https://www.metos.at/download.html

Anonymous. (2008). Zirai Mücadele Teknik Talimatı. Cilt V. Ankara, Turkey: T.C. Tarım ve Orman Bakanlığı, Koruma Kontrol Genel Müdürlüğü, Ankara.

Anonymous. (2011). *Integrated Pest Management on ERMES.* Retrieved from http://www.ermesagricoltura.it

Anonymous. (2014). *Alternative pest control methods for agricultural use.* Retrieved from http://education-portal.com/academy/lesson/alternative-pest-control-methods-for-agricultural-use.html#lesson

Anonymous. (2019a). *Adcon Telemetry applications agriculture*. Retrieved from https://www.adcon.com/

Anonymous. (2019b). *Bitki koruma ürünleri veri tabanı*. Tarım ve Orman Bakanlığı. Retrieved from https://bku.tarim.gov.tr/

Aydar, A., Sabahoğlu, Y., Cevdet, Z., & Mesut, İ. (2010). Elma bahçelerinde Elma içkurdu Cydia pomonella (L.)(Lepidoptera: Tortricidae) mücadelesinde yardımcı hava akımlı hidrolik bahçe pülverizatörünün biyolojik performansının belirlenmesi. *Bitki Koruma Bulteni*, *50*(2), 51–63.

Azfar, S., Nadeem, A., & Basit, A. (2015). Pest detection and control techniques using wireless sensor network: A review. *Journal of Entomology and Zoology Studies*, *3*(2), 92–99.

Baogang, Y. (2006). Development of Agricultural Mechanization and Modern Agriculture. *Nongye Jixie Xuebao*, 1.

Binswanger, H. (1986). Agricultural mechanization: A comparative historical perspective. *The World Bank Research Observer*, *1*(1), 27–56. doi:10.1093/wbro/1.1.27

Birgücü, A. K., & Karsavuran, Y. (2009). Degree-days models and possibilities of usage in plant protection. *Anadolu*, *19*(2), 98–117.

Boissard, P., Martin, V., & Moisan, S. (2008). A cognitive vision approach to early pest detection in greenhouse crops. *Computers and Electronics in Agriculture*, *62*(2), 81–93. doi:10.1016/j.compag.2007.11.009

Boserup, E. (2017). The conditions of agricultural growth: The economics of agrarian change under population pressure. Routledge, Taylor & Francis Group. doi:10.4324/9781315131450

Brain, C.K. (1924). Preliminary note on the adaptation of certain radio principles to insect investigation work. *Annual of University Stellenbosch Ser., A2*, 45-47.

Brandhorst-Hubbard, J. L., Flanders, K. L., Mankin, R. W., Guertal, E. A., & Crocker, R. L. (2001). Mapping of soil insect infestations sampled by excavation and acoustic methods. *Journal of Economic Entomology*, *94*(6), 1452–1458. doi:10.1603/0022-0493-94.6.1452 PMID:11777048

Damalas, C. A., Georgiou, E. B., & Theodorou, M. G. (2006). Pesticide use and safety practices among Greek tobacco farmers: A survey. *International Journal of Environmental Health Research*, *16*(5), 339–348. doi:10.1080/09603120600869190 PMID:16990175

Dan, L. I. U., Xin, C., Chongwei, H., & Liangliang, J. (2015, December). Intelligent agriculture greenhouse environment monitoring system based on IOT technology. In *2015 International Conference on Intelligent Transportation, Big Data and Smart City* (pp. 487-490). 10.1109/ICITBS.2015.126

Demirel, M., Kılınç, G., & Kumral, N. A. (2018, September). Görüntü İşleme ve Sensör Destekli Akıllı Tarımsal Mücadele Sistemi (GÖRSENTAM)'nin Zeytin Pamuklu Biti Mücadelesinde Kullanım Olanakları. In 5. Ulusal Tarım Kongresi (p. 5). Academic Press.

Dent, D. R., Elliott, N. C., Farrell, J. A., Gutierrez, A. P., van Lenteren, J. C., Walton, M. P., & Wratten, S. (1995). *Integrated pest management*. Chapman and Hall.

Eliopoulos, P. A., Potamitis, I., Kontodimas, D. C., & Givropoulou, E. G. (2015). Detection of adult beetles inside the stored wheat mass based on their acoustic emissions. *Journal of Economic Entomology*, *108*(6), 2808–2814. doi:10.1093/jee/tov231 PMID:26470377

Facello, A., & Cavallo, E. (2013, June). Insect remote detection in pheromones traps. In *EFITA-WC-CACIGR Conference on Sustainable Agriculture through ICT Innovation* (pp. 1376-1383). Torino, Italy: Academic Press.

FAO. (2014). *Food and Agriculture Organization, Pesticide consumption statistics*. Retrieved from http://www.fao.org/faostat/en/#home

Finney, C. (1996). The benefits of land leveling on irrigation schemes in Turkey and Sindh Province, Pakistan. *ICID Journal*, *45*(1), 21–37.

Fleurat-Lessard, F., Tomasini, B., Kostine, L., & Fuzeau, B. (2006). Acoustic detection and automatic identification of insect stages activity in grain bulks by noise spectra processing through classification algorithms. In *9th International Conference on Stored Product Protection* (pp. 476-786). Passo Fundo, RS, Brazil: Academic Press.

Flint, M. L., & Van den Bosch, R. (1981). *Introduction to integrated pest management*. Springer. doi:10.1007/978-1-4615-9212-9

Fukatsu, T., Watanabe, T., Hu, H., Yoichi, H., & Hirafuji, M. (2012). Field monitoring support system for the occurrence of Leptocorisa chinensis Dallas (Hemiptera: Alydidae) using synthetic attractants, Field Servers, and image analysis. *Computers and Electronics in Agriculture*, *80*, 8–16. doi:10.1016/j.compag.2011.10.005

Gallardo, A., Ocete, R., Lopez, M. A., Maistrello, L., Ortega, F., Semedo, A., & Soria, F. J. (2009). Forecasting the flight activity of *Lobesia botrana* (Denis & Schiffermüller) (Lepidoptera, Tortricidae) in southwestern Spain. *Journal of Applied Entomology*, *133*(8), 626–632. doi:10.1111/j.1439-0418.2009.01417.x

Giblin-Davis, R.M., Faleiro, J.R., Jacas, J.A., Peña, J.E., & Vidyasagar, P.S.P.V. (2013). Biology and management of the red palm weevil, *Rhynchophorus ferrugineus. Potential Invasive Pests of Agricultural Crops,* 1-34.

Gökdoğan, A., & Tarım, G. (2015). Türkiye'de Süne ile Mücadelenin Tarihsel Gelişimi. *Dört Öge*, *7*, 33–46.

Gürses A., Altay M., Tüzün Ş., Erkam B., Gürkan S., Sezer S. & Akın M. (1985). *Marmara Bölgesi Elma Zararlılarına Karşı Tüm Savaşım Olanakları Üzerine Araştırmalar.* Project grant no: A.107015.

Huang, W., Guan, Q., Luo, J., Zhang, J., Zhao, J., Liang, D., & Zhang, D. (2014). New optimized spectral indices for identifying and monitoring winter wheat diseases. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *7*(6), 2516–2524. doi:10.1109/JSTARS.2013.2294961

Husin, Z. B., Shakaff, A. Y. B. M., Aziz, A. H. B. A., & Farook, R. B. S. M. (2012). Feasibility study on plant chili disease detection using image processing techniques. In *Third International Conference on Intelligent Systems Modelling and Simulation* (pp. 291-296). Kota Kinabalu, Malaysia. 10.1109/ISMS.2012.33

Jhuria, M., Kumar, A., & Borse, R. (2013). Image processing for smart farming: Detection of disease and fruit grading. In *IEEE Second International Conference on Image Information* (pp. 521-526). Jaypee, India 10.1109/ICIIP.2013.6707647

Jones, J. W., Tsuji, G. Y., Hoogenboom, G. J., Hunt, L. A., Thorton, P. K., Wilkens, P. W., Immamura, D. T., Bowen, W. T., & Singh, U. (1994). *Systems Approaches for Sustainable Agricultural Development: Decision support system for agrotechnology transfer: DSSAT v3*. Springer.

Khirade, S. D., & Patil, A. B. (2015). Plant disease detection using image processing. In *2015 International conference on computing communication control and automation* (pp. 768-771). Pune, Maharashtra, India. 10.1109/ICCUBEA.2015.153

Kıroğlu, H., Aykaç, K. M., Ergüder, M. T., Çamlıdere, R., Kılıç, M., & Çevik, T. (1992). Karadeniz Bölgesi elma bahçelerinde entegre savaş olanakları üzerine çalışmalar. *Zirai Mücadele Araştırma Enstitüsü Müdürlüğü Yayınları*, *21-22*, 44–46.

Koçak, E. (2006). Süne mücadelesinde zamanlamanın önemi. *Türktarım*, *168*, 42–45.

Kogan, M. (1998). Integrated pest management: Historical perspectives and contemporary developments. *Annual Review of Entomology*, *43*(1), 243–270. doi:10.1146/annurev.ento.43.1.243 PMID:9444752

Kumral, N. A., Kılınc, G., Selvi, A., Ozdemir, B. N., Unveren, B. E., Bozogulları, H. İ., Demirel, H., Balta, P., Pat, S., & Kocak, U. D. (2017). A survey study: pest problems and pest management strategies of farmers in Bursa province (Turkey). In *VIII International Scientific Agriculture Symposium," Agrosym 2017"* (pp. 1421-1426). Jahorina, Bosnia and Herzegovina: Academic Press.

Kumral, N. A., Kovanci, B., & Akbudak, B. (2005). Pheromone trap catches of the olive moth, *Prays oleae* (Bern.) (Lep., Plutellidae) in relation to olive phenology and degree-day models. *Journal of Applied Entomology*, *129*(7), 375–381. doi:10.1111/j.1439-0418.2005.00985.x

Kumral, N. A., Kovanci, B., & Akbudak, B. (2008). Using degree-day accumulations and host phenology for predicting larval emergence patterns of the olive psyllid, *Euphyllura phillyreae. Journal of Pest Science*, *81*(2), 63–69. doi:10.100710340-007-0185-6

Kürklü, A., & Çağlayan, N. (2005). Sera otomasyon sistemlerinin geliştirilmesine yönelik bir çalışma. *Akdeniz Üniversitesi Ziraat Fakültesi Dergisi*, *18*(1), 25–34.

Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, *6*(4), 239–242. doi:10.100712599-014-0334-4

Lee, W. S., Alchanatis, V., Yang, C., Hirafuji, M., Moshou, D., & Li, C. (2010). Sensing technologies for precision specialty crop production. *Computers and Electronics in Agriculture*, *74*(1), 2–33. doi:10.1016/j.compag.2010.08.005

Mankin, R. W., Weaver, D. K., Grieshop, M., Larson, B., & Morrill, W. L. (2004). Acoustic system for insect detection in plant stems: Comparisons of *Cephus cinctus* in wheat and *Metamasius callizona* in bromeliads. *Journal of Agricultural and Urban Entomology*, *21*(4), 239–248.

Martinelli, F., Scalenghe, R., Davino, S., Panno, S., Scuderi, G., Ruisi, P., & Davis, C. E. (2015). Advanced methods of plant disease detection. A review. *Agronomy for Sustainable Development*, *35*(1), 1–25. doi:10.100713593-014-0246-1

Murray, M. S. (2008). *Using Degree Days to Time Treatments for Insect Pests*. Utah State University Extension and Utah Plant Pest Diagnostic Laboratory. Retrieved from https://climate.usu.edu/includes/pestFactSheets/degree-days08.pdf

Öncüer, C. (2004). Tarımsal Zararlılarla Savaşım Yöntemleri ve İlaçları. *Adnan Menderes Üniversitesi Yayınları*, *19*, 424.

Otsu, N. (1979). A threshold selection method from gray-level histograms. *IEEE Transactions on Systems, Man, and Cybernetics*, *9*(1), 62–66. doi:10.1109/TSMC.1979.4310076

Ozcan, G. E., Cicek, O., Enez, K., & Yildiz, M. (2014). A new approach to determine the capture conditions of bark beetles in pheromone-baited traps. *Biotechnology, Biotechnological Equipment*, *28*(6), 1057–1064. doi:10.1080/13102818.2014.974015 PMID:26019592

Patil, K. A., & Kale, N. R. (2016). A model for smart agriculture using IoT. In *International Conference on Global Trends in Signal Processing, Information Computing and Communication* (pp. 543-545). Maharasthra, India. 10.1109/ICGTSPICC.2016.7955360

Phadikar, S., & Sil, J. (2008). Rice disease identification using pattern recognition techniques. In *11th International Conference on Computer and Information Technology* (pp. 420-423). Khulna, Bangladesh. 10.1109/ICCITECHN.2008.4803079

Piao, S., Ciais, P., Huang, Y., Shen, Z., Peng, S., Li, J., Zhou, L., Liu, H., Ma, Y., Ding, Y., Friedlingstein, P., Liu, C., Tan, K., Yu, Y., Zhang, T., & Fang, J. (2010). The impacts of climate change on water resources and agriculture in China. *Nature*, *467*(7311), 43–51. doi:10.1038/nature09364 PMID:20811450

Popp, J., Pető, K., & Nagy, J. (2013). Pesticide productivity and food security. A review. *Agronomy for Sustainable Development*, *33*(1), 243–255. doi:10.100713593-012-0105-x

Potamitis, I., Ganchev, T., & Kontodimas, D. (2009). On automatic bioacoustic detection of pests: The cases of *Rhynchophorus ferrugineus* and *Sitophilus oryzae*. *Journal of Economic Entomology*, *102*(4), 1681–1690. doi:10.1603/029.102.0436 PMID:19736784

Potamitis, I., & Rigakis, I. (2015). Smart traps for automatic remote monitoring of *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) Peer J. *PrePrints,* 3:1337v1. doi:10.7287/peerj.preprints.1337v1

Quarcoo, F., Bonsi, C., & Tackie, N. (2014). Pesticides, the environment, and human health. In *Pesticides-Toxic Aspects*. IntechOpen. doi:10.5772/57553

Sabir, N., Balraj, S., Hasan, M., Sumitha, R., Deka, S., Tanwar, R. K., Ahuja, D. B., Tomar, B. S., Bambawale, O. M., & Khah, E. M. (2010). Good Agricultural Practices (GAP) for IPM in protected cultivation. *Technical Bulletin, 23*, 1-14.

Scherm, H. (2004). Climate change: Can we predict the impacts on plant pathology and pest management? *Canadian Journal of Plant Pathology*, *26*(3), 267–273. doi:10.1080/07060660409507143

Shade, R. E., Furgason, E. S., & Murdock, L. L. (1989). *Ultrasonic insect detector*. U.S. Patent No. 4,809,554. Washington, DC: U.S. Patent and Trademark Office. Retrieved from https://patents.google.com/patent/US4809554A/en

Shade, R. E., Furgason, E. S., & Murdock, L. L. (1990). Detection of hidden insect infestations by feeding-generated ultrasonic signals. *American Entomologist (Lanham, Md.)*, *36*(3), 231–235. doi:10.1093/ae/36.3.231

Shimoda, N., Kataoka, T., Okamoto, H., Terawaki, M., & Hata, S. I. (2006). Automatic pest counting system using image processing technique. *Nogyo Kikai Gakkaishi*, *68*(3), 59–64.

Simon, J. Y. (2014). *The toxicology and biochemistry of insecticides*. CRC press.

Singh, O. V., Ghai, S., Paul, D., & Jain, R. K. (2006). Genetically modified crops: Success, safety assessment, and public concern. *Applied Microbiology and Biotechnology*, *71*(5), 598–607. doi:10.100700253-006-0449-8 PMID:16639559

Swanson, B. E. (2008). *Global review of good agricultural extension and advisory service practices.* Rome: Food and Agriculture Organization of the United Nations. USA, Research and Extension Unit (NRRR). Retrieved from http://www.fao.org/nr/gen/gen_081001_en.htm

Tirelli, P., Borghese, N. A., Pedersini, F., Galassi, G., & Oberti, R. (2011). Automatic monitoring of pest insects traps by Zigbee-based wireless networking of image sensors. In *IEEE International Instrumentation and Measurement Technology Conference* (pp. 1-5). Binjiang, Hangzhou, China. 10.1109/IMTC.2011.5944204

Wang, N., Zhang, N., & Wang, M. (2006). Wireless sensors in agriculture and food industry—Recent development and future perspective. *Computers and Electronics in Agriculture*, *50*(1), 1–14. doi:10.1016/j.compag.2005.09.003

Welch, S. M. (1984). Developments in computer-based IPM extension delivery systems. *Annual Review of Entomology*, *29*(1), 359–381. doi:10.1146/annurev.en.29.010184.002043

Weller, S., Culbreath, A., Gianessi, L., Godfrey, L., Jachetta, J., Norsworthy, J., & Madsen, J. (2014). The contributions of pesticides to pest management in meeting the global need for food production by 2050. *Issue Paper - Council for Agricultural Science and Technology*, (55), 1–28.

Zhang, M., Crocker, R. L., Mankin, R., Flanders, K., Hickling, R., & Brandhorst-Hubbard, J. (2000). Inferring activities and incidental soil-borne sounds of white grubs. In *Proceedings of the XXI International Congress of Entomology* (Vol. 1, p. 238). Londrina, Brazil: Academic Press.

Chapter 19
Application of Convoluted Neural Network and Its Architectures for Fungal Plant Disease Detection

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ABSTRACT

Eighty-five percent of the plants are affected by diseases caused by organisms like fungus, bacteria, and virus, which devastate the natural ecosystem. The most common clues provided by the plants affected by fungal diseases are defaming of the plant color. In literature, several traditional rule-based algorithms and normal image processing techniques are used to identify the fungal plant diseases. However, the traditional approach suffers from poor disease identification accuracy. Convoluted neural network (CNN) is one of the potential deep learning neural networks used for image recognition and classification in plant pathology. In this chapter, some of the potential CNN architectures used for plant disease detection like LeNet, AlexNet, VGGNet, GoogLeNet, ResNet, and ZFnet are discussed with the architecture and advantages. The efficiencies achieved by ResNet and ZFNet are found to be good in terms of accuracy and error rate.

1.0. INTRODUCTION

Around 85 percentage of the plants are affected by diseases caused by fungal organisms which devastate the natural ecosystem. The microorganisms which commonly cause fungal diseases in plants are fungus, bacteria, and virus. By paying careful attention to the appearance of the plant, the diseases can be suspected at the early stage itself. The most common clues provided by the plants affected by fungal

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diseases are defaming of the plant color, deterioration of the leafs shape, yellowing of the stems, rusting of branches, damping of seedlings, formation of white molds, crooked stem edges, crinkling of leaves, and so on Larkin, and Fravel (1998).

The fungus in fungi affected plants absorbs all energy and vitamins from the plants causing a great deal of damage to the plants and its byproducts. The damage causes stress to the plants by destroying the cells and tissues of the plants. Some of the sources of fungal diseases are animal, soil, tools used, human workers, weeds, seeds, and so on. From these sources the fungus are generated and they enter the plant through their natural opening i.e. stomata or through any holes created over the plant due to insects or any other mechanical device usage while planting. Most commonly occurring fungal plant diseases are sclerotium rots, leaf blight, powdery mildews, anthracnose, rusts, and so on Xavier and Boyetchko, (2004).

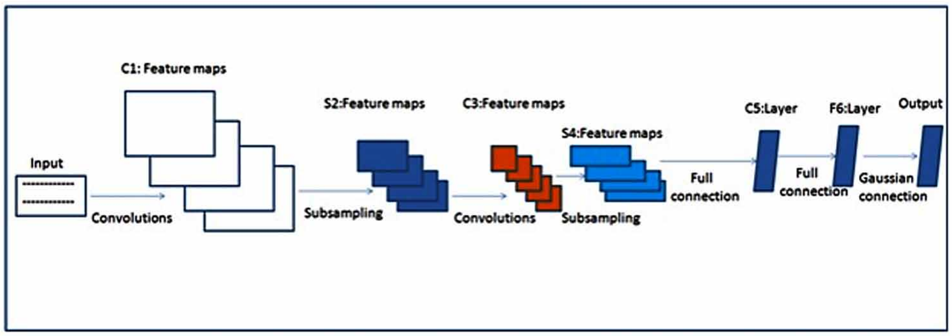
In literature several traditional rule based algorithms and normal image processing techniques are used identify the fungal plant diseases. However the traditional approach suffer from several limitations like poor disease identification accuracy, improper preprocessing of data, repetition of laborious tasks, unable manage uncontrolled data capturing conditions, bottlenecks during segmentation, lack of scalability, cannot handle data transition, and so on. This lead to the application of automated algorithms based on artificial intelligence for identifying pathogenic fungal plant diseases. Some of the popularly used artificial intelligence approaches for fungal plant disease identification are in e backpropogation neural network, deep learning, supervised learning, reinforcement learning, unsupervised learning, convoluted neural network, recurrent network, and so on. The automated approaches either uses numerical data or images gathered over the wide variety of fungi affected plants to train the algorithms for disease identification. The automated artificial intelligence approaches does precise operation by efficiently handling the problems related to real time operation, computational resources, insufficient gathering of data, distribution of training data, side effects during computation, data transition, and so on Khirade and Patil, (2015), Petrellis, (2017), Barbedo, Koenigkan, and Santos, (2016).

Among all forms of automated approaches, image based approaches achieves superior quality of output compared to all other approaches while identifying the fungal plant diseases. CNN is one of the potential deep learning neural networks used for image recognition and classification in plant pathology. CNN is composed of three layers i.e. convolutional, pooling, and fully connected with learnable weights and bias which can successfully the dependencies related to spatial and temporal properties of images. Some of the powerful architectures of CNN used for image analysis are LeNet, AlexNet, VGGNet, GoogLeNet, ResNet, and ZFnet Wu, (2017), O'Shea and Nash, (2015).

2.0. LeNet

LeNet stands for Lenet-5 composed of two sets of convolutional layers and pooling layer invented by Yann LeCun in the year 1998 at Bell lab. It is one of the oldest CNN model invented for the sake of deep learning being first applied to the backpropogation based learning algorithm. The very first application of LeNet was to classify the handwritten digit or character recognition problem. LeNet-5 is composed of six layers in addition to input and output layers where the parameters of one layer are used to train the parameters of other layers. First layer is C1 consisting of six convolutional kernels of size 5*5 and the feature mapping is performed with the size 28*28. Second layer is S2 which perform subsampling and features in each layer are of size 14*14. Third layer is C3 which is a convolutional layer consisting of kernels of size 16*5*5. Fourth layer is S4 which is similar to S2 of size 2*2 and generates 16 samples of output of size 5*5. Fifth layer is C5 which is a convolutional layer which is made up of 120 kernels of size 5*5. The sixth layer is F6 which is fully connected to C5 layer and generated graphs consisting of 84 features as output. A typical architecture of LeNet5 is given in Figure 1.

Figure 1. A typical architecture of LeNet5



Some of the challenges encountered in LeNet5 architecture are frequent happening of class imbalance ratio, suffers from overfitting problem, improper future prediction, large accumulation of error gradients, unstability in the network due to overtraining, longer duration of training, explosion of gradient problems, geometric variation due to distortions, traction during mission critical problems, improper strauctural mapping, slow progressive learning, and so on.

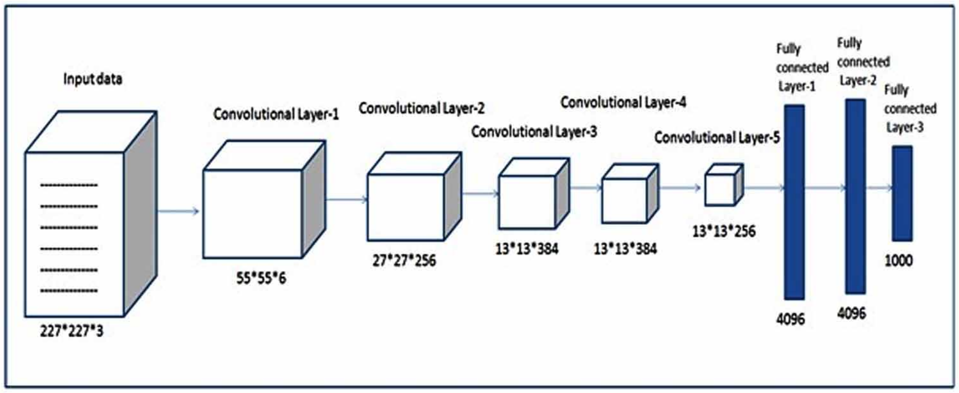
Some of the potential advantages of LeNet architecture are; the architecture is easy to understand as it is composed of less number of layers with little depth; capable of producing the trained architecture which is globally acceptable as all the modules are optimized together; produces a good and robust response to spatially distributed input pattern as it learns through filters; achieves high accuracy compared to other shallow architectures since filters are added to each layer of the network; leads to fastest implementation of the network due to the simplest form of layer composition in the network; the speed of learning is moderate but it can be increased by careful selection grids of appropriate sizes; the parallel strategy of the network helps in ease module training and reduces the dependency over the other heterogeneous layers of the network; and so on Bouti, Mahraz, Riffi, and Tairi, (2019), El-Sawy, Hazem, and Loey, (2016).

Some of the applications of LeNet5 architecture in plant pathology are deteriorated parts recognition, plant image classification, disease signs identification, disease classification, analyses of plant disease data, early recognition of disease signs in the plant images, and so on.

3.0. AlexNet

AlexNet is a tree of layers larger than LeNet in which the beginning layers are composed of nodes and remaining layers are composed of computing units. A typical architecture of AlexNet is composed of sixty million parameters and six hindered fifty thousand neurons and to train the architecture five to six days is needed. The architecture of AlexNet is larger compared to the LeNet which makes it suitable to perform takes related to computer vision. It is made up of eight layers in which first five layers

Figure 2. A typical architecture of AlexNet



are convolutional layers and remaining three layers are fully connected layers. A typical architecture of AlexNet is shown in Figure 2.

Some of the challenges encountered in AlexNet architecture are performance degradation during large scale image processing, occurrence frequent bottleneck during complicated image classification problems, suffers from overfitting problem, difficult to train larger network, poor accuracy while dealing with low resolution images, non transparency of the concurrent architecture, exploded gradient problem during training, errors while fine tunning the network, and so on.

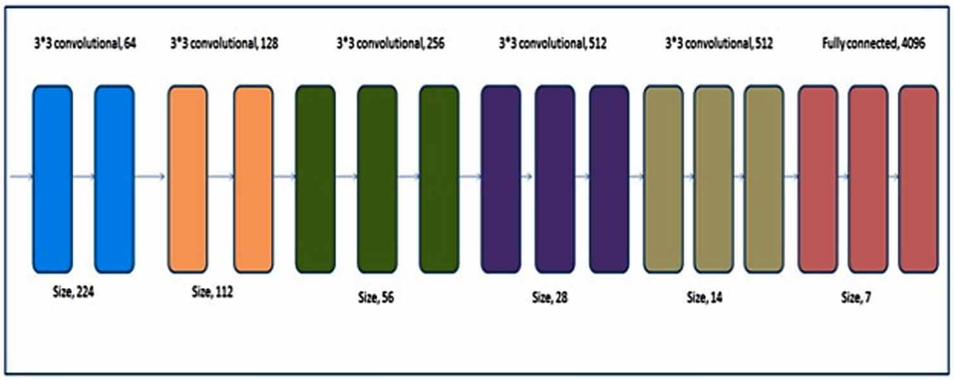
Some of the potential advantages of AlexNet architecture are; uses Rectified Linear Units (ReLU) instead of the tanh function which makes it faster and reduces the error rate by twenty five percentage compared to LeNet; allows training the network using multiple Graphical Processing Units (GPU) which reduces the time involved in training the large sized network; exhibits the ability to pool the neighboring set of neurons with minimum or zero overlapping which prevents the overfitting problem; label preserving capability of the network makes it easy to handle varied from of data; allows to switch off some of the neurons with predefined value of probability during training which increases the convergence rate; achieves higher accuracy over larger datasets as it performs principal component analysis over the pixels of the input images; and so on Iandola Han, Moskewicz Ashraf Dally and Keutzer, (2016), Alom Taha, Yakopcic, Westberg, Sidike, Nasrin, and Asari, (2018).

Some of the applications of AlexNet architecture in plant pathology are plant image vision, disease prediction, fine grained leave image segmentation, early detection of aster yellows, video feature extraction of bacterial wilt, bacterial bite identification, birds eye spot recognition, image processing of chlorosis, abnormality identification in seedlings images, chlorosis recognition, and so on.

4.0. VGGNet

VGGNet is a better version of AlexNet in which the large sized kernel is replaced by 3*3 kernel sized filters. It is made up of sixteen convolutional layers and is a uniform form of network and very appealing in nature. Much similarity is exhibited towards AlexNet as it consists of 3*3 convolutional layers with more number of filters. The training time taken by VGGNet on a typical four GPU based system is two to three weeks and is composed of one hundred thirty eight neurons pr parameters. Instead of having single sized large kernel multiple smaller sized kernels are made use to increase the depth of learning. The width of the network begins from 64 and increases by a factor of two after addition of every sampling layer or pooling layer. A typical architecture of VGGNet is shown in Figure 3.

Figure 3. A typical architecture of VGGNet



Some of the challenges encountered in VGGNet architecture are vanishing gradient problem, improper feature extraction, slow convergence, overtraining of the model, error in extracting hand crafted documents, over usage of computational resources, bias problem during convergence, frequent mislabeling of objects, improper patch alignment of solutions, uneven illumination, inability to suppress the noise in the large scale inputs, higher complexity due to increased depth, and so on.

Some of the potential advantages of VGGNet architecture are; accuracy achieved in extracting the features of the images is high due to ease eight configurations; the training time incurred is less as less number of parameters are involved; the problem of vanishing gradient is solved by skipping the connections in the network; the multi scale training helps in easy identification of wrong classification of objects; complex structures are learnt easily and low cost due to the use of multiple nonlinear layers; since the kernel size fixed is less the finer features of the input image is retained; and so on Kim, (2018), Wang, Guo, Huang, and Qiao, (2015).

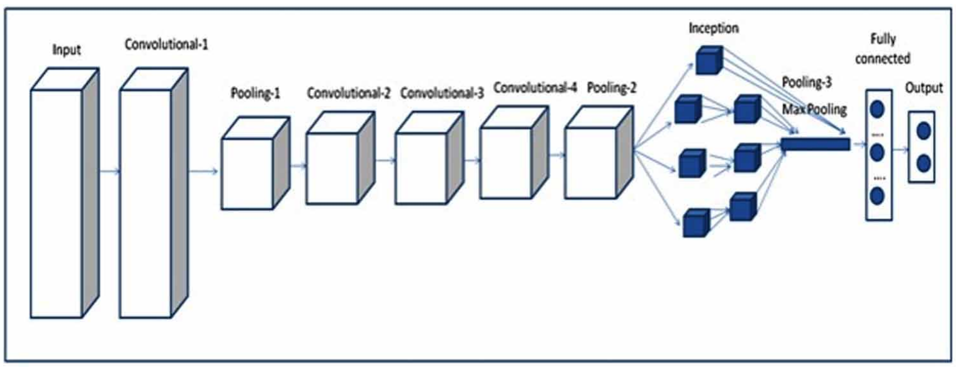
Some of the applications of VGGNet architecture in plant pathology are plant cell wall classification, stomata visualization, soft rot identification, acid tolerance level of the plant determination, leaf rust identification, bioinformatics, powdery mildew identification, stem rust recognition, automated identification of white mold formation, spotting of bacterial oozes, fruit spot analysis, canker segmentation, and so on.

5.0. GoogLeNet

GoogLeNet consist of 22 layers that are deep nested for object detection in image recognition operations proposed at Google. The architecture of GoogLeNet is different compared to AlexNet and ZFnet as the number of parameters considered drops from sixty million to four million. It consists of 1*1 convolution, global average pooling, inception module, and auxiliary classifier which enables construction of deeper architecture. The global average pooling layer inputs the images of size 7*7 and averages it to 1*1. A bottleneck layer is included which leads to massive reduction in the computation al requirement for the operation of the network. A typical architecture of GoogLeNet is shown in Figure 4.

Some of the challenges encountered in GoogLeNet are overfitting problem, vanishing gradient problem, maintaining consistency during image processing, poor accuracy during image retrieval, improper patch alignment, exploded gradient problem, hyperparameters involvement, inefficiency in selection of filter sizes in every layer of the network, improper mapping between input and output functions, getting trapped in local minima solutions, improper reasoning, and so on.

Figure 4. A typical architecture of GoogLeNet



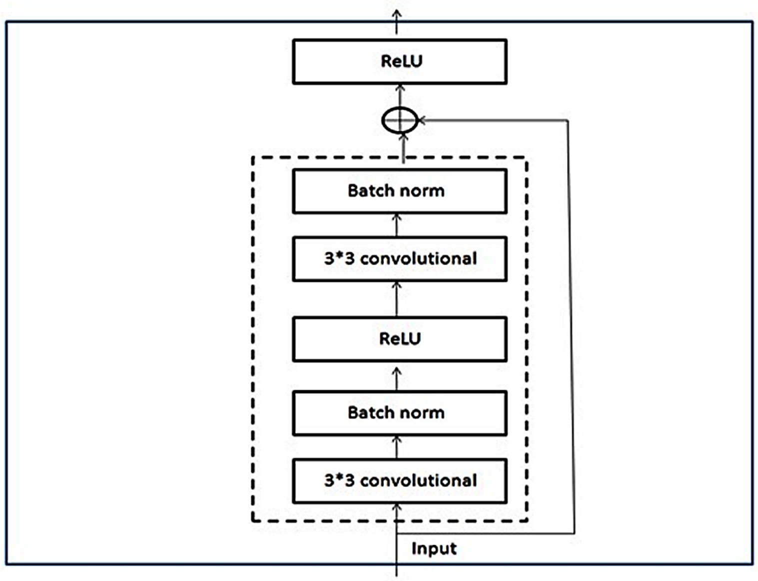
Some of the potential advantages of GoogLeNet architecture are; the number of parameters involved in training is less as it involves only small level of convolutions; the depth of the architecture is high as it uses 1*1 convolution; the trainable accuracy achieved is high as the global average pooling is applied at the end; the input images of different sizes are handled at better scalability as convolutional filters of different sizes are used; performs precise classification and detection task as the error rate encountered in training is less; can be executed on the individual devices with less computational resources as it consists of two auxiliary classifier layers; and so on Al-Qizwini, Barjasteh, Al-Qassab, and Radha, (2017), Singla, Yuan, and Ebrahimi, (2016).

Some of the applications of GoogLeNet architecture in plant pathology are mosaic leaf pattern, crinkled leaves recognition, plant stunts processing, leaf blight classification, canker detection, stem rot prediction,, fruit rot recognition, damping of seedlings determination, borer insects bite detection, plum attacks identification, soaked lesions development tracking, concentric rings identification, tuber disease analysis, Atrophy fraud identification, dwarfing classification, hyperplasia assistance, and so on.

6.0. ResNet

ResNet is a residual form of neural network invented by Kaiming, which is build on top of the pyramid shaped cells in the cerebral cortex which functions by skipping several repetitive layers. There are several forms of ResNet architectures but the popular architectures are ResNet50 and ResNet101. It allows around eleven million parameters to be trained at once and consists of 3*3 convolutional layers and two pooling layers. The pooling layers are positioned at the beginning and end of the network which makes it capable enough to handle the input images of varying sizes. The foundation block of the ResNet is Residual block which does the role of learning and gets repeated throughout the network. In order to achieve optimal learning the weights assigned to intermediate layers are made zero and gradually it is incremented to one. Two kinds of mapping are achieved one is nontrainable, which does padding of zero and the other one is trainable mapping in which convolutional layer is responsible for mapping the inputs to outputs. A typical architecture of ResNet is shown in Figure 5.

Figure 5. A typical architecture of ResNet



Some of the challenges encountered in ResNet are vanishing gradient problem, auxiliary loss due to extra supervision, structured regression problem, uneven size of the network, uderfitting, exponential increase in the number of free parameters, inability to solve multi class image classification problem, improper specification of stop criteria, inadequate learning rate, improper data segmentation, improper handling of gradient descent in deep network, unequal representation of hidden layers in the network, and so on.

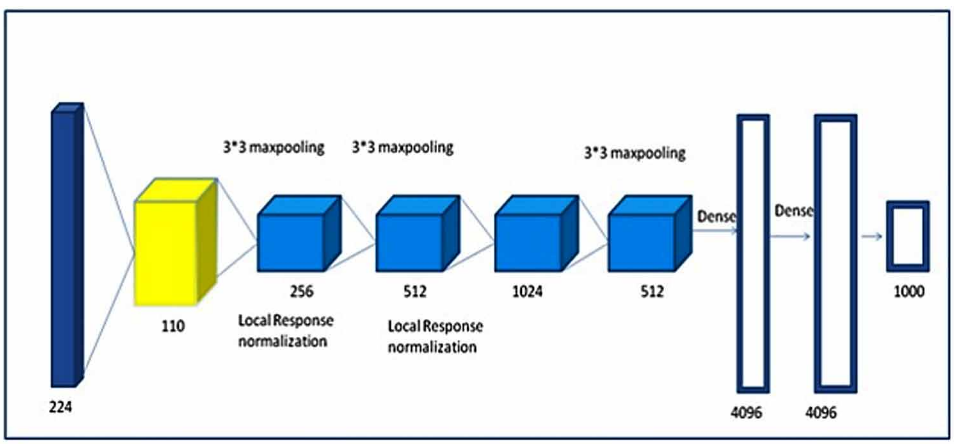
Some of the potential advantages of ResNet architecture are; Able to train large neural networks consisting of thousands of neurons as it exhibits lower complexity compared to conventional networks; since it allows several levels of nesting vanishing gradient problem is very well addressed; the probability of occurrence of misclassification errors is avoided by increasing the depth of the network; able to perform faster training of the network as ReLu layer sits over the sigmoid function; the effect of vanishing gradient problem is reduced by increasing the number of residual connections; the architecture is very light as it uses few residual units; the learning process is interpretable as it considers only those input data which exhibits closeness towards periodic mean of the input data; and so on Targ, Almeida, and Lyman, (2016), Szegedy, Ioffe, Vanhoucke, and Alemi, (2017).

Some of the applications of ResNet architecture in plant pathology are powdery mildew detection, internal obligate pattern recognition,, leaf coating classification, fungal spores monitoring system, plant shot holes imaging, wounds development in stem, affected tissues segmentation, swellings identification, abnormal increase in plant organs recognition, loss of turgidity identification, autonomous monitoring of sooty leaves, downy mildews surveillance, white conidia forecasting, visual deviation detection, fungal disease risk assessment, and so on.

7.0. ZFnet

ZFnet stands for Zeiler Furgus Net is improved version of AlexNet invented by Zeiler and Fergus in the year 2013. In ZFnet, the size of the filter is reduced to prevent the loss of pixel information of the images. It is mainly composed of five convolutional layers in sharable format, max-pooling layers, dropout layers, and three fully connected feed forward layers. A filter of size 7*7 with decreased stride value is used in the first layer and the last layer is a softmax layer. The deconvolutional layer is used for visualization and basic understanding of the convolutional networks. The number of activation maps involved in the third, fourth, and fifth convolutional layers are increased which makes the network capable enough in detecting the faults.

Figure 6. A typical architecture of ZFNet



Some of the challenges encountered in ZFNet are overlapping of Max layers, increased error rate during image recognition, inability to accommodate multiple sources, smaller receptive fields, more debugging issue in hidden layers, increased delay while processing large documents, poor accuracy while processing quality distorted images, inefficient segmentation of ultrasound network, inability to handle noise in the input data, unable to extract baseline features during noisy peaks, multiple ZFnets mapping is time consuming, significant use of computational resources during large scale optimization, and so on.

Some of the potential advantages of ZFnet architecture are; the accuracy achieved by the ZFnet is higher compared to AlexNet as it uses 7*7 filters; the error rate incurred gets reduced drastically due to improved parameterization; the visualization technique is improved through deep learning mechanism; suitable to be used for advanced technology for the benefit of humanity due to higher classification accuracy; the overfitting problem is avoided as ZFNet uses 256 depthwise feature map of the input images; and so on Antioquia, Tan, Azcarraga, Cheng, and Hua, (2018), Fu, Feng, Majeed, Zhang, Karkee, and Zhang, (2018).

Some of the applications of ZFnet architecture in plant pathology are leaf wilting recognition, plant pathogens processing, plant health determination, stem blight management, digital plant diagnosis, frogeye leaf spots identification, leaf curl segmentation, oak wilt early detection, bacterial ooze classification, damaged plant tissue identification, gray mold detection, black spot parsing, dropping leafs prediction.

8.0. EFFICIENCY ANALYSIS

The comparison of efficiency achieved by various CNN types i.e. LeNet, AlexNet, VGGNet, GoogLeNet, ResNet, and ZFnet towards efficiency parameters like number of parameters, error rate, depth, accuracy, and best feature is shown in Table 1 (Miles, and Mikolajczyk 2020). It is observed from the table that the efficiency achieved by the ZFnet and Resnet is high as the accuracy achieved is high and error rate encountered is less.

Table 1. Comparison of efficiency achieved by CNN types

CNN Types	No of Parameters	Error Rate	Depth	Accuracy	Best Feature
LeNet	60 thousand	20%	5	79.7	Simple layer composition
AlexNet	60 million	15%	8	80.2	Deeper
VGGNet	138 million	7.3%	19	91.2	Fixed size kernel
GoogLeNet	4 million	6.6%	22	60.0	Wide parallel kernels
ResNet	23 million	3.6%	152	93.0	Shortcut connections
ZFnet	60 million	14.8%	08	98.0	Visualization layers

9.0. CONCLUSION

This chapter provides a brief introduction to fungal diseases to plants and the damages caused it towards productivity of the plant. Comparison between traditional and automated approaches in identifying the fungal plant diseases is carried out. Some of the potential CNNarchitectures i.e LeNet, AlexNet, VGGNet, GoogLeNet, ResNet, and ZFnet in detecting plant diseases is discussed. Efficiency analysis of the above CNN architectures is carried out in terms of performance parameters like accuracy, error rate, depth, and number of parameters involved in training. The efficiency of the ZFNet and ResNet architectures are high compared to other CNN architectures considered for analysis towards plant disease detection.

REFERENCES

Al-Qizwini, M., Barjasteh, I., Al-Qassab, H., & Radha, H. (2017, June). Deep learning algorithm for autonomous driving using googlenet. In *2017 IEEE Intelligent Vehicles Symposium (IV)* (pp. 89-96). IEEE. 10.1109/IVS.2017.7995703

Alom, M. Z., Taha, T. M., Yakopcic, C., Westberg, S., Sidike, P., Nasrin, M. S., . . . Asari, V. K. (2018). *The history began from alexnet: A comprehensive survey on deep learning approaches.* arXiv preprint arXiv:1803.01164

Alom, M. Z., Taha, T. M., Yakopcic, C., Westberg, S., Sidike, P., Nasrin, M. S., . . . Asari, V. K. (2018). *The history began from alexnet: A comprehensive survey on deep learning approaches.* arXiv preprint arXiv:1803.01164

Antioquia, A. M. C., Tan, D. S., Azcarraga, A., Cheng, W. H., & Hua, K. L. (2018, December). ZipNet: ZFNet-level Accuracy with 48× Fewer Parameters. In 2018 IEEE Visual Communications and Image Processing (VCIP) (pp. 1-4). IEEE.

Ballester, P., & Araujo, R. M. (2016, February). On the performance of GoogLeNet and AlexNet applied to sketches. *Thirtieth AAAI Conference on Artificial Intelligence*.

Barbedo, J. G. A., Koenigkan, L. V., & Santos, T. T. (2016). Identifying multiple plant diseases using digital image processing. *Biosystems Engineering*, *147*, 104–116. doi:10.1016/j.biosystemseng.2016.03.012

Bouti, A., Mahraz, M. A., Riffi, J., & Tairi, H. (2019). A robust system for road sign detection and classification using LeNet architecture based on convolutional neural network. *Soft Computing*, 1–13. doi:10.100700500-019-04307-6

El-Sawy, A., Hazem, E. B., & Loey, M. (2016, October). CNN for handwritten arabic digits recognition based on LeNet-5. In *International conference on advanced intelligent systems and informatics* (pp. 566-575). Springer.

Fu, L., Feng, Y., Majeed, Y., Zhang, X., Zhang, J., Karkee, M., & Zhang, Q. (2018). Kiwifruit detection in field images using Faster R-CNN with ZFNet. *IFAC-PapersOnLine*, *51*(17), 45–50. doi:10.1016/j.ifacol.2018.08.059

Iandola, F. N., Han, S., Moskewicz, M. W., Ashraf, K., Dally, W. J., & Keutzer, K. (2016). *SqueezeNet: AlexNet-level accuracy with 50x fewer parameters and< 0.5 MB model size.* arXiv preprint arXiv:1602.07360

Khirade, S. D., & Patil, A. B. (2015, February). Plant disease detection using image processing. In *2015 International conference on computing communication control and automation* (pp. 768-771). IEEE. 10.1109/ICCUBEA.2015.153

Kim, M. K. (2018). Contactless Palmprint Identification Using the Pretrained VGGNet Model. *Journal of Korea Multimedia Society*, *21*(12), 1439–1447.

Larkin, R. P., & Fravel, D. R. (1998). Efficacy of various fungal and bacterial biocontrol organisms for control of Fusarium wilt of tomato. *Plant Disease*, *82*(9), 1022–1028. doi:10.1094/PDIS.1998.82.9.1022 PMID:30856829

Miles, R., & Mikolajczyk, K. (2020). *Compression of convolutional neural networks for high performance imagematching tasks on mobile devices.* arXiv preprint arXiv:2001.03102

O'Shea, K., & Nash, R. (2015). *An introduction to convolutional neural networks.* arXiv preprint arXiv:1511.08458

Petrellis, N. (2017, May). A smart phone image processing application for plant disease diagnosis. In *2017 6th International Conference on Modern Circuits and Systems Technologies (MOCAST)* (pp. 1-4). IEEE. 10.1109/MOCAST.2017.7937683

Singla, A., Yuan, L., & Ebrahimi, T. (2016, October). Food/non-food image classification and food categorization using pre-trained googlenet model. In *Proceedings of the 2nd International Workshop on Multimedia Assisted Dietary Management* (pp. 3-11). 10.1145/2986035.2986039

Szegedy, C., Ioffe, S., Vanhoucke, V., & Alemi, A. A. (2017, February). Inception-v4, inception-resnet and the impact of residual connections on learning. *Thirty-first AAAI conference on artificial intelligence*.

Targ, S., Almeida, D., & Lyman, K. (2016). *Resnet in resnet: Generalizing residual architectures.* arXiv preprint arXiv:1603.08029

Wang, L., Guo, S., Huang, W., & Qiao, Y. (2015). Places205-vggnet models for scene recognition. *arXiv preprint arXiv:1508.01667*.

Wu, J. (2017). Introduction to convolutional neural networks. National Key Lab for Novel Software Technology. Nanjing University.

Xavier, L. J., & Boyetchko, S. M. (2004). Arbuscular mycorrhizal fungi in plant disease control. *Fungal biotechnology in agricultural, food, and environmental applications*, 183-194.

Chapter 20
Deep Learning Applications in Agriculture:
The Role of Deep Learning in Smart Agriculture

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ABSTRACT

Deep learning (DL), a part of machine learning (ML), comprises a contemporary technique for processing the images and analyzing the big data with promising outcomes. Deep learning methods are successfully being used in various sectors to gain better results. Agriculture sector is one of the sectors that could be benefitted from the deep learning techniques since the current agriculture techniques cannot keep up with the rapid growth in population. In this chapter, the recent trends in the applications of deep learning techniques in the agricultural sector and the survey of the research efforts that employ deep learning techniques are going to be discussed. Also, the models that are implemented are going to be analyzed and compared with the other existing models.

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INTRODUCTION

Agriculture does not only provide a livelihood to the people, but also contributes significantly towards the national income, and therefore, national development. Agricultural products when processed and exported, provide a very valuable source of foreign exchange. The money so generated helps a lot with the development of a country, ensures the stability of the country's currency, and gives the nation a veritable tool for importation. Agricultural products that are consumed have been the main sustenance of the human race since time immemorial. Since hardly anyone can stay without eating for several days, the role of agriculture in global civilization cannot be overemphasized. Yet the rapid, continuous increase in the human population will lead the world to face a severe catastrophe: food shortage and unprecedented hunger. According to some researchers, by the year 2050, it is assessed that the global population is going to exceed 9.5 billion (Alexandratos & Bruinsma, 2012). In such a case, food production has to be increased by two times to meet the growing demands of the population. In the meantime, the constraints like global warming and urbanization will make increasing the food production problematic. Global warming is drying up previously fertile ground, rendering them unproductive while making planning more difficult in the face of weather and seasons unpredictability. Urbanization has taken over agricultural lands, converting them into cities, and abysmally reducing available land for agriculture. This makes commercial agriculture difficult and reduces8 to a big extent total agricultural output.

Moreover, the collective effects of changes in climate, scarcity of energy and water requires a drastic change in the present agricultural systems. Industrial wastes, unburnt carbon, and oil spillage have combined to contaminate our waters and deny the world of aquatic agricultural products while also poisoning lands, killing crops and other plants. Thus, there's a need to not only confront all of these problems but to also produce enough products to meet up with the food needs of an astronomically rising population. This is where Machine Learning (ML) can play an essential role to double the production rate. Machine learning in agriculture will usher in and augment current efforts in building smart agriculture. (Smart Agriculture is a concept of agriculture management that uses the latest technologies such as Global Positioning System, soil scanning, IoT, data processing, and management to improve the quantity and quality of agricultural products, production efficiency, and agricultural resources optimization).

Smart agriculture is crucial to confront the challenges of crop production, such as crop diseases, sustainability, food security, and environmental impact. Nowadays, the new concepts of deep learning algorithms have been proven to be highly accurate. Deep learning algorithms make inference for future uses by analyzing images and pictures from phenomenons of interest. It goes into an in-depth study of such phenomenons, studying their characteristics deep into their genetic makeup. These deep learning algorithms empower smart agriculture. There are various applications of these deep learning algorithms in agriculture, such as leaf classification, plant disease identification, yield approximation, weed detection, weather prediction, and soil moisture prediction. These applications are going to be discussed in this chapter by comparing and analyzing the deep learning procedures with the present techniques that are being used.

BACKGROUND

Deep Learning

Deep learning is a section of machine learning that can conclude the desired result using various layers by gradually extracting higher-level features from many data set (LeCun et al., 2015). Deep learning converts input data into a complex illustration of the data at every level. A deep learning algorithm enables computer systems to improve their performance with experience and data. Every day, machines learn to crack complex activities, and they improve each time. They undergo a study of these activities until they master it and can replicate it without much stress. These are activities that are, in most cases, human activities. Deep learning machines, using well-tailored algorithms, learn how humans do these activities by trying to think just like a human performing that activity. Eventually, they acquire some intelligence on how humans do this, known as artificial intelligence, and keep learning until they know all they need to perform the activity just like a human would. The first-ever working deep learning algorithm was published in 1967 (Ivakhnenko et al., 1967). Since then, various algorithms have been developed, and more are still being developed to provide reliable solutions for many issues that are being faced by humans. The need to have machines do the work of humans is borne out of the need to make life easier for humans and to save highly valuable time and scarce resources, and conserve ever depleting human energy.

There are three different types of learning models in machine learning. They are Supervised Learning[1], Semi-supervised Learning[2], and Unsupervised Learning[3]. Supervised learning machines are fed with training data that are properly labeled, unsupervised learning machines are allowed to learn on their own without being fed any training data and semi-supervised learning machines have some but not all the required training data, and the few training data supplied are properly labeled. These learning techniques use some neural network architectures to provide solutions. The following are some of the mainly used neural network architectures in deep learning:

- Deep Neural Network
- Recurrent Neural Network
- Convolutional Neural Network

Deep Neural Network

Deep Neural Networks (DNN) is a type of Artificial Neural Network (ANN)[4] which contains various layers connecting the input layer and the output layer with the help of some mathematical functions. This network passes from one layer to another layer by calculating the probability of each outcome. Deep neural networks can be trained to study anything and make conclusions about another thing by making predictions on the probability of this thing being just that thing it was trained to study. This it does by comprehensively studying the object of interest, understanding all its features, and making deductions it can always use to pick out that particular thing from a field of a thousand others. An example is a deep neural network that's trained to identify cassava stems. If given an image, it studies that image and runs a comparative analysis of that image with what it has deduced to be the features of a cassava stem. In the end, it posts the probability of this image is that of a cassava stem. A probability of one shows that the network is certain it's the image of a cassava stem. If four-fifth, it means the system thinks it's the closest thing to a cassava stem and if it's zero, that's clear evidence the image is certainly not of a cassava stem. What such networks do is to dress down whatever object they are studying to its atomic level. At the atomic level, fractional numerical values are assigned to artificial neurons and the connections between them. These values or weights are what generate probabilities when the network is put to work.

Recurrent Neural Network

Recurrent Neural Networks (RNN) is also a section of Artificial Neural Network where the data can flow in any direction. RNNs constitute a network of neuron-like nodes each connected to the next in a one-way direction, and all of them are organized into successive layers. Each of the nodes carries values and could either receive data from the outside network, yield results or modify the data moving from input to output. Two types of recurrent networks exist. These are infinite impulse and finite impulse recurrent networks. A finite impulse recurrent neural network has a directed graph with no directed cycles that can be unrolled. An infinite impulse recurrent network, on the other hand, has a directed graph with directed cycles that cannot be unrolled. The two types of recurrent neural networks have storage states that are controlled by the neural network. These storage states form the long short-term memory network (LSTMs) of RNNs. RNNs can process variable-length data input since it can use its internal memory for processing the information. Hence, these RNNs are mostly used in language modeling and speech recognition[5] .

Convolutional Neural Network

Convolutional Neural Networks (CNN), a section of the Deep Neural Networks (DNN) are multilayer perceptrons in which all the neurons in a layer are associated with all the neurons in another layer and so on for all the layers. These architectures are commonly used for image processing. CNN's do not always need existing knowledge or special human effort to classify images. It rather patiently learns the characteristics of images and then goes on to process such images to achieve the desired result. Convolutional Neural Networks capture all the spatial and temporal dependencies in an image by applying filters. A CNN has input and output layers, and several hidden layers. All the input neurons have weights attached to them. The output is arrived at by subjecting all the weighted input to some arithmetical computation. Parameters are reduced as much as possible, and weights can be reused. This makes it easier to train the network to understand even sophisticated images.

In a Convolutional Neural Network (CNN), when an image input is received by the system, 3D maps of it are made, dividing it into layers and layers of the object. The image is further divided into more stack of distinct layers, and local connectivity is established between all the volumes of neurons that constitute the image. Eventually, the input volume is transformed into output volume. Several Convolutional Neural Network (CNN) architectures exist, including VGG, RESNET, DENSENET, Inception, and SQUEEZENET. Any of these can evaluate the performance of data sets and the applicability of management platforms.

CROP MONITORING USING DEEP LEARNING

Plant diseases threaten food security on a global scale and have terrible effects on small scale farmers whose source of income depends only on the crops which they produce. In this emerging world, it is assessed that small scale farmers generate nearly 80 percent of the total agricultural production (Kistler et al., 2020). Yet this could have been even higher not to mention that what is produced is hardly ever enough. It has been established that more than 50% of the total yield is lost every single year. The same study identified the common causes for the failure of more than 50% of the harvest to be pests and diseases (Harvey et al., 2014). A statistic like this should worry everyone. Such huge losses affect not only the farmers themselves who lose trillions annually but also the global food supply, which is gravely reduced. It becomes imperative that solutions are found. Hitherto, agricultural researchers have been able to find cures and drugs for these diseases. But these drugs are disease-specific in that they were designed for curing particular diseases. Farmers may not always know what particular disease is affecting their crops or what medicine to cure an ailment with. It becomes necessary that alternatives are found. Deep learning makes precision agriculture possible.

Precision agriculture is also called as satellite farming. It is a concept in agriculture management that observes, measures, and responds to field variability in crops by defining a decision support system (DSS) to maximize farm output while optimizing the use of farming resources. Real-time sensor arrays on GPS equipment helping go locate the precise position of a particular thing on a farm, allowing for the creation of maps showing such diverse phenomenon as organic matter content and moisture levels, are the ideals of precision agriculture brought to life. Such sensors arrays not only create such maps but make measurements such as chlorophyll levels and plant water status which when combined with satellite imagery are very useful to seeders, sprayers, and harvesters. This equipment, all collectively referred to as variable rate technology, use data from precision agriculture to optimally distribute resources and transmit data without human presence.

With precision agriculture, the disease can easily be pointed out in a crop, and cures found, fruits can be counted and crop varieties can very easily be identified including deciding which variety from many would yield the highest.

Mobile camera is commonly used in gathering data set for crop monitoring using deep learning. The figure is a mobile camera that gathers data and is also capable of transmitting data. This mobile camera could be an Internet-of-Things camera. Autonomous spray robots, autonomous pinking robots, mobile cameras, and smartphones are also authentic tools in data gathering.

The following topics are going to explain how deep learning algorithms can be used to solve the identified problems.

Plant Disease and Pest Identification

Crops are mostly affected by various plant diseases and pests which threaten food security. These pests and diseases are sometimes not noticed by the farmers until it's too late at which point they can no longer be controlled. Sometimes, the farmers may see one of their plants looking a certain way, perhaps more greenish than normal or the appearance of some spots, instead of seeing it for what it is, they would assume it's just the plant passing through some of its normal growth processes. Before they realize it is a disease, it may have taken over the whole farm and effectively reduced their farm's yield for that planting cycle. It is important farmers, especially farmers lacking advanced agricultural training, are helped to identify diseases early enough to know how to fight them.

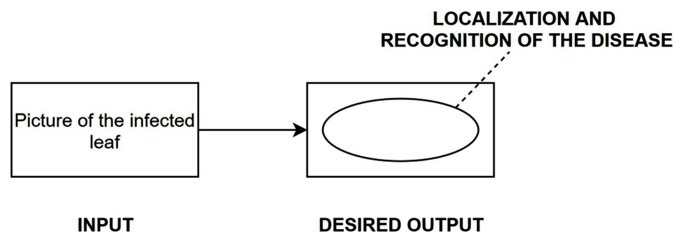
Previously, agriculture organizations and other institutions, like local plant clinics, supported the identification of the disease in plants. In a visible spectrum[6], most of the infections produce a type of sign, so the trained professional's bare eye examination is the major technique implemented in practice for the detection of disease in the plants. But this might sometimes fail due to poor observation skills. Human capabilities also have limitations and could be overstretched by stress or illnesses such as eye problems; in such cases, the observer may not be able to accurately make deductions from what he is seeing. So, to prevent these problems and to simplify the process of disease identification, various image-based deep learning algorithms can be used. To make this possible, certain attributes and characteristics of all possible diseases have to be identified and noted. Some of the characteristics of the diseases or pests which can be used for the analysis are listed below.

- Stage of the infection: A plant shows various patterns with different stages of infection throughout its life cycle. This can be useful in the process of identification of the disease. The particular pattern a plant shows at a particular stage of infection has to be identified and properly labeled. This should be done for all the stages such that it can be known that once a certain pattern appears, a plant's infection is at so and so stage.
- Shape and Colour: A plant can show different types of colors and shapes of infection depending on the disease. In the algorithm, a table of a sort can be made of diseases and their associated shape and color such that it is possible to identify the disease from the identified shape and color.
- Location of the infected region: The location of the infested region is not confined to the leaf region, but it can also show various symptoms on stems or fruits. Different diseases infect plants at different parts. By knowing the location of infection on a plant, it becomes easier to know the disease, and identifying the right cure is thus one step closer.
- Type of fungus: A straight-forward approach to understand the differences between the diseases is to identify and understand what kind of fungus it is. To know the type of fungus affecting the plant, it would be necessary to identify the characteristics of each known fungus, including the color and shape they leave on affected plants as well as which part of the plant they affect.
- Leaf Pattern: Depending on the disease, a change in the pattern of the leaf can also be observed. If a particular disease has been noted to leave a certain pattern on the leaves of affected plants, on such a pattern it will be quite easy to know that the plant has been infected by the disease in question.

While some of these characteristics can be identified visually, doing so is a huge burden on anyone and likely to result in errors. But with deep learning, the noted characteristics and other important ones will be incorporated into the network. The network would then be fed with a whole lot of images that it could study. The images would contain different plants, some healthy, others unhealthy. Characteristics would be mapped to their appropriate diseases and the network would be allowed to study, and process all of it.

Figure 1 describes how the problem should be formulated i.e., how to identify and locate the disease on the leaf. Neural networks provide the mapping from the input(image of the infected plant) to the output (identifying the disease) (Fuentes et al., 2017). Every node in the neural network is a mathematical function where the inward links are used to collect inputs and deliver a result as an outward link in the

Figure 1. The general process of the disease detection algorithm



form of numerical values. The deep learning tool mostly used here is Convolutional Neural Networks (CNNs) because CNN consists of powerful techniques to model the composite processes and to recognize the patterns from the images. These CNN architectures are trained and tested using various databases containing images of healthy and infected plants. So, when an image of the leaf is provided to these deep learning architectures, they analyze the image using the characteristics mentioned above and locate the infected region and also displays the type of the disease or pest which has infected the plant. Based on this information, a suitable solution to treat the plant can also be provided to the user.

Plant Phenology Recognition

The phenology of agricultural plants is the study of a plant's life cycle and how these will be affected by seasonal changes in the climate and environmental aspects (Merriam-Webster, 2020). It is a crucial understanding of precision agriculture[7]. Plant phenological studies consider the day a plant was planted, the day its leaves first appeared, when it started having flowers, attracting butterflies, the date its leafs started coloring and falling, if a deciduous tree and the dates the fruits started forming, got ripe and finally got harvested. All of these are noted while checking how variations in weather and climate, as well as in habitat factors such as elevation and soil topology, may have affected the plant.

Small variations in climate, such as changes in temperature and humidity, can gravely affect plant yields. Historical phenological records from a particularly arable land can be a useful guide in making future farming decisions. These records can as well be a measurement suitable for use as an indicator of the value of temperature in historical climatology, providing high temporal resolution in the study of climate change and global warming.

Applying deep learning algorithms for exact identification of plant's change in phenological states will enhance the results such as accurate time to harvest, to control the pests, for predicting yield, to monitor the farm, etc. Over the years, various countries have started working on agricultural monitoring network systems. But most of them produce a measure for monitoring the phenology only dependent on the colors which can be observed through the photos taken. But they are unreliable because these techniques are solely based on the color analysis which can be affected due to many reasons such as the jitter, change due to zooming effect, and unpredicted changes in parameters of the camera. Some plants do not have greenish colors. Plants such as maize and rice mature within a few months after planting and change color while it is still rainy season. How do you use only colors of the image of such plants to conclude that the plants' phenology? So, this is where deep learning algorithms can immensely help by eliminating the bottlenecks associated with using the colors of plants to decide phenology.

A pre-trained Convolutional Neural Network architecture (CNN) such as AlexNet, VGG_Net, GoogleNet, etc can be used to immediately get the characteristics of pictures and provide outcomes. Researchers use a process to employ a pre-trained CNN architecture which is based on the data similarity and the dataset's range. To test the procedure, a data set such as TARBIL (Turkish Agricultural Monitoring and Information Systems) can be used.

If the data set that is being used has less data similarity and size, the bottom layer of the pre-trained model has to be fine-tuned. For calibrating the bottom layer, the preordained model's first k layers have to be frozen and the other layers have to be trained. Thus the upper layers are tailored to the new data set (Yalcin, 2018). To avoid the above-mentioned problems, images have to be captured properly using appropriate tools. These images are reliable and can be used for accurate recognition of plant phenological states. These images have to be captured at a particular interval of time at the same place to understand the growth of the plants and also to have a better understanding of the phenological states of these plants. Also, to improve the accuracy of the results, a large set of images have to be captured, which should not be affected by any kind of disturbances caused while capturing the images. This capturing should also be done at many times as possible throughout the lifetime of a plant. This method helps the farmers to get more insights and a clear understanding of the plant phenological states which play a crucial role in precision agriculture.

Crop Irrigation

Irrigation systems are one of the most important aspects when it comes to agriculture. Irrigation is the process of watering the land to preserve the growth of the plant. It is very important to farmers in places with seasonal rainfall, a low amount of rainfall per year, or no rainfall at all as sometimes seen in desert areas. By watering the land, farmers can produce crops where they wouldn't have ordinarily. They can also increase yield and give the plants a good enough environment to mature for harvest. Watering the plants, however, need much human effort, and also consumes a lot of time. Many processes are usually involved in irrigation, making it too difficult for subsistence farmers and too expensive for commercial farmers. Irrigation can also waterlog soils, and increase its salt level to a point it could become harmful to plants. In this situation, a better irrigation system based on deep learning concepts will be very helpful for plant growth and as well as to reduce human efforts.

Today, there are many systems of irrigation adopted by farmers, whether subsistence or commercial. Drip systems and sprinklers are the most popular irrigation systems. These systems are designed in such a way that it will open the valves to supply water to the plants in frequent intervals of time. But these systems are not without their shortcomings and therefore bring some disadvantages to the farmer and his farm. One of the main disadvantages encountered by implementing these systems is inappropriate irrigation scheduling. Improper scheduling leads to either overwatering or under watering of the plants. Sufficient oxygen cannot be absorbed by the plants if they are overwatered due to which plant may die, and if the water is not sufficient to the plant, it will not absorb necessary nutrients from the soil. Not only that it is also impossible to continuously change the program due to the weather changes. As the owner cannot predict the seasonal changes that occur each year, he cannot pre-program the irrigation system that suits the weather at any instance. As shown in table-1, the soil moisture content varies from plant to plant. Providing the same amount of water regardless of the crop type causes an issue for the growth of the plant (Brouwer & Heibloem, 1986).

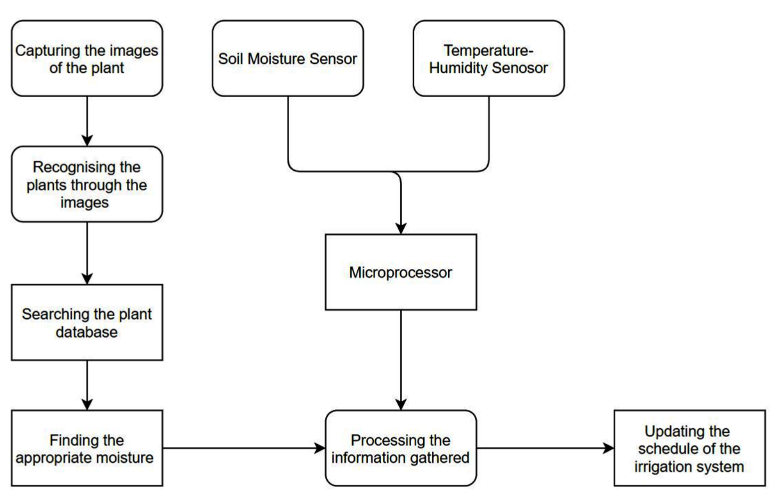
Table 1. The approximate requirement of water for some of the seasonal crops

S. No.	Crop	Crop Water Requirement (mm/total growing period)
1.	Tomato	400-800
2.	Pepper	600-900
3.	Onion	350-550
4.	Rice	450-700
5.	Melon	400-600
6.	Banana	1200-2200
7.	Wheat	450-650
8.	Cotton	700-1300
9.	Peanut	500-700
10.	Potato	500-700
11.	Sugarcane	1500-2500

Source: (Brouwer & Heibloem, 1986)

An IoT based system which is developed based on deep learning concepts can be implemented to resolve these issues. These deep learning concepts are adopted because they can identify the nonlinearities existing in the plant data. Various images of the plant have to be taken and should be uploaded to a deep learning software platform. Deep learning algorithms are used to classify plants with the help of images taken. Once the images are uploaded, the software calculates the probability of the image that belongs to a particular category of the plants. After identifying the plant, its appropriate moisture content will be retrieved from the database. Then with the support of the temperature sensor, humidity sensor, and soil moisture sensors, the present level of the moisture and humidity are calculated and given to the microprocessor[8]. Then the software uses the data collected by the microprocessor and the database and

Figure 2. The general process of smart IoT based irrigation system
Source: (Kwok & Sun, 2018)



then updates the schedule of the irrigation system as per the requirements as shown in Figure 2. (Kwok & Sun, 2018)

HARVESTING AND YIELD PREDICTING USING DEEP LEARNING

Crop yield prediction is highly important for food production across the world. Seed companies have to predict the yield of their new hybrid seeds that show how the seeds perform in all environments (Syngenta, 2018). Dealers and policy-makers require exact predictions to make decisions about importing and exporting the products.

Predicting yield is mainly beneficial to the farmers to take financial decisions and to choose which crop to plant in what kind of environment (T. Horiea, M.Yajimab, 1992). Lack of such knowledge may result in losses for the farmer and lost investment for all agricultural investors. It is important to know if what is being invested could be recouped from the expected yield right before the land is cleared. The process of predicting crop yield has many challenges because of the various complicated aspects. By knowing the exact number of fruits, flowers, etc., alone will not help in estimating yield production. The present method of manually counting fruits by the workers is more consuming of time, and an expensive method. Automatic yield estimation using the robotic agriculture method gives a feasible solution in this situation.

CROP VARIETY SELECTION

Crop selection is the act of choosing which crops to grow. Crop selection plays a vital role in predicting yield. In selecting crops, there are various factors like soil, prevailing farming condition, season, machinery, marketing and profitability, security, availability, and cost of planting materials, and minimum support price (MSP)[9] for that respective year to consider. Sometimes, it is difficult to know which of these factors will best contribute to the yield of a particular crop or which will impend its yield. It becomes even more difficult when there are hundreds of varieties of a particular crop to choose from. To overcome this problem, an algorithm called crop variety selection method (CVSM) will consider all the possible factors like seasonal and financial factors. It is this algorithm that will be used to select the crop variety that helps to achieve maximum yield.

Predicting the yield rate for the respective crop is the main purpose of CVSM. This algorithm contains three segments that are important to achieving its goal. The segments include selecting the crop, considering the market rate, and selecting the variety of crops. The CVSM technique uses Artificial Neural Networks (ANN) in deciding which variety is best. Artificial Neural Networks are used because they are good at recognizing patterns, and will be best for predicting yield rate. The networks are expected to have input and output layers. The neurons in the input layer contain environmental parameters such as temperature, rainfall, humidity, and the contents in the soil such as Nitrogen, Potassium, and Phosphorous. After processing the input layers, one output layer will be obtained with a single neuron that contains the predicted yield rate. And this process will be repeated for all the other crops as well (Vishwa et al., 2019). In the end, it is expected that the rate yield of each variety will be known and from here it would be becoming clear which the best variety would be.

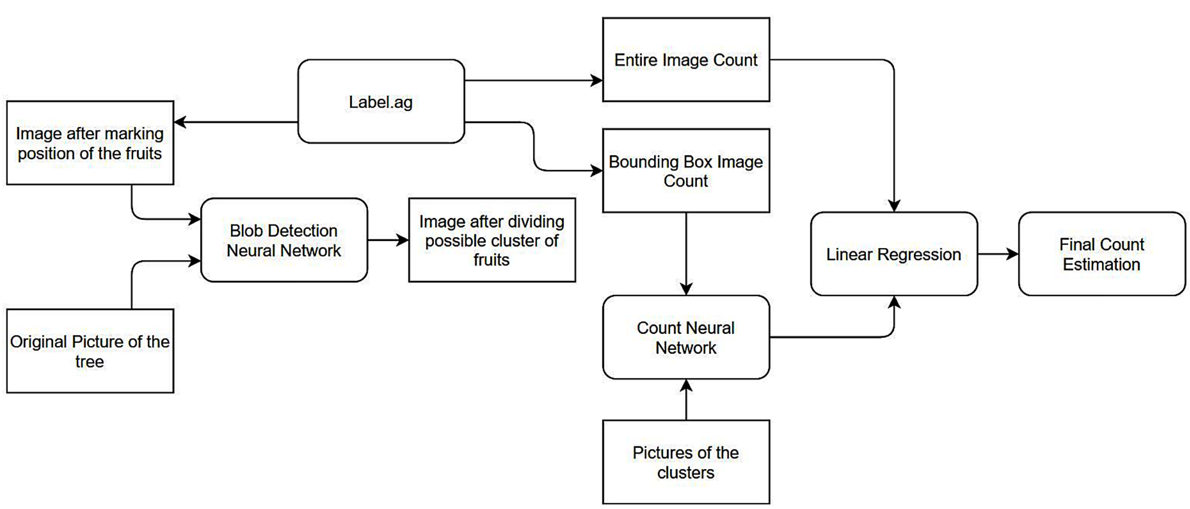
Crop varieties will be selected by the crop selector according to the given type of the soil. It is essential to know that certain crops won't do well in certain soil types and to choose only crops that are suitable for a particular soil type in the study. Even without doing so, the low rate at the end of processing, if the soil type is included in the factors, would be enough to discourage planting a crop in an unsuitable soil type. For every crop that is selected, its yield rate is multiplied with the MSP for the respective year to calculate the profit of that crop. The crop selector then chooses the crop which gives the highest profit.

Fruit Count

A farmer would naturally want to count the number of fruits on his plant. The reason for counting fruits is to aid in planning and to know if security protocols had somehow been breached. Sometimes, farmers count their fruits by taking photographs of their plants and trees and counting the number of fruits according to what they see in the photographed image. Estimating the number of fruits based on the photographs is a tough and complicated task for many reasons, including variability in appearance due to lighting, clarity, and obstruction because of neighboring leaves and fruits. The existing algorithms to count the number of fruits are based on computer vision[10] methods that require specialized characteristics that utilizes shape, color, and the texture of a variety of fruits. But these methods have limitations, they work ideally under specific conditions. These are usually fruit-speciðc and cannot be extrapolated to cover different fruits or even similar fruits from a different tree. Again, to get a good enough result for even that one fruit, the environment needs to be controlled carefully (Jiménez et al., 2000). This is without question tasking and takes away time that could have better been used for something else.

Deep learning is a better way to work with these unstructured environments than the computer methods which have more complications (Nekrasov et al., 2016). To count fruits successfully, one of the effective methods is executing deep learning algorithms in a pipelining architecture. First of all, to generate the ground-truth labels this approach uses a crowd-sourcing labeling platform, the group of human labelers gather truth labels. These are stored in Label.ag which is a web-based labeling framework. In this, a user generates SVG [11](Scalable Vector Graphics) data from the images by circling the

Figure 3. The step-by-step process of counting the fruits using deep learning



fruits. Then they are stored for further analysis. Figure 3 depicts the general process of counting fruits from images using deep learning.

Blob detection is then implemented with the help of a fully convolutional network to divide possible clusters of fruit from the background. The advantage of possessing this type of network is that it will accept any size of an image. It can be trained on one side of the image and applied to another. The next step estimates the fruit count utilizing a convolutional network. Sometimes each blob detected contains multiple fruits, this may result in the wrong estimation of fruits. So, this problem can be overcome by using convolutional neural networks that consider bounding boxes around each blob as input and outputs the number of fruits that the box contains. And these steps are conducted on every training image to obtain the estimated count. A count of the neural network is also taken. After this, they carry out a linear regression[12] of the count estimation on the ground truth count(Chen et al., 2017). By using this type of deep learning algorithm, the fruit count can then be estimated.

FRUIT HARVESTING

In recent years, the agriculture sector is facing many problems due to a smaller number of agricultural laborers and high cost of fruit harvesting. It becomes painful that after spending so much to plant crops, harvesting the fruits becomes a big headache on its own. Farmers begin to compute how much they had spent from the time they cleared their farmlands to the amount they are now going to pay the very few laborers available whose wages are shooting above the roof on a daily. Farmer everywhere would heave a sigh of relief knowing there's a cheaper alternative anywhere. Developing an automated robot that harvests fruit is one of the best answers to this problem. This involves three tasks performed in the under-listed steps.

Step 1: To locate the fruit's position on the tree.
Step 2: To position the robotic arm at the location of the fruit.
Step 3: Finally, collect the fruit without causing any damage to both the tree and the fruit.

The harvesting robot is arranged with a robotic hand and is connected to a stereo camera. There are three steps in the pre-written algorithm. The first step is detecting the fruit's position in 2D. In the study, researchers used the tool for the harvesting of apple fruits. In detecting the apple fruit's position, the stereo camera sends a picture through which the position of the apples can be detected. This method uses an SSD(Liu et al., 2016) to spot the location. SSD is a technique developed on the concept of the Convolutional Neural Network (CNN)(Alex et al., n.d.). Operating with only one DNN and with the aid of speed and high-accuracy object detection algorithms, it detects multiple objects from a single shot of the image.

For the fruits identified by SSD, select one that is near to the robotic arm. Then after receiving a point cloud data from the stereo camera and the pixel selected 2D position, to get a 3D position, three-dimensional reformation using a stereo camera has to be done. This is done by triangulation from the parallax between the right and left pictures. Then measure the distance from a stereo camera to the apple. Knowing the distance will help better coordinate the movement of the robotic hand in trying to harvest the fruit.

Harvesting is the last step performed by the bot. For positioning the robotic arm below the fruit, the robot will first move to some centimeters towards the targeted fruit. This is to make it easier for the robot arm to reach the fruit. The robots are carefully designed so that they do not bruise the fruits in the course of picking them. Once the robot is close enough to the targeted fruit, the robotic hand (embedded with suction grippers to avoid spoiling the fruits) grasps the fruit and harvests it by twisting from the stalk bearing that fruit by rotating four times. The experimental results state that for the apple tree, it took 2 s to detect the position of the apple and 14 s for harvesting the fruit. The speed can be increased by reconsidering these points. The proposed fruit harvesting can be applied to the near species of apples(Onishi et al., 2019).

FUTURE RESEARCH DIRECTIONS

In smart agriculture, there are several prospects for applications of deep learning. These techniques can be used to solve various problems that are faced in agriculture, such as irrigation, water erosion assessment, and greenhouse monitoring. Images that are captured through unmanned aerial vehicles can be used to create a database that will increase the efficiency of the current image processing systems. These deep learning techniques can be integrated into mobile applications and can be made more accessible to farmers. Deep learning-powered mobile applications with the help of satellite images can be used to intimate farmers about the unexpected weather conditions and insect attacks, which may cause damage to the crop.

CONCLUSION

The agricultural applications of deep learning are reviewed in this chapter. Deep learning has been used extensively in various agricultural areas, and here we showed how they can be used to make life easier for farmers in carrying out certain farming operations. Some of the operations illustrated included the detection of diseases in plants, identification of weeds and pests, fruit counting, yield prediction, harvesting fruits, and crop quality. While deep learning research in many other fields such as healthcare is gaining a great response, as per the analysis, responses to findings on the research of deep learning in the areas of agriculture, though still very far and few in between, are very different (Zhu et al., 2018) and (Kamilaris & Prenafeta-Boldú, 2018). This is mostly because findings have mostly been constrained to theories instead of finding applications in the industry. With time, however, industry players would get involved and these findings would revolutionize the agriculture sector. Besides deep learning, other imaging processing techniques could help optimize agriculture, yet deep learning offers better performance than the other usual image processing techniques. With the help of these techniques, many agriculture activities can be performed by using less manpower and hence at less cost. Deep learning also promises to increase not only farming process efficiency but also overall productivity. Hence, deep learning applications will help in achieving a better rate of food production to fulfil the needs of the rapidly going human population. It would eliminate the quantity correctly being lost to pest and diseases, optimize resources and make the whole process more effective. This will no doubt increase yields, earnings and food supply.

REFERENCES

Alex, K., Sutskever, I., & Hinton, G. E. (n.d.). *ImageNet Classification with Deep Convolutional Neural Networks*. doi:10.1201/9781420010749

Alexandratos, N., & Bruinsma, J. (2012). *World agriculture towards 2030/2050: the 2012 revision*. doi:10.22004/ag.econ.288998

Brouwer, C., & Heibloem, M. (1986). *Crop water needs*. Irrigation Water Management. http://www.fao.org/3/s2022e/s2022e02.htm

Chen, S. W., Shivakumar, S. S., Dcunha, S., Das, J., Okon, E., Qu, C., Taylor, C. J., & Kumar, V. (2017). Counting Apples and Oranges with Deep Learning: A Data-Driven Approach. *IEEE Robotics and Automation Letters*, *2*(2), 781–788. doi:10.1109/LRA.2017.2651944

Fuentes, A., Yoon, S., Kim, S. C., & Park, D. S. (2017). A Robust Deep-Learning-Based Detector for Real-Time Tomato Plant Diseases and Pests Recognition. *Sensors (Basel)*, *17*(9), 2022. Advance online publication. doi:10.339017092022 PMID:28869539

Harvey, C. A., Rakotobe, Z. L., Rao, N. S., Dave, R., Razafimahatratra, H., Rabarijohn, R. H., Rajaofara, H., & Mackinnon, J. L. (2014). Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *369*(1639), 20130089. doi:10.1098/rstb.2013.0089 PMID:24535397

Horiea, T., & Yajimab, M. (1992). Yield forecasting. *Agricultural Systems*, *40*(1–3), 211–236. doi:10.1016/0308-521X(92)90022-G

Ivakhnenko, A. G., Ivakhnenko, A. G., Lapa, V. G., Lapa, V. G. & McDonough, R. N. (1967). *Cybernetics and Forecasting Techniques*. American Elsevier Publishing Company. https://books.google.co.in/books?id=rGFgAAAAMAAJ

Jiménez, A. R., Ceres, R., & Pons, J. L. (2000). A survey of computer vision methods for locating fruit on trees. *Transactions of the ASAE. American Society of Agricultural Engineers*, *43*(6), 1911–1920. doi:10.13031/2013.3096

Kamilaris, A., & Prenafeta-Boldú, F. X. (2018). Deep learning in agriculture: A survey. *Computers and Electronics in Agriculture*, *147*(February), 70–90. doi:10.1016/j.compag.2018.02.016

Kistler, L., Bieker, V. C., Martin, M. D., Pedersen, M. W., Madrigal, J. R., & Wales, N. (2020). *Smallholders, food security, and the Environment*. Academic Press.

Kwok, J., & Sun, Y. (2018). A smart IoT-based irrigation system with automated plant recognition using deep learning. *ACM International Conference Proceeding Series*, 87–91. 10.1145/3177457.3177506

LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, *521*(7553), 436–444. doi:10.1038/nature14539 PMID:26017442

Liu, W., Anguelov, D., Erhan, D., Szegedy, C., Reed, S., Fu, C. Y., & Berg, A. C. (2016). SSD: Single shot multibox detector. Lecture Notes in Computer Science, 9905, 21–37. doi:10.1007/978-3-319-46448-0_2

Merriam-Webster. (2020). *Phenology*. https://www.merriam-webster.com/dictionary/phenology

Nekrasov, V., Ju, J., & Choi, J. (2016). Global deconvolutional networks for semantic segmentation. *British Machine Vision Conference 2016, BMVC 2016,* 124.1-124.14. 10.5244/C.30.124

Onishi, Y., Yoshida, T., Kurita, H., Fukao, T., Arihara, H., & Iwai, A. (2019). An automated fruit harvesting robot by using deep learning. *ROBOMECH Journal*, *6*(1), 2–9. doi:10.118640648-019-0141-2

Syngenta. (2018). *Syngenta Crop Challenge In Analytics*. https://www.ideaconnection.com/ Syngenta-crop-challenge/challenge.php/

Vishwa, G., Venkatesh, J., & Geetha, C. (2019). Crop Variety Selection Method using. *Machine Learning*, *12*(4), 35–38.

Yalcin, H. (2018). Phenology recognition using deep learning: DeepPheno. *26th IEEE Signal Processing and Communications Applications Conference, SIU 2018*, 1–4. 10.1109/SIU.2018.8404165

Zhu, N., Liu, X., Liu, Z., Hu, K., Wang, Y., Tan, J., Huang, M., Zhu, Q., Ji, X., Jiang, Y., & Guo, Y. (2018). Deep learning for smart agriculture: Concepts, tools, applications, and opportunities. *International Journal of Agricultural and Biological Engineering*, *11*(4), 21–28. doi:10.25165/j.ijabe.20181104.4475

ADDITIONAL READING

Amara, J., Bouaziz, B., & Algergawy, A. (2017). A deep learning-based approach for banana leaf disease classification. *Lecture Notes in Informatics (LNI), Proceedings - Series of the Gesellschaft Fur Informatik (GI), 266*, 79–88.

Durmus, H., Gunes, E. O., & Kirci, M. (2017). Disease detection on the leaves of the tomato plants by using deep learning. *2017 6th International Conference on Agro-Geoinformatics, Agro-Geoinformatics 2017*. 10.1109/Agro-Geoinformatics.2017.8047016

Kussul, N., Lavreniuk, M., Skakun, S., & Shelestov, A. (2017). Deep Learning Classification of Land Cover and Crop Types Using Remote Sensing Data. *IEEE Geoscience and Remote Sensing Letters*, *14*(5), 778–782. doi:10.1109/LGRS.2017.2681128

Kuwata, K., & Shibasaki, R. (2015). Estimating crop yields with deep learning and remotely sensed data. *International Geoscience and Remote Sensing Symposium (IGARSS), 2015-Novem*, 858–861. 10.1109/IGARSS.2015.7325900

Lu, Y., Yi, S., Zeng, N., Liu, Y., & Zhang, Y. (2017). Identification of rice diseases using deep convolutional neural networks. *Neurocomputing*, *267*, 378–384. doi:10.1016/j.neucom.2017.06.023

Sa, I., Ge, Z., Dayoub, F., Upcroft, B., Perez, T., & McCool, C. (2016). Deepfruits: A fruit detection system using deep neural networks. *Sensors (Switzerland)*, *16*(8), 1222. Advance online publication. doi:10.339016081222 PMID:27527168

Wang, G., Sun, Y., & Wang, J. (2017). Automatic Image-Based Plant Disease Severity Estimation Using Deep Learning. *Computational Intelligence and Neuroscience*, *2017*, 1–8. Advance online publication. doi:10.1155/2017/2917536 PMID:28757863

Xinshao, W., & Cheng, C. (2016). Weed seeds classification based on PCANet deep learning baseline. *2015 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference, APSIPA ASC 2015, December*, 408–415. 10.1109/APSIPA.2015.7415304

Zheng, Y. Y., Kong, J. L., Jin, X. B., Wang, X. Y., & Zuo, M. (2019). CropDeep: The Crop Vision data set for Deep-Learning-Based Classification and Detection in Precision Agriculture. *Sensors (Basel)*, *19*(5), 1058. doi:10.339019051058 PMID:30832283

KEY TERMS AND DEFINITIONS

Algorithm: An algorithm is an ordered, accurate step-by-step process for a problem that provides a solution in a finite number of steps and that is unambiguous.

Artificial Intelligence (AI): AI is a simulation of human intelligence through the progress of intelligent machines that think and work like humans carrying out such human activities as speech recognition, problem-solving, learning, and planning.

Artificial Neural Network (ANN): Artificial neural networks (ANNs) are a type of computing system that is inspired by biological neural networks present in the animal brain.

Blob Recognition: Blob recognition is a process in computer vision that is used to recognize a specific region in an image that differs from its surroundings in some properties such as brightness or color.

Clusters: A cluster is a group of data objects which have similarities among them. It's a group of the same or similar elements gathered or occurring closely together.

Computer Vision (CV): Computer vision is a subset of AI which deals with the concept of how a computer can gain knowledge through digital images.

Crop Variety Selection Method (CVSM): Crop variety selection method is an algorithm for predicting the yield rate of a crop by selecting the best crop variety amongst many through a fair consideration of current and variable market prices.

Crop Yield: The total production of fruits from planted crops.

Data Collection: The method of collecting and evaluating data on selected variables, which helps in analyzing and answering relevant questions is known as data collection.

Data Set: A collection of relevant data that can be used for analysis is known as dataset.

Database: It is a collection of information in a proper and tabulated structure, which can be in a machine-readable format accessible by a computer.

Detection Device: It is a tool for identifying concealed objects or information.

Diseases: Diseases are abnormal conditions of a human, animal, or plant that results in discomfort or dysfunction.

Efficiency: Efficiency is the degree to which a resource is utilized for the intended task.

Global Warming: The gradual increase in the overall temperature of the earth's atmosphere generally attributed to the greenhouse effect is known as global warming.

GPS: A global positioning system is a satellite navigation system used to determine the ground position, which is the geographical location, of an object.

Image Classification: Image classification is the process of categorizing and labeling groups of pixels or vectors within an image based on specific rules, it is the primary domain, in which deep neural networks play the most important role of image analysis.

Internet of Things (IoT): IoT is a network of real-world objects which consists of sensors, software, and other technologies to exchange data with the other systems over the internet.

Irrigation: It is the process of providing water to land that in turn assists in the production of crops.

Linear Regression: Linear regression is a supervised machine learning technique in which the predicted outcomes are continuous

Machine Learning (ML): Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed and in the process developing computer programs that can access data and use it to learn for themselves.

Microprocessor: A microprocessor is an integrated circuit (IC) that contains all the functions of a central processing unit (CPU) of a computer.

Minimum Support Price (MSP): Minimum support price is a guaranteed price, usually given by the government, on the products that are produced by the farmers.

Modeling: Modeling here refers to the representation of depth in a two-dimensional (2D) image.

Monitoring: Monitoring is the act of keeping something under systematic review by observing and checking the progress or quality of that thing over a while.

Neural Network: An artificial neural network is based on a simplification of neurons in an animal brain which is a group of interconnected neurons.

Neuron: An artificial neuron is a model of a neuron present in an animal brain that is perceived as a mathematical function.

Node: A node is a computer or some other device that is attached to a network.

Optimization: Optimization is the design and operation of a system or process to make it as good as possible in some defined sense, it is the action of making the best or most effective use of a situation or resource.

Parallax: Apparent change in the position of an object because the variation in the location of the viewer is known as parallax.

Perceptron: these are machine learning algorithms that undertake supervised learning of functions called binary classifiers which decide whether or not an input, usually identified with a vector of numbers, belongs to a particular class.

Pipelining: Pipelining is a technique where various instructions execute in an overlapping manner.

Plant Phenology: It is a study of the plant's life cycle and how these will be affected by seasonal changes in the climate and environmental aspects.

Precision Agriculture: It is a concept in farming management that observes, measures, and responds to field variability in crops by defining a decision support system (DSS) to maximize farm output while optimizing the use of farming resources.

Prediction: Prediction is a forecast, a statement of what will happen in the future.

Probabilities: A probability refers to the precise likelihood of an event happening which is most often expressed in a number, between 0 and 1, that make an accurate prediction of the likely occurrence of a certain event.

Robot: A computer-programmed, self-aware machine built to carry out complex tasks or a group of tasks.

Scalable Vector Graphics (SVG): It is a vector-based picture format that makes use of Extensible Markup language (XML) and which unlike other images/graphics formats such as PNG comes with support for interactivity and animation.

Semi-Supervised Learning: Semi-supervised learning aims at labeling a set of unlabelled data with the help of a small set of labeled data.

Sensors: It is a device or module, and its task is to identify the variations in its physical or electrical or other quantities and produces an output as a response to that change.

Speech Recognition: Speech recognition is a process through which machines convert words or phrases spoken into a machine-readable format.

Supervised Learning: Supervised learning aims at developing a function for a set of labeled data and outputs.

TARBIL (Turkish Agricultural Monitoring and Information Systems): The Turkish Agricultural Monitoring and Information Systems is an information system built by the Turkish government in 2008 to provide parcel-based continuous agro-meteorological parameter prediction, yield monitoring for precision farming, and good agricultural practices support.

Triangulation: Triangulation is a process of identifying a point in a three-dimensional space given its projection on multiple images.

Unsupervised Learning: Unsupervised Learning aims at inferring the given unlabelled data using a different type of structures present in the data points.

ENDNOTES

1 Supervised Learning aims at developing a function for a set of labelled data and outputs.

2 Semi-supervised Learning aims at labelling a set of unlabelled data with the help of small set of labelled data.

3 Unsupervised Learning aims at inferring the given unlabelled data using a different type of structures present in the data points.

4 Artificial Neural Networks (ANNs) are a type of computing systems that are inspired from biological neural networks present in animal brain.

5 Speech recognition is a process through which machines convert words or phrases spoken into a machine-readable format.

6 Visible spectrum is a segment of electromagnetic spectrum that is perceivable by the human's naked eye where the wavelength is in between 380 to 740 nm.

7 Precision agriculture is a management technique to respond to the inter and intra-field variabilities by observing and measuring them.

8 Microprocessor is a controlling unit that is present on an integrated circuit which is capable of performing arithmetic and logical operations.

9 Minimum support price (MSP) is a guarantee price on the products that are produced by the farmers which is given by the Government.

[10] Computer vision (CV) is a branch of artificial intelligence (AI) which deals with the concept on how computer can gain knowledge through digital images

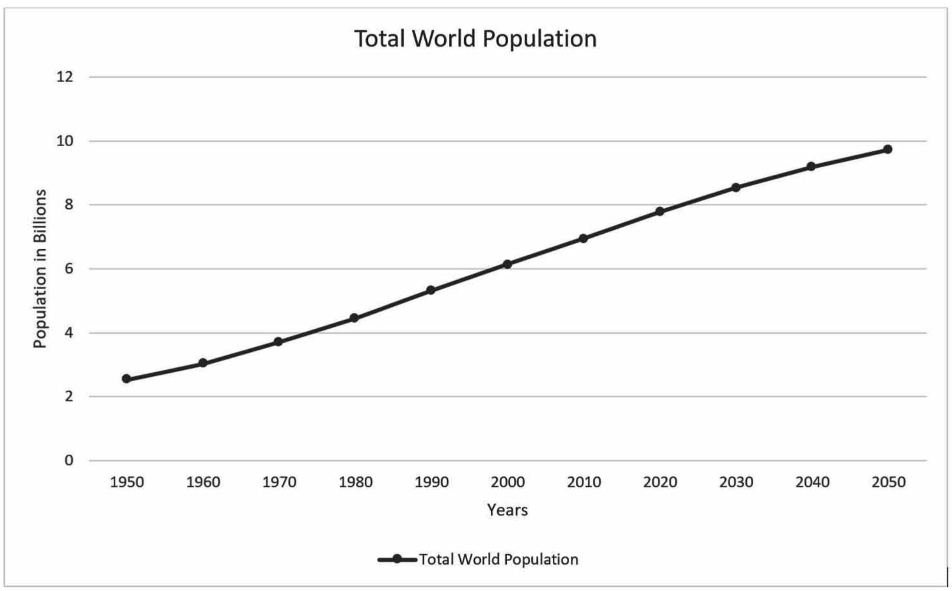
[11] Scalable vector graphics (SVG) is a vector-based image format which is based on Extensible Markup Language.

[12] Linear Regression is a supervised machine learning technique where the predicted outcomes are continuous.

APPENDIX 1

Every year the United Nations conducts surveys and provides the data regarding the total world population and it also estimates the world population of forthcoming years. Figure 4 shows the graphical representation of the data collected by the United Nations, which indicates a drastic increase in the population when compared to the previous years. According to that survey, the world population is going to cross 9.5 billion by the year 2050 which is approximately four times more than the population in the year 1950. The study reveals the need to increase the rate of food production to meet the growing requirements.

Figure 4. Year-wise estimation of the world population
(Data Source: United Nations World population prospects, 2019)



APPENDIX 2

The following table contains the list of publicly available data sets that can be used for deep learning applications in agriculture. These are free of cost and are available to anyone for non-commercial purposes.

Table 2. Visits to public libraries

S.No	Name of the Data Set/ Organization	Contents of the Data Set	Source
1.	Crop/Weed Field Image data set (CWFID)	This data set consists of images of the field and annotations of crop/weed plants	https://github.com/cwfid/data set
2.	Agriculture Production in India from 2001-2014	This data set consists the information regarding agricultural production in India from the year 2001-2014	https://www.kaggle.com/srinivas1/agricuture-crops-production-in-india/home
3.	Flavia leaf data-set	It consists of leaf images of 32 various plants.	http://flavia.sourceforge.net/
4.	Leafsnap data-set	It consists of leaf images of 182 various species	http://leafsnap.com/dataset/
5.	Image-Net data set	This data set consists of various plant images.	http://image-net.org/explore?wnid=n07707451
6.	V2 Plant Seedlings data set	This data set consists of approximately 5500 seedling images that belong to 12 different species	https://www.kaggle.com/vbookshelf/v2-plant-seedlings-data set
7.	MalayaKew data set	This data set consists of scan-like images of leaves of 44 different species	http://web.fsktm.um.edu.my/~cschan/downloads_MKLeaf_dataset.html
8.	UC Merced Land Use data set	This data set consists of images of land uses of 21 different categories	http://vision.ucmerced.edu/datasets/landuse.html
9.	LifeCLEF data set	This data set consists of information regarding geographic distribution and images of some plants of different species	https://www.imageclef.org/2014/lifeclef/plant
10.	University of Bonn Photogrammetry, IGG	This data set consists of images of plants which can be used for classification, localization, and mapping	https://www.imageclef.org/2014/lifeclef/plant

Chapter 21
Development of a Solar-Powered Greenhouse Integrated With SMS and Web Notification Systems

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ABSTRACT

Energy for heating and cooling is among the biggest costs in greenhouse crop production. This has led to a rethink on energy-saving strategies, including the demand for solar energy as a viable renewable and sustainable choice for greenhouse farming. This chapter presents the development of a solar-powered system leveraging on internet of things and GSM technologies for sensing, controlling, and maintaining optimal climatic parameters inside a greenhouse. The proposed system is designed to automatically measure and monitor changes in temperature, humidity, soil moisture, and the light intensity. The strategy utilized in the design framework provides the user with the information of the measured parameters online and via SMS regardless of their geographical location. The chapter also incorporates a mechanism to self-regulate the climatic condition inside the greenhouse, suitable for the plant growth. Such a system can help improve the quantity and quality of crops grown in a greenhouse. Tests carried out on the system prove its effectiveness according to the design considerations.

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INTRODUCTION

A greenhouse is a structure covered mainly with transparent materials, such as plastic, glass and fiberglass, in which regulated environmental conditions suitable for plants growth is maintained (Hassanien, Li, & Dong Lin, 2016). The greenhouse industry is one of the fastest-growing sectors in the world (Panwar, Kaushik, & Kothari, 2011). The greenhouse provides a shelter for the crop away from the direct influence of natural weather conditions (Panwar et al., 2011). This allows for crop production in areas with unstable seasons or climatic conditions. The enclosure of the greenhouse allows for regulation of the crop environment to improve cultivation suitable for the plant needs. This leads to higher production, better quality, less use of pesticides and prolonged production (Panwar et al., 2011).

Energy for heating and cooling is among the biggest cost in greenhouse crop production. This has led to a rethink on energy-saving strategies, including the demand for solar energy as a sustainable choice for greenhouse farming (Hassanien et al., 2016). Factors such as increasing global population growth, high energy consumption, unpredictable weather patterns and poor water resource management, and the need to produce sufficient amount of food, is favouring greenhouse as viable means of supporting the agricultural sector (Hassanien et al., 2016; Sadik, 1991).

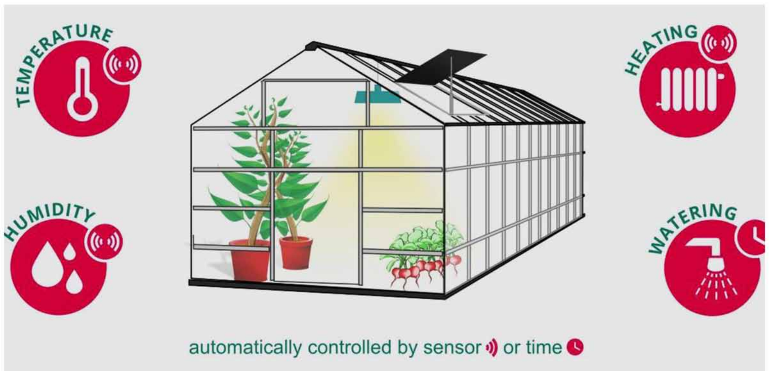
In South Africa as a case study, there are roughly 2 million smallholder or family unit farmers in contrast with 35 thousand business farmers. A number of these farmers depend predominately on the land to sustain their families with ideally some surplus to sell or exchange. However, the erratic climatic condition often experienced is hurting agriculture, for example, dry spells, floods, heatwaves or heavy winds, harm crops production in no small measure. It also increasingly render lower scale farmers helpless (Scott Ramsay & WWF South Africa, 2019). These extreme climate conditions likewise further disintegrate soils, which decrease the capacity of these zones for animals grazing and lessening harvests yields (Sadik, 1991). Ultimately impacts on food security for millions (Sadik, 1991). The idea of smart farming which includes the greenhouse industry is progressively been used to portray how innovation could be utilised to improve quality crops and increase the quantity of crop production (Nate Dorsey & Precisionag, 2017).

Plants need to be monitored regularly to survive these volatile extreme climatic conditions. Farmers with greenhouse environments are required to always be on-site to monitor plants. However, it is practically a challenge for a greenhouse farmer to be always present to monitor and control the conditions of the greenhouse to guarantee high-quality plants growth. More so, the situation is exacerbated by challenges related to the power supply, especially in developing countries. This paper, therefore, seeks to design and implement a solar-powered greenhouse system that leverages on the Internet of things (IoT) and GSM technologies and that remotely monitors greenhouse climate conditions. This system would replicate favourable climatic conditions inside a greenhouse (temperature, relative humidity, soil moisture and lightning) and provide regular updates about these parameters via the internet using GSM technology. Figure 1 depicts a typical greenhouse, which is auto controlled by sensors in real-time.

RELATED WORK

There are several works on greenhouse systems that have been developed under a broader smart farming or precision agriculture domain, leveraging on technologies such as IoT, cloud computing, sensors

Figure 1. An example of a smart greenhouse
(Eigen Technologies, 2013)



and embedded systems etc. This section provides a review of some related works in solar-powered IoT based greenhouse systems.

In (Sharma Subedi, 2018), the authors implemented an automated irrigation system for monitoring and control of environmental changes in the greenhouse. The prototype system uses a wireless sensor network, a client-server web service. The work had two major design considerations: to lower power consumption and long-distance monitoring and control. The authors proposed a variety of monitoring systems to cater for different environmental conditions of different plants. Five sensors namely humidity, soil moisture, light, temperature, and carbon dioxide sensors were used in their proposed design. Additionally, an Android application was integrated and used to monitor and control the greenhouse sensor parameters.

In the work in (Kodali, Jain, & Karagwal, 2016), the authors developed a drip irrigation based greenhouse. LDR, temperature, humidity and soil moisture are the sensors utilised. The Arduino microcontroller is used to interconnect and control the sensors and the other hardware components of the system. The design also incorporated an IoT based mechanism, leveraging on RFID tag and cloud computing that allows farmers to interact directly with their customers/buyers giving them information on the produce available.

The authors in (Vatari, Bakshi, & Thakur, 2016), developed an automated greenhouse system based on IoT and distributed cloud computing setup. This framework detects all the natural parameters and sends that information to the client by means via the cloud. Temperature, humidity, soil moisture and Co2 sensors are utilised and interconnected using ZigBee wireless technology. The system is also able to regulate the sensing parameters whenever unsuitable changes in the greenhouse occur.

In (Shirsath, Kamble, Mane, Kolap, & More, 2017), the authors proposed a greenhouse monitoring and controlling system using an Arduino microcontroller to interconnect the sensors and actuators that make up the system. Humidity, temperature, light and soil moisture sensors are utilised, in addition to sprinkler and air vent controllers. The system also incorporates an Arduino Wi-Fi shield to transmit wirelessly the sensor parameters.

From the reviewed works some of the proposed designs have technical limitations such as unnecessary complexities, not considering renewable sources of energy and not a fully IoT based integrated system, to ensure easy monitoring and control of the greenhouse. Hence, the study proposes a low-cost solar-powered greenhouse integrated with SMS and web notification systems, to ensure easy monitoring, control and regulation of the greenhouse environment.

SYSTEM DESIGN

Hardware Design

The block diagram of the greenhouse design is depicted shown in Figure 2. The Arduino acts as the central processing unit, on which the hardware components are interconnected. Figure 3 shows the detailed circuit diagram of the system.

Figure 2. Block diagram of the system

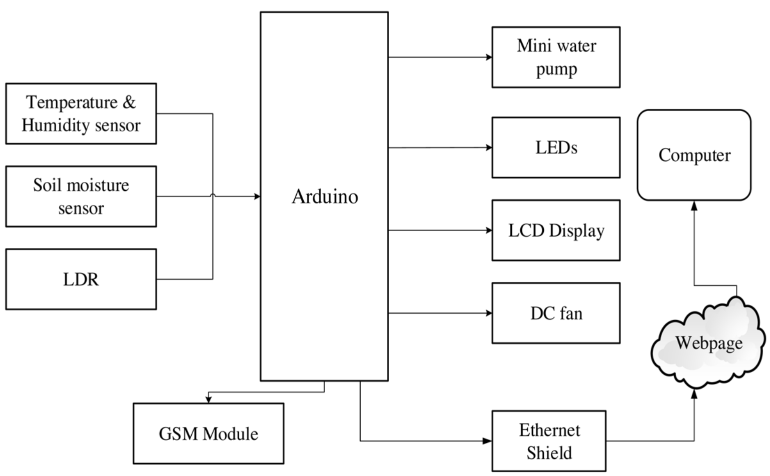
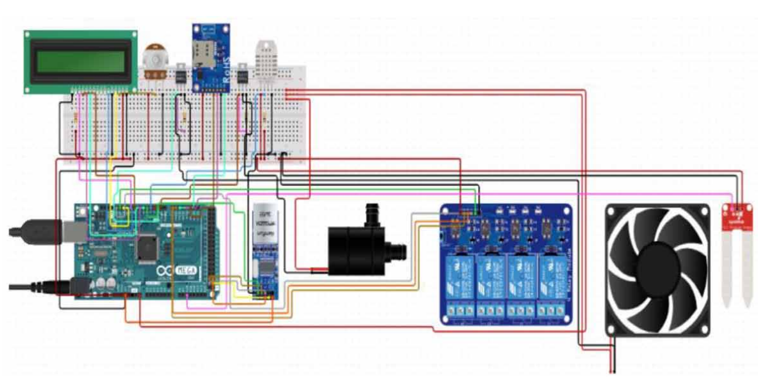


Figure 3. Detailed circuit diagram of the system



Power Supply Unit

The greenhouse power supply unit depicted in Figure 4, consists of a solar panel, a battery and a charge controller. The solar panel charges the 12V battery through the charge controller and then the battery supplies power to all the components of the greenhouse.

Software Design

The system carries out its function as depicted in the detailed flowchart diagram of the system in Figure 5, comprising five subsystems, IoT, notification, server, client and control systems.

Figure 4. The solar power supply unit

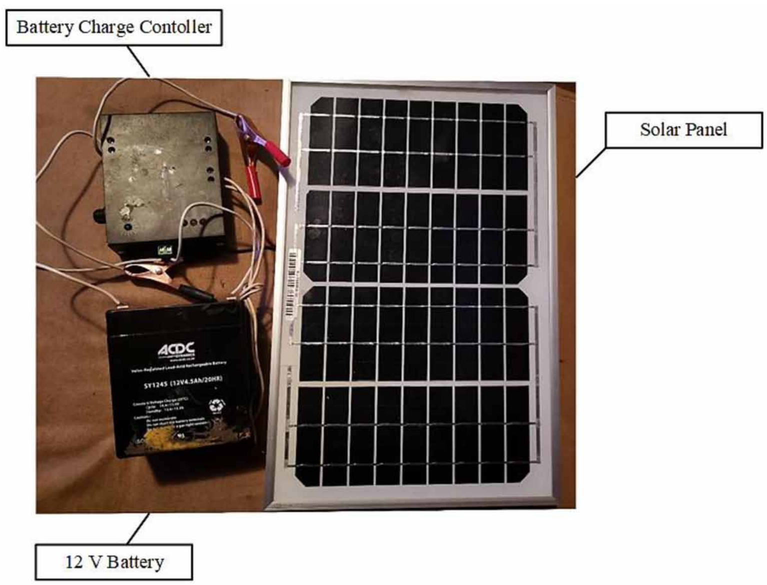
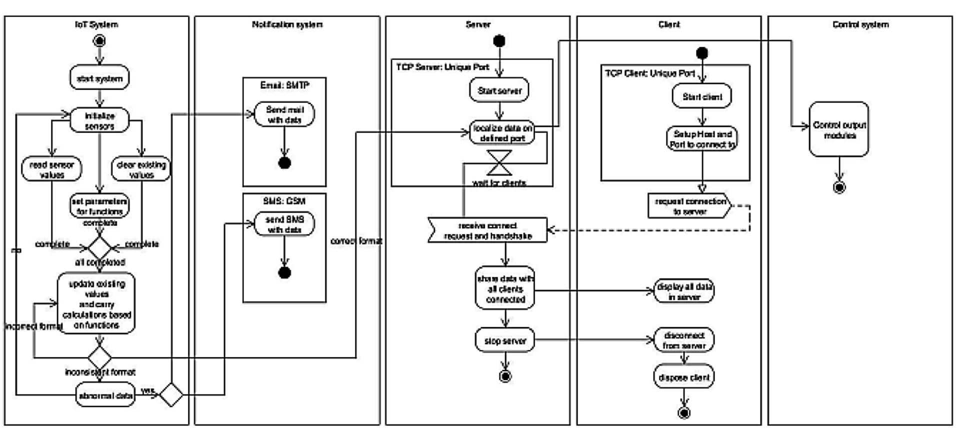


Figure 5. Flow chart diagram



On system start, the sensors are initialised. The analogue values are stored and used as system parameters and then cleared after all have been collected. The existing values are then updated and calculations carried out. Output setup for the incorrect format is reverted for recalculation. Abnormal sensed data are reinitialised and the data is recollected. Normal data is then sent to the server using transfer control protocol (TCP) running on a specific port which constantly waits for clients to connect. Once a client connects, a handshake is done to share data from the sensors. In this process, data is converted to information and a graphical user interface (GUI) format of the information shown. Once the client disconnects the session is closed.

TESTING RESULTS OF THE SYSTEM

Table 1 compares the temperature reading of the temperature sensor to the room temperature. The results are similar hence; the temperature sensor is configured correctly.

Table 1. Testing DHT11 sensor readings

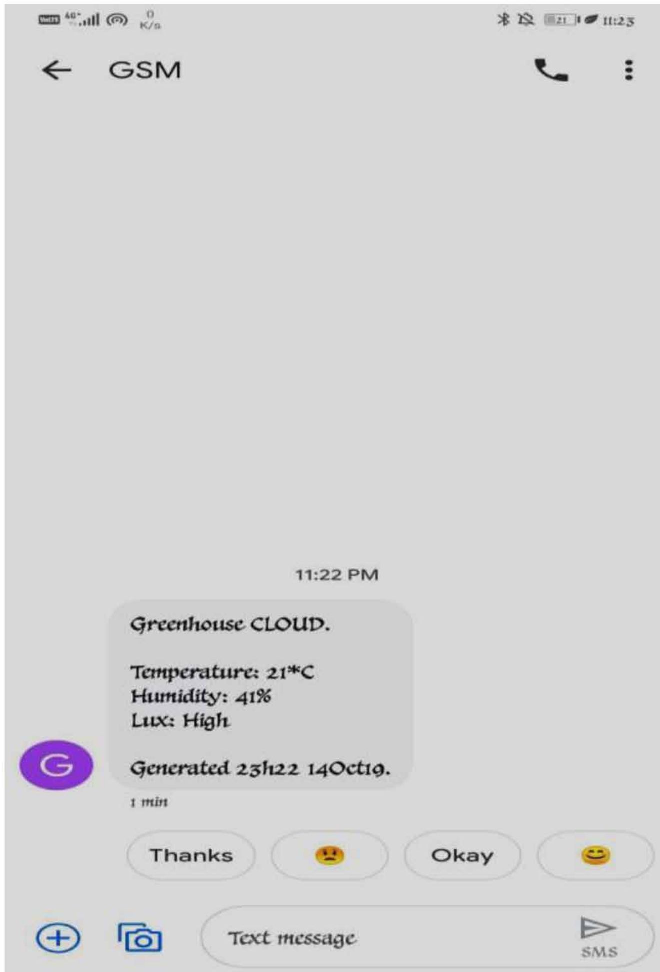
Iteration(s)	Temperature, ^{0}C (Measured by DHT11)			Temperature, ^{0}C (Measured by Samsung Air-Conditioned)
	Test1	Test 2	Test 3	
1	21	20	20	21
2	20	23	20	22
3	24	23	21	23
4	22	23	22	24
5	23	22	22	25
6	26	25	26	26
7	25	25	27	27

Figure 6 provides the short message sent by the GSM module notifying the user about the greenhouse parameters. While Figure 7 shows the webpage that is obtained by the user to monitor the greenhouse parameters. The main parameters displayed on the webserver includes temperature, humidity and soil moisture.

CONCLUSION AND FUTURE WORK

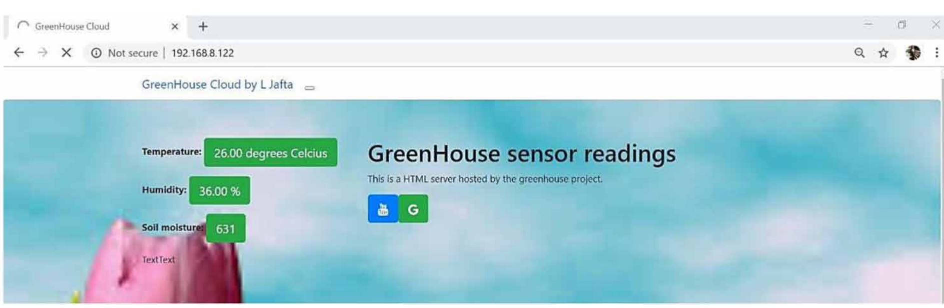
The essential target of this work was to design and implement a prototype solar-powered greenhouse using the internet of things concept. The use of both internet connection in the form of a web server as well as the GSM module allows the user of the greenhouse to be able to monitor the greenhouse remotely via SMS and a webpage interface. The objectives and requirements for the work were met based on the desired outcome.

Figure 6. Displayed message on smartphone



In the future, the greenhouse monitoring system could be improved by incorporating Artificial Intelligence, such as machine learning on the generated sensor data, as a way of predicting or forecasting

Figure 7. Webpage sensor readings interface



future occurrences in the system. Additional, sensor parameters could also be incorporated, such as carbon dioxide and pH control, as well as cameras for visual monitoring and analysis of plant growth.

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REFERENCES

Eigen Technologies. (2013). *MeshFarm- smart agriculture.* https://www.eigen.in/Meshfarm

Hassanien, R. H. E., Li, M., & Dong Lin, W. (2016). Advanced applications of solar energy in agricultural greenhouses. *Renewable & Sustainable Energy Reviews*, *54*, 989–1001. doi:10.1016/j.rser.2015.10.095

Kodali, R. K., Jain, V., & Karagwal, S. (2016). *IoT based smart greenhouse. In 2016 IEEE Region 10 Humanitarian Technology Conference (R10-HTC)*. IEEE.

Nate Dorsey, N., & Precisionag. (2017). *4 important ways precision technology is impacting irrigation - PrecisionAg.* https://www.precisionag.com/in-field-technologies/irrigation/4-important-ways-precision-technology-is-impacting-irrigation/

Panwar, N. L., Kaushik, S. C., & Kothari, S. (2011). Solar greenhouse an option for renewable and sustainable farming. *Renewable & Sustainable Energy Reviews*, *15*(8), 3934–3945. doi:10.1016/j.rser.2011.07.030

Sadik, N. (1991). *Population growth and the food crisis.* http://www.fao.org/3/U3550t/u3550t02.htm

Scott Ramsay, S., & South Africa, W. W. F. (2019). *Climate smart smallholder farming - WWF South Africa.* https://www.wwf.org.za/our_work/initiatives/climate_smart_smallholder_farming.cfm

Sharma Subedi, J. R. (2018). *Design and Implementation of IoT Based Smart Greenhouse Monitoring System* (Doctoral dissertation). Université d'Ottawa/University of Ottawa.

Shirsath, P. D. O., Kamble, P., Mane, R., Kolap, A., & More, P. R. S. (2017). IoT based smart greenhouse automation using Arduino. *International Journal of Innovative Research in Computer Science & Technology*, *5*(2), 234–238. doi:10.21276/ijircst.2017.5.2.4

Vatari, S., Bakshi, A., & Thakur, T. (2016). Green house by using IOT and cloud computing. In *2016 IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)* (pp. 246-250). IEEE. 10.1109/RTEICT.2016.7807821

Compilation of References

(n.d.). Puri, Nayyar, & [Agriculture drones: A modern breakthrough in precision agriculture. *Journal of Statistics and Management Systems*.]. *Raja.*

Abbasi, M., Yaghmaee, M. H., & Rahnama, F. (2019, April). Internet of Things in agriculture: A survey. In *2019 3rd International Conference on Internet of Things and Applications (IoT)* (pp. 1-12). IEEE. doi:10.1016/j.comnet.2020.107148

Abdul Hakkim, V.M., Abhilash Joseph, E., Ajay Gokul, A.J., & Mufeedha, K. (2016). Precision Farming: The Future of Indian Agriculture. *Journal of Applied Biology & Biotechnology, 4*(6), 68-72.

Abdul Rasheeque, K.A., & Savitha. (2017). E-Farming Using Internet of Things. *International Journal of Latest Trends in Engineering and Technology*, 419-422.

Abedin, Z., Chowdhury, A. S., Hossain, M. S., Andersson, K., & Karim, R. (2017). An interoperable IP based WSN for smart irrigation system. *14th IEEE Annual Consumer Communications Networking Conference (CCNC)*, 1–5. 10.1109/CCNC.2017.8013434

Abhishesh, P., Ryuh, B., Oh, Y., Moon, H., & Akanksha, R. (2017). Multipurpose agricultural robot platform: Conceptual design of control system software for autonomous driving and agricultural operations using programmable logic controller. *Mechatronic and Manufacturing Engineering*, *11*(3), 496–500.

Abubakar, I., Khalid, S. N., Mustafa, M. W., Shareef, H., & Mustapha, M. (2017). Application of load monitoring in appliances' energy management—A review. *Renewable & Sustainable Energy Reviews*, *67*, 235–245. doi:10.1016/j.rser.2016.09.064

Accidental Deaths & Suicides in India. (2015). Retrieved from https://ncrb.gov.in/StatPublications/ADSI/ADSI2015/adsi-2015-full-report.pdf

Agarwal, M. C., & Goel, A. C. (1981). Effect of field levelling quality on irrigation efficiency and crop yield. *Agricultural Water Management*, *4*(4), 457–464. doi:10.1016/0378-3774(81)90033-0

Agbo, M., Rousseliere, D., & Salanie, J. (2015). Agricultural marketing cooperatives with direct selling: A cooperative-non-cooperative game. *Journal of Economic Behavior & Organization, 109*.

Agrawal, H., Dhall, R., Iyer, K. S. S., & Chetlapalli, V. (2019). An improved energy efficient system for IoT enabled precision agriculture. *Journal of Ambient Intelligence and Humanized Computing*, 1–12. doi:10.100712652-019-01359-2

Agrobot. (2020, July 4). Retrieved from www.agrobot.com/

AgTech. (2018). *Emerging Technologies in Agriculture: Regulatory & other challenges*. ACIL Allen Consulting, AgriFutures Australia.

Ahirwar, S., Swarnkar, R., Bhukya, S., & Namwade, G. (2019). Application of Drone in Agriculture. *Int. J. Curr. Microbiol. App. Sci*, *8*(01), 2500–2505.

Ahmed, De, & Hussain. (2018). Internet of Things (IoT) for Smart Precision Agriculture and Farming in Rural Areas. *IEEE Internet of Things Journal, 5,* 4890-4899.

Ahmed, N., De, D., & Hussain, I. (2018). Internet of Things (IoT) for smart precision agriculture and farming in rural areas. *IEEE Internet of Things Journal*, *5*(6), 4890–4899. doi:10.1109/JIOT.2018.2879579

Aksoy, S. (2017). Değişen teknolojiler ve endüstri 4.0: Endüstri 4.0'ı anlamaya dair bir giriş. *SAV Katkı*, *4*, 34–4.

Aleksandrova, M. (2018). *IoT in Agriculture: Five Technology Uses for Smart Farming and Challenges to Consider*. Academic Press.

Alex, K., Sutskever, I., & Hinton, G. E. (n.d.). *ImageNet Classification with Deep Convolutional Neural Networks*. doi:10.1201/9781420010749

Alexandratos, N., & Bruinsma, J. (2012). *World agriculture towards 2030/2050: the 2012 revision*. doi:10.22004/ag.econ.288998

Alexandratos, N., & Bruinsma, J. (2012). *World agriculture towards 2030/2050: the 2012 revision*. Agricultural Development Economics Division, Food and Agriculture Organization of the United Nations.

Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of things: A survey on enabling technologies, protocols, and applications. *IEEE Communications Surveys and Tutorials*, *4*(17), 2347–2376. doi:10.1109/COMST.2015.2444095

Al-Hiary, H., Bani-Ahmad, S., Reyalat, M., Braik, M., & ALRahamneh, Z. (2011). Fast and accurate detection and classification of plant diseases. *International Journal of Computers and Applications*, *17*(1), 31–38. doi:10.5120/2183-2754

Alkan, M. A. (2016). *Karanlık fabrikalar ile insansız üretim.* Retrieved from http://www.endustri40. com/karanlik-fabrikalar-ile-insansiz-uretim

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop Evapotranspiration-Guidelines for Computing Crop Water Requirements-FAO Irrigation and Drainage Paper 56. Rome: FAO.

Alom, M. Z., Taha, T. M., Yakopcic, C., Westberg, S., Sidike, P., Nasrin, M. S., . . . Asari, V. K. (2018). *The history began from alexnet: A comprehensive survey on deep learning approaches.* arXiv preprint arXiv:1803.01164

Al-Qizwini, M., Barjasteh, I., Al-Qassab, H., & Radha, H. (2017, June). Deep learning algorithm for autonomous driving using googlenet. In *2017 IEEE Intelligent Vehicles Symposium (IV)* (pp. 89-96). IEEE. 10.1109/IVS.2017.7995703

Alston, D., Murray, M., & Reding, M. (2010). *Codling Moth (Cydia pomonella).* Utah State University Extension and Utah Plant Pest Diagnostic Laboratory publicatios. Retrieved from https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1879&context=extension_curall

Altieri, M. A., & Nicholls, C. I. (2020). Agroecology and the emergence of a post COVID-19 agriculture. *Agriculture and Human Values*, 1–2.

Andrew, R. C., Malekian, R., & Bogatinoska, D. C. (2018, May). IoT solutions for precision agriculture. In *2018 41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)* (pp. 0345-0349). IEEE. 10.23919/MIPRO.2018.8400066

Anil, A., Thampi, A. R., John, M. P., & Shanthi, K. J. (2012, December). Project HARITHA-an automated irrigation system for home gardens. In *2012 Annual IEEE India Conference (INDICON)* (pp. 635-639). IEEE. 10.1109/INDCON.2012.6420695

Anonymous. (1995). Zirai Mücadele Teknik Talimatları. Cilt III. T.C. Tarım ve Orman Bakanlığı, Koruma Kontrol Genel Müdürlüğü, Ankara.

Anonymous. (2000). *Pessl Instruments. Product page on Metos.* Retrieved from https://www.metos.at/download.html

Anonymous. (2008). Zirai Mücadele Teknik Talimatı. Cilt V. Ankara, Turkey: T.C. Tarım ve Orman Bakanlığı, Koruma Kontrol Genel Müdürlüğü, Ankara.

Anonymous. (2011). *Integrated Pest Management on ERMES.* Retrieved from http://www.ermesagricoltura.it

Anonymous. (2014). *Alternative pest control methods for agricultural use.* Retrieved from http://education-portal.com/academy/lesson/alternative-pest-control-methods-for-agricultural-use.html#lesson

Anonymous. (2019a). *Adcon Telemetry applications agriculture*. Retrieved from https://www.adcon.com/

Anonymous. (2019b). *Bitki koruma ürünleri veri tabanı*. Tarım ve Orman Bakanlığı. Retrieved from https://bku.tarim.gov.tr/

Antioquia, A. M. C., Tan, D. S., Azcarraga, A., Cheng, W. H., & Hua, K. L. (2018, December). ZipNet: ZFNet-level Accuracy with 48× Fewer Parameters. In 2018 IEEE Visual Communications and Image Processing (VCIP) (pp. 1-4). IEEE.

Araby, A. A., Elhameed, M. M. A., Magdy, N. M., Abdelaal, N., Allah, Y. T. A., Darweesh, M. S., . . . Mostafa, H. (2019, May). Smart IoT Monitoring System for Agriculture with Predictive Analysis. In *2019 8th International Conference on Modern Circuits and Systems Technologies (MOCAST)* (pp. 1-4). IEEE.

Arad, B. S. (2020, May). Development of a Sweet Pepper Harvesting Robot. *Journal of Field Robotics*, 1–13. http://www.sweeper-robot.eu/

Arif, C., Mizoguchi, M., Setiawan, B. I., & Doi, R. (2012). Estimation of soil moisture in paddy field using Artificial Neural Networks. *International Journal of Advanced Research in Artificial Intelligence.*, *1*(1), 17–21. doi:10.14569/IJARAI.2012.010104

Aubert, B. A., Schroeder, A., & Grimaudo, J. (2012). IT as an enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. *Decision Support Systems*, *54*(1), 510–520. doi:10.1016/j.dss.2012.07.002

Ayaz, M., Ammad-Uddin, M., Sharif, Z., Mansour, A., & Aggoune, E.-H. M. (2019). Internet-of-Things (IoT)-Based Smart Agriculture: Toward Making the Fields Talk. *IEEE Access: Practical Innovations, Open Solutions*, *7*, 129551–129583. doi:10.1109/ACCESS.2019.2932609

Aydar, A., Sabahoğlu, Y., Cevdet, Z., & Mesut, İ. (2010). Elma bahçelerinde Elma içkurdu Cydia pomonella (L.)(Lepidoptera: Tortricidae) mücadelesinde yardımcı hava akımlı hidrolik bahçe pülverizatörünün biyolojik performansının belirlenmesi. *Bitki Koruma Bulteni*, *50*(2), 51–63.

Azfar, S., Nadeem, A., & Basit, A. (2015). Pest detection and control techniques using wireless sensor network: A review. *Journal of Entomology and Zoology Studies*, *3*(2), 92–99.

Babu, V. S., Kumar, U. A., Priyadharshini, R., Premkumar, K., & Nithin, S. (2016). An intelligent controller for smart home. In *Proceedings of international conference on advances in computing, communications and informatics (ICACCI)* (pp. 2654–2657). IEEE.

Bacco, Berton, & Ferro. (2018). *Smart Farming: Opportunities, Challenges, and Technology Enablers*. IEEE Explore.

Bacco, M., Barsocchi, P., Ferro, E., Gotta, A., & Ruggeri, M. (2019). The Digitisation of Agriculture: A Survey of Research Activities on Smart Farming. *Array*, *3*, 100009. doi:10.1016/j.array.2019.100009

Bacco, M., Berton, A., Gotta, A., & Caviglione, L. (2018). IEEE 802.15.4 Air-Ground UAV Communications in Smart Farming Scenarios. *IEEE Communications Letters*, *22*(9), 1910–1913. doi:10.1109/LCOMM.2018.2855211

Bagchi, A. (2000). *Artificial Intelligence in Agriculture*. MindTree.

Baggio, A. (2005). *Wireless sensor networks in precision agriculture*, Paper presented at the ACM Workshop on Real-World Wireless Sensor Networks, Stockholm, Sweden.

Baggio, A. (2005). Wireless sensor networks in precision agriculture. *The REALWSN'05 Workshop on Real-World Wireless Sensor Networks*, 1-2.

Baker, A. (2019). *How were Steam Engines used in agriculture?* Available: https://www.bressingham.co.uk/blog/posts/2014/how-were-steam-engines-used-in-agriculture.aspx

Balakrishna, K. (2020). Fusion Approach-Based Horticulture Plant Diseases Identification Using Image Processing. In S. Chakraborty & K. Mali (Eds.), Applications of Advanced Machine Intelligence in Computer Vision and Object Recognition: Emerging Research and Opportunities (pp. 119–132). IGI Global. doi:10.4018/978-1-7998-2736-8.ch005 doi:10.4018/978-1-7998-2736-8.ch005

Balakrishna, K. (2020). WSN-Based Information Dissemination for Optimizing Irrigation Through Prescriptive Farming. International Journal of Agricultural and Environmental Information Systems, 11(4), 41–54. doi:10.4018/IJAEIS.2020100103 doi:10.4018/IJAEIS.2020100103

Balakrishna, K., & Rao, M. (2019). Tomato Plant Leaves Disease Classification Using KNN and PNN. International Journal of Computer Vision and Image Processing, 9(1), 51–63. doi:10.4018/IJCVIP.2019010104 doi:10.4018/IJCVIP.2019010104

Balakrishna, K., Nethravathi, S.N., & Krishna, H. (2016). Real-Time Soil Monitoring System for the Application of Agriculture. *International Journal of Engineering Science and Computing*, *5326*. https://ijesc.org/

Balakrishna, Rao, & Kumar. (2018). A WSN Application to Optimize the Irrigation for Horticulture Crops in Real-time using Climatic Parameters. *Elsevier Scopus Journal of Advanced Research in Dynamic and Control Systems, 10*(12), 199-207.

Balas, E. (1965). An additive algorithm for solving linear programs with zero-one variables. *Operations Research*, *13*(4), 518–545. doi:10.1287/opre.13.4.517

Baldassari, P., & Roux, J. D. (2017). Industry 4.0: Preparing for the future of work. *People Strateg.*, *40*(3), 20–23.

Baliga, J., Ayre, R., Hinton, K., & Tucker, R. (2011). Energy consumption in wired and wireless access networks. *IEEE Communications Magazine*, *49*(6), 70–77. doi:10.1109/MCOM.2011.5783987

Ballester, P., & Araujo, R. M. (2016, February). On the performance of GoogLeNet and AlexNet applied to sketches. *Thirtieth AAAI Conference on Artificial Intelligence*.

Banhazi, T. M., Lehr, H., Black, J. L., Crabtree, H., Schofield, P., Tscharke, M., & Berckmans, D. (2012). Precision livestock farming: An international review of scientific and commercial aspects. *International Journal of Agricultural and Biological Engineering*, *5*(3), 1–9.

Banu S., (2015). Precision Agriculture: Tomorrow's Technology for Today's Farmer. *J Food Processing and Technology, 6*(8), 1-6.

Baogang, Y. (2006). Development of Agricultural Mechanization and Modern Agriculture. *Nongye Jixie Xuebao*, 1.

Barbedo, J. G. A., Koenigkan, L. V., & Santos, T. T. (2016). Identifying multiple plant diseases using digital image processing. *Biosystems Engineering*, *147*, 104–116. doi:10.1016/j.biosystemseng.2016.03.012

Bargoti, S., & Underwood, J. (2017). Deep Fruit Detection in Orchards. *IEEE International Conference on Robotics and Automation (ICRA)*, 3626–3633. 10.1109/ICRA.2017.7989417

Bechar, A., & Vigneault, C. (2017). Agricultural robots for field operations. Part 2: Operations and system. *Biosystems Engineering*, *153*, 110–128. doi:10.1016/j.biosystemseng.2016.11.004

Beckwith, R., Teibel, D., & Bowen, P. (2004). *Report from the field: results from an agricultural wireless sensor network*. Paper presented at the 29th Annual IEEE International Conference on Local Computer Networks, Tampa, FL. 10.1109/LCN.2004.105

Bekhti, M., Achir, N., Boussetta, K., & Abdennebi, M. (2017). Drone Package Delivery: A Heuristic approach for UAVs path planning and tracking. *EAI Endorsed Transactions on Internet of Things*, *3*(9), 1–12. doi:10.4108/eai.31-8-2017.153048

Bellmore, M., & Nemhauser, G. L. (1968). The Traveling Salesman Problem: A Survey. *Operations Research*, *16*(3), 538–558. doi:10.1287/opre.16.3.538

Benke, K., & Tomkins, B. (2017). Future food-production systems: vertical farming and controlled-environment agriculture. *Sustainability: Science*. *Practice and Policy*, *13*(1), 13–26.

Bera, S., Member, G. S., Misra, S., & Member, S. (2016). Soft-WSN : Software-Defined WSN Management System for IoT Applications. *IEEE Systems Journal*, *12*(3), 1–8.

Berry, J. (1996). *Mathematics learning and assesment: sharing innovative practices*. Arnold.

Bezanson, J., Edelman, A., Karpinski, S., & Shah, V. B. (2017). Julia: A Fresh Approach to Numerical Computing. *SIAM Review*, *59*(1), 65–98. doi:10.1137/141000671

Binswanger, H. (1986). Agricultural mechanization: A comparative historical perspective. *The World Bank Research Observer*, *1*(1), 27–56. doi:10.1093/wbro/1.1.27

Biradar, H. B., & Shabadi, L. (2017, May). Review on IOT based multidisciplinary models for smart farming. In *2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)* (pp. 1923-1926). IEEE. 10.1109/RTEICT.2017.8256932

Birgücü, A. K., & Karsavuran, Y. (2009). Degree-days models and possibilities of usage in plant protection. *Anadolu*, *19*(2), 98–117.

Blanco-Novoa, Ó., Fernández-Caramés, T. M., Fraga-Lamas, P., & Castedo, L. (2017). An electricity price-aware open-source smart socket for the internet of energy. *Sensors (Basel)*, *17*(3), 643. doi:10.339017030643 PMID:28335568

Boissard, P., Martin, V., & Moisan, S. (2008). A cognitive vision approach to early pest detection in greenhouse crops. *Computers and Electronics in Agriculture*, *62*(2), 81–93. doi:10.1016/j.compag.2007.11.009

Boserup, E. (2017). The conditions of agricultural growth: The economics of agrarian change under population pressure. Routledge, Taylor & Francis Group. doi:10.4324/9781315131450

Bouti, A., Mahraz, M. A., Riffi, J., & Tairi, H. (2019). A robust system for road sign detection and classification using LeNet architecture based on convolutional neural network. *Soft Computing*, 1–13. doi:10.100700500-019-04307-6

Brain, C.K. (1924). Preliminary note on the adaptation of certain radio principles to insect investigation work. *Annual of University Stellenbosch Ser., A2*, 45-47.

Brandhorst-Hubbard, J. L., Flanders, K. L., Mankin, R. W., Guertal, E. A., & Crocker, R. L. (2001). Mapping of soil insect infestations sampled by excavation and acoustic methods. *Journal of Economic Entomology*, *94*(6), 1452–1458. doi:10.1603/0022-0493-94.6.1452 PMID:11777048

BrelieH. (2020, June 26). *Euronews*. Retrieved from https://www.euronews.com/2020/04/17/french-farm-producers-suffer-during-the-covid-19-restrictions

Brouwer, C., & Heibloem, M. (1986). *Crop water needs*. Irrigation Water Management. http://www.fao.org/3/s2022e/s2022e02.htm

Brynjolfsson, A., & McAfee, E. (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*. W.W. Norton & Company.

Burrell, J., Brooke, T., & Beckwith, R. (2004). Vineyard computing: Sensor networks in agriculture production. *IEEE Pervasive Computing*, *3*(1), 38–45. doi:10.1109/MPRV.2004.1269130

Burwood-Taylor, L. (2017). *What is AgriFood Tech?* Academic Press.

Caivano, D., Fogli, D., Lanzilotti, R., Piccinno, A., & Cassano, F. (2018). Supporting end users to control their smart home: Design implications from a literature review and an empirical investigation. *Journal of Systems and Software*, *144*, 295–313. doi:10.1016/j.jss.2018.06.035

Caja, C., Castro-Costa, A., & Knight, C. H. (2016). Engineering to support the well-being of dairy animals. *The Journal of Dairy Research*, *83*(2), 136–147. doi:10.1017/S0022029916000261 PMID:27210489

Cambra, C., Sendra, S., Lloret, J., & Garcia, L. (2017, May). An IoT service-oriented system for agriculture monitoring. In *2017 IEEE International Conference on Communications (ICC)* (pp. 1-6). IEEE. 10.1109/ICC.2017.7996640

Carolan, M. (2020). Automated agrifood futures: Robotics, labor and the distributive politics of digital agriculture. *The Journal of Peasant Studies*, *47*(1), 184–207. doi:10.1080/03066150.2019.1584189

Casas, O., López, M., Quílez, M., Martinez-Farre, X., Hornero, G., Rovira, C., Pinilla, M. R., Ramos, P. M., Borges, B., Marques, H., & Girão, P. S. (2014). Wireless sensor network for smart composting monitoring and control. *Measurement*, *47*, 483–495. doi:10.1016/j.measurement.2013.09.026

Chandra. (2017). *How data-driven farming could transform agriculture*. https://www.youtube.com/watch?v=dpVylFjT-Cw&feature=youtu.be

Chen, T., & Meng, F. (n.d.). Development and Performance Test of a Height Adaptive Pesticide Spraying System. *IEEE Access*, 12342-12350.

Chen, S. W., Shivakumar, S. S., Dcunha, S., Das, J., Okon, E., Qu, C., Taylor, C. J., & Kumar, V. (2017). Counting Apples and Oranges with Deep Learning: A Data-Driven Approach. *IEEE Robotics and Automation Letters*, *2*(2), 781–788. doi:10.1109/LRA.2017.2651944

Chester, R. (2017). *The future of food safety: the revolution is on our doorsteps*. Available: https://www.newfoodmagazine.com/article/41390/future-food-safety-revolution-doorsteps/

Chieochan, O., Saokaew, A., & Boonchieng, E. (2017). IoT for smart farm: A case study of the lingzhi mushroom farm at maejo university. *14th International Joint Conference on Computer Science and Software Engineering (JCSSE)*, 1–6. 10.1109/JCSSE.2017.8025904

Chokkareddy, R., Thondavada, N., Thakur, S., & Kanchi, S. (2019). Recent Trends in Sensors for Health and Agricultural Applications. In *Advanced Biosensors for Health Care Applications*. Elsevier Inc. doi:10.1016/B978-0-12-815743-5.00013-5

Composite Water Management Index. (2018). *NITI Aayog*. Retrieved from http://pibphoto.nic.in/documents/rlink/2018/jun/p201861401.pdf

Corallo, A., Latino, M. E., & Menegoli, M. (2018). From Industry 4.0 to Agriculture 4.0: A Framework to Manage Product Data in Agri-Food Supply Chain for Voluntary Traceability. *Int. J. Nutr. Food Eng.*, *12*(5), 146–150.

Costa, F., Ueyama, J., Braun, T., Pessin, G., Osorio, F., & Vargas, P. (2012). The use of unmanned aerial vehicles and wireless sensor network in agricultural applications. *IEEE conference on Geoscience and Remote Sensing Symposium (IGARSS-2012)*, 5045–5048. 10.1109/IGARSS.2012.6352477

Creating a Sustainable Food Future. (n.d.). World Resources Report 2013–14: Interim Findings.

Croes, G. (1958). A Method for Solving Travelling-Salesman Problems. *Operations Research*, *6*(6), 791–812. doi:10.1287/opre.6.6.791

Cropx. (2017). Available: https://cropx.com/

Cugati, S., Miller, W., & Schueller, J. (2003). *Automation concepts for the variable rate fertilizer applicator for tree farming*. Paper presented at the 4th European Conference in Precision Agriculture, Berlin, Germany.

Damalas, C. A., Georgiou, E. B., & Theodorou, M. G. (2006). Pesticide use and safety practices among Greek tobacco farmers: A survey. *International Journal of Environmental Health Research*, *16*(5), 339–348. doi:10.1080/09603120600869190 PMID:16990175

Dan, L., Xin, C., Chongwei, H., & Liangliang, J. (2015). Intelligent agriculture greenhouse environment monitoring system based on IoT technology. *International Conference on Intelligent Transportation, Big Data and Smart City*, 487–490. 10.1109/ICITBS.2015.126

Datta. (2019). *Smart Farming is the Future of Agriculture*. Academic Press.

De Clercq, M., Vats, A., & Biel, A. (2018). Agriculture 4.0: The future of farming technology. *Proceedings of the World Government Summit,* 11-13.

Deeksha Jain, Krishna, & Saritha. (2012). *A Study on Internet of Things based Applications*. Academic Press.

Deichmann, U., Goyal, A., & Mishra, D. (2016). *Will digital technologies transform agriculture in developing countries?* The World Bank. doi:10.1596/1813-9450-7669

dela Cruz, J. R., Baldovino, R. G., Bandala, A. A., & Dadios, E. P. (2017). Water usage optimization of Smart Farm Automated Irrigation System using artificial neural network. *2017 5th International Conference on Information and Communication Technology (ICoIC7)*, 1-5. doi:10.1109/ICoICT.2017.807466810.1109/ICoICT.2017.8074668

Demirel, M., Kılınç, G., & Kumral, N. A. (2018, September). Görüntü İşleme ve Sensör Destekli Akıllı Tarımsal Mücadele Sistemi (GÖRSENTAM)'nin Zeytin Pamuklu Biti Mücadelesinde Kullanım Olanakları. In 5. Ulusal Tarım Kongresi (p. 5). Academic Press.

Dent, D. R., Elliott, N. C., Farrell, J. A., Gutierrez, A. P., van Lenteren, J. C., Walton, M. P., & Wratten, S. (1995). *Integrated pest management*. Chapman and Hall.

DePuy, G. W., Moraga, R. J., & Whitehouse, G. E. (2005). Meta - RaPS: A simple and effective approach for solving the traveling salesman problem. *Transportation Research Part E, Logistics and Transportation Review*, *41*(2), 115–130. doi:10.1016/j.tre.2004.02.001

Desa, U. (2017). *Population division*. World Population Prospects.

Devi & Kumari. (2013). Real-Time Automation and Monitoring System for Modernized Agriculture. *International Journal of Review and Research in Applied Sciences and Engineering, 3*(1), 7-12.

Dewi, C., & Chen, R. C. (2019, April). Decision making based on IoT data collection for precision agriculture. In *Asian Conference on Intelligent Information and Database Systems* (pp. 31-42). Springer.

Diao, Z., Diao, C., & Wu, Y. (2017). Algorithm of Wheat Disease Identification in the Spraying Robot System. *9th International Conference on Intelligent Human-Machine Systems and Cybernetics (IHMSC)*, 316 – 319. 10.1109/IHMSC.2017.183

Diedrichs. (2014). Low-Power Wireless Sensor Network for Frost Monitoring in Agriculture Research. IEEE.

Digital agriculture: helping to feed a growing world. (2019). Retrieved from https://consulting.ey.com/digital-agriculture-helping-to-feed-a-growing-world/

Dongoski, A. (2019). *Digital Agriculture and Big Data*. Available: https://consulting.ey.com/digital-agriculture-helping-to-feed-a-growing-world/

Doshi, H. S., Shah, M. S., & Shaikh, U. S. A. (2017). Internet Of Things (IoT): Integration of Blynk for Domestic Usability. *Vishwakarma Journal of Engineering Research*, *1*(4), 149–157.

Dumbre, N., Chikane, O., Gitesh, D., & Phule, S. (2015). System for Agriculture Recommendation Using Data Mining. Internal Education and Research Journal, 1(1).

Dunning, I., Huchette, J., & Lubin, M. (2017). JuMP: A Modeling Language for Mathematical Optimization. *SIAM Review*, *59*(2), 295–320. doi:10.1137/15M1020575

Dutta & Neogy. (2016). Enabling agricultural automation to optimize utilization of water, fertilizer and insecticides by implementing internet of things (IoT). *International Conference on Information Technology (InCITe) - The Next Generation IT Summit on the Theme - Internet of Things: Connect your Worlds*, 125–131.

Dwivedy, N. (2011). Challenges faced by the Agriculture Sector in Developing Countries with special reference to India. *International Journal of Rural Studies*, *18*(2), 2–7.

Easton, K. M., Carrodus, G., Delaney, T., Howitt, B., Smith, R., Butler, H., & McArthur. (2014). Oxford big ideas geography. Oxford University Press.

Eaton, R., Katupitiya, J., Siew, K. W., & Dang, K. S. (2008, April). Precision guidance of agricultural tractors for autonomous farming. In *2008 2nd annual IEEE systems conference* (pp. 1-8). IEEE. 10.1109/SYSTEMS.2008.4519026

Edan, Y., Han, S., & Kondo, N. (2009). Automation in agriculture. In *Springer handbook of automation* (pp. 1095–1128). Springer. doi:10.1007/978-3-540-78831-7_63

Eigen Technologies. (2013). *MeshFarm- smart agriculture.* https://www.eigen.in/Meshfarm

Eisenbeiss, H. (2004). A mini unmanned aerial vehicle (UAV): system overview and image acquisition. International Archives of Photogrammetry. *Remote Sensing and Spatial Information Sciences, 36*(5).

Elijah, O., Rahman, T. A., Orikumhi, I., Leow, C. Y., & Hindia, M. H. D. N. (2018). An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges. *IEEE Internet of Things Journal*, *5*(5), 3758–3773. doi:10.1109/JIOT.2018.2844296

Eliopoulos, P. A., Potamitis, I., Kontodimas, D. C., & Givropoulou, E. G. (2015). Detection of adult beetles inside the stored wheat mass based on their acoustic emissions. *Journal of Economic Entomology*, *108*(6), 2808–2814. doi:10.1093/jee/tov231 PMID:26470377

El-Sawy, A., Hazem, E. B., & Loey, M. (2016, October). CNN for handwritten arabic digits recognition based on LeNet-5. In *International conference on advanced intelligent systems and informatics* (pp. 566-575). Springer.

Erlich, Y. (2015). A vision for ubiquitous sequencing. *Genome Research,* 1411–1416.

Estadísticas del agua en. (2018). *Statistics of water in Mexico*. Available: http://sina.conagua.gob.mx/publicaciones/EAM_2018.pdf

Facello, A., & Cavallo, E. (2013, June). Insect remote detection in pheromones traps. In *EFITA-WCCACIGR Conference on Sustainable Agriculture through ICT Innovation* (pp. 1376-1383). Torino, Italy: Academic Press.

FAO (Food and Agricultural Organisation Of United Nations). (2014). *Coping with water scarcity in agriculture a global framework for action in a changing climate*. Retrieved from http://www.fao.org/3/a-i6459e.pdf

FAO. (2009). *Global agriculture towards 2050*. UN Food and Agriculture Organization.

FAO. (2014). *Food and Agriculture Organization, Pesticide consumption statistics.* Retrieved from http://www.fao.org/faostat/en/#home

FAO. (2014). *Information and communication technologies for sustainable agriculture: Indicators from Asia and the Pacific*. FAO.

FAO. (2015). *Success stories on information and communication technologies for agriculture and rural development.* Available: http://www.fao.org/3/a-i4622e.pdf

FAO. (2017). *The State of Food and Agriculture, Leveraging Food Systems for Inclusive Rural Transformation.* Available: https://www.fao.org/3/a-i7658e.pdf

FarmE. Z. (2017). Available: https://www-03.ibm.com/software/ usinesscasestudies/lb/en/corp?synkey=T869341Z93257N45

Farmlogs. (2017). Available: https://farmlogs.com/

Fernández-Caramés, T. M., Fraga-Lamas, P., Suárez-Albela, M., & Castedo, L. (2017). Reverse engineering and security evaluation of commercial tags for RFID-based IoT applications. *Sensors (Switzerland)*, *17*(1). Advance online publication. doi:10.339017010028 PMID:28029119

Ferrandez, S. (2016). Optimization of a truck-drone in tandem delivery network using k-means and genetic algorithm. *Journal of Industrial Engineering and Management*, *9*(2), 374–388. doi:10.3926/jiem.1929

ffrobotics. (2020, July 4). Retrieved from www.ffrobotics.com

Field, E. (2020, May 20). *The Traveling Salesman Problem (TSP).* Retrieved from https://www2.seas.gwu.edu/~simhaweb/champalg/tsp/tsp.html

Finney, C. (1996). The benefits of land leveling on irrigation schemes in Turkey and Sindh Province, Pakistan. *ICID Journal*, *45*(1), 21–37.

Fleurat-Lessard, F., Tomasini, B., Kostine, L., & Fuzeau, B. (2006). Acoustic detection and automatic identification of insect stages activity in grain bulks by noise spectra processing through classification algorithms. In *9th International Conference on Stored Product Protection* (pp. 476-786). Passo Fundo, RS, Brazil: Academic Press.

Flint, M. L., & Van den Bosch, R. (1981). *Introduction to integrated pest management*. Springer. doi:10.1007/978-1-4615-9212-9

Fountas, S., Carli, G., Sørensen, C. G., Tsiropoulos, Z., Cavalaris, C., Vatsanidou, A., Liakos, B., Canavari, M., Wiebensohn, J., & Tisserye, B. (2015). Farm management information systems: Current situation and future perspective. *Computers and Electronics in Agriculture*, *115*, 40–50. doi:10.1016/j.compag.2015.05.011

Fuentes, A., Yoon, S., Kim, S. C., & Park, D. S. (2017). A Robust Deep-Learning-Based Detector for Real-Time Tomato Plant Diseases and Pests Recognition. *Sensors (Basel)*, *17*(9), 2022. Advance online publication. doi:10.339017092022 PMID:28869539

Fukatsu, T., Watanabe, T., Hu, H., Yoichi, H., & Hirafuji, M. (2012). Field monitoring support system for the occurrence of Leptocorisa chinensis Dallas (Hemiptera: Alydidae) using synthetic attractants, Field Servers, and image analysis. *Computers and Electronics in Agriculture*, *80*, 8–16. doi:10.1016/j.compag.2011.10.005

Fu, L., Feng, Y., Majeed, Y., Zhang, X., Zhang, J., Karkee, M., & Zhang, Q. (2018). Kiwifruit detection in field images using Faster R-CNN with ZFNet. *IFAC-PapersOnLine*, *51*(17), 45–50. doi:10.1016/j.ifacol.2018.08.059

Gallardo, A., Ocete, R., Lopez, M. A., Maistrello, L., Ortega, F., Semedo, A., & Soria, F. J. (2009). Forecasting the flight activity of *Lobesia botrana* (Denis & Schiffermüller) (Lepidoptera, Tortricidae) in southwestern Spain. *Journal of Applied Entomology*, *133*(8), 626–632. doi:10.1111/j.1439-0418.2009.01417.x

García. (2020). IoT-Based Smart Irrigation Systems: An Overview on the Recent Trends on Sensors and Iot Systems for Irrigation in Precision Agriculture. Sensors, 20(4).

García-Lesta, D., Cabello, D., Ferro, E., López, P., & Brea, V. M. (2017). Wireless sensor network with perpetual motes for terrestrial snail activity monitoring. *IEEE Sensors Journal*, *17*(15), 5008–5015. doi:10.1109/JSEN.2017.2718107

Geng, H. (2017). *Data analytics and predictive analytics in the era of big data*. Wiley Telecom.

Ghadage, S. A., & Doshi, M. N. A. (2017, December). IoT based garbage management (Monitor and acknowledgment) system: A review. In *2017 International Conference on Intelligent Sustainable Systems (ICISS)* (pp. 642-644). IEEE. 10.1109/ISS1.2017.8389250

Ghassan, B., & Saman, Z. (2015). *Teaching Cyber-Physical Systems using MIT App Inventer2*. Paper presented at the 2nd International Conference on Education and Social Sciences, Istanbul, Turkey.

Ghosh, S., & Hingoliwala, H. A. (2016). Smart Irrigation : A Smart Drip Irrigation System Using Cloud, Android And Data Mining. *2016 IEEE International Conference on Advances in Electronics, Communication and Computer Technology (ICAECCT)*, 236–239. 10.1109/ICAECCT.2016.7942589

Giblin-Davis, R.M., Faleiro, J.R., Jacas, J.A., Peña, J.E., & Vidyasagar, P.S.P.V. (2013). Biology and management of the red palm weevil, *Rhynchophorus ferrugineus. Potential Invasive Pests of Agricultural Crops,* 1-34.

Gobhinath, S., Darshini, M., Durga, K., & Priyanga, R. (2019). Smart irrigation with field protection and crop health monitoring system using autonomous rover. *IEEE 5th International Conference on Advanced Computing & Communication Systems*. 10.1109/ICACCS.2019.8728468

Gökdoğan, A., & Tarım, G. (2015). Türkiye'de Süne ile Mücadelenin Tarihsel Gelişimi. *Dört Öge*, *7*, 33–46.

Gondchawar, N., & Kawitkar, R. S. (2016). IoT based smart agriculture. *International Journal of Advanced Research in Computer and Communication Engineering*, *5*(6), 838–842.

Government of Agriculture. (2013). State of Indian Agriculture 2012-13. Ministry of Agriculture Department of Agriculture & Cooperation New Delhi.

Grassi, M. J. (2018). *Driverless Tractor Automation*. Available: https://www.precisionag.com/in-field-technologies/smart-ag-announces-driverless-tractor-automation-platform/

Gregorioa, G. B., & Ancog, R. C. (2020). Assessing the Impact of the COVID-19 Pandemic on Agricultural Production in Southeast Asia: Toward Transformative Change in Agricultural Food Systems. *Asian Journal of Agriculture and Development, 17*, 1-13.

Grenzdörffer, G. J., Engel, A., & Teichert, B. (2008). The photogrammetric potential of low-cost UAVs in forestry and agriculture. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *31*(B3), 1207–1214.

Grocery Manufacturers Association. (2011). *Capturing Recall Costs: Measuring and Recovering the Losses.* Available: https://www.gmaonline.org/file-manager/ images/gmapublications/Capturing_Recall_Costs_GMA_Whitepaper_FINAL.pdf

Guo, X., Shen, Z., Zhang, Y., & Wu, T. (2019). Review on the application of artificial intelligence in smart homes. *Smart Cities*, *2*(3), 402–420. doi:10.3390martcities2030025

Gürses A., Altay M., Tüzün Ş., Erkam B., Gürkan S., Sezer S. & Akın M. (1985). *Marmara Bölgesi Elma Zararlılarına Karşı Tüm Savaşım Olanakları Üzerine Araştırmalar.* Project grant no: A.107015.

Gutiérrez, Villa-Medina, Nieto-Garibay, & Porta-Gándara. (2013). Automated Irrigation System Using a Wireless Sensor Network and GPRS Module. *IEEE Transactions on Instrumentation and Measurement*.

Gutiérrez, J., Medina, J. F. V., Garibay, A. N., & Gándara, M. A. P. (2014). Automated irrigation system using a wireless sensor network and GPRS module. *IEEE Transactions on Instrumentation and Measurement*, *63*(1), 1–11. doi:10.1109/TIM.2013.2276487

Güzey, A. (2020). Smart Agriculture with Autonomous Ground and Air Vehicles: An Application on to Harvest Optimization. *Ankara Hacý Bayram Veli Ьniversitesi Эktisadi ve Эdari Bilimler Fakültesi Dergisi*, *20th International Symposium on Econometrics, Operations Research and Statistics EYI 2020*, 207-220.

Hajjaj, S., & Sahari, K. (2016). Review of agriculture robotics: Practicality and feasibility. *IEEE International Symposium on Robotics and Intelligent Sensors (IRIS).* 10.1109/IRIS.2016.8066090

Hamish, Brown, Huth, Holzworth, Teixeira, Zyskowski, Hargreaves, & Moot. (2014). Plant modeling framework: Software for building and running crop models on the APSIM platform. Journal Environmental Modeling and Software, 385-398.

Hampannavar, K., Bhajantri, V., & Totad, S. (2018). Prediction of crop fertilizer consumption. *IEEE Fourth International Conference on Computing Communication Control and Automation (ICCUBEA).* 10.1109/ICCUBEA.2018.8697827

Hamshere, P., Sheng, Y., Moir, B., Gunning-Trant, C., & Mobsby, D. (2014). *What India wants: Analysis of India's food demand to 2050*. Retrieved from https://www.agriculture.gov.au/SiteCollectionDocuments/abares/publications/AnalysisIndiaFoodDemandTo2050_v.1.0.0.pdf

Hancock, G., Ovenden, M., Sharma, K., Walter, W., Gibson, A., & Wells, T. (2020). Soil erosion- The impact of grazing and regrowth trees. In *Geoderma* (Vol. 361). Elsevier. doi:10.1016/j.geoderma.2019.114102

Harvey, C. A., Rakotobe, Z. L., Rao, N. S., Dave, R., Razafimahatratra, H., Rabarijohn, R. H., Rajaofara, H., & Mackinnon, J. L. (2014). Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *369*(1639), 20130089. doi:10.1098/rstb.2013.0089 PMID:24535397

Hassanien, R. H. E., Li, M., & Dong Lin, W. (2016). Advanced applications of solar energy in agricultural greenhouses. *Renewable & Sustainable Energy Reviews*, *54*, 989–1001. doi:10.1016/j.rser.2015.10.095

Hassan, Q. (2018). *Introduction to Internet of Things*. Wiley-IEEE Press. doi:10.1002/9781119456735

Hayden. (nd.). *What Does "Data-Driven Farming" Mean?* https://blog.heatspring.com/what-does-data-driven-farming-mean/(2015)

Heble, S. (2018). A Low Power IoT Network for Smart Agriculture. *IEEE World Forum on Internet of Things, WF-IoT 2018 – Proceedings*, 609–14. 10.1109/WF-IoT.2018.8355152

Heikkila, A. (2017). *Innovative Agricultural Practices That Are Changing the World*. Available: https://www.innovationexcellence.com/blog/2018/08/06/5-innovative-agricultural-practices-that-are-changing-the-world/

Hillier, F. S. (1986). *Introduction To Operations Research*. Holden-Day,Inc.

Hinnell, A. C., Lazarovitch, N., Furman, A., Poulton, M., & Warrick, A. W. (2010). Neuro-drip: Estimation of subsurface wetting patterns for drip irrigation using neural networks. *Irrigation Science*, *28*(6), 535–544. doi:10.100700271-010-0214-8

Hooijdonk, R. (2020, June 26). Retrieved from Robotics Business Review: https://www.roboticsbusinessreview.com/agriculture/4-ways-robotics-change-agriculture-in-2019/

Hori, M. (2010). *Application of Cloud Computing to Agriculture and Prospects in Other Fields*. Retrieved from https://www.fujitsu.com/global/documents/about/resources/publications/fstj/archives/vol46-4/paper15.pdf

Horiea, T., & Yajimab, M. (1992). Yield forecasting. *Agricultural Systems*, *40*(1–3), 211–236. doi:10.1016/0308-521X(92)90022-G

Hossam, M., Kamal, M., Moawad, M., Maher, M., Salah, M., Abady, Y., Hesham, A., & Khattab, A. (2018, December). PLANTAE: an IoT-based predictive platform for precision agriculture. In *2018 International Japan-Africa Conference on Electronics, Communications and Computations (JAC-ECC)* (pp. 87-90). IEEE. 10.1109/JEC-ECC.2018.8679571

House of Commons Library. (2019). *Fourth industrial revolution*. Available: https://researchbriefings.files.parliament.uk/documents/CDP-2016-0153/CDP-2016-0153.pdf

How to Feed the World in 2050. (n.d.). Retrieved from http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

Huang, L., & Liu, P. (2014). *Key Technologies and Alogrithms' Application in Agricultural Food Supply Chain Tracking System in E-commerce*. Springer Berlin Heidelberg.

Huang, W., Guan, Q., Luo, J., Zhang, J., Zhao, J., Liang, D., & Zhang, D. (2014). New optimized spectral indices for identifying and monitoring winter wheat diseases. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *7*(6), 2516–2524. doi:10.1109/JSTARS.2013.2294961

Hudson, D., & Cohen, M. (2000). *Artificial Intelligence*. Wiley-IEEE Press.

Husin, Z. B., Shakaff, A. Y. B. M., Aziz, A. H. B. A., & Farook, R. B. S. M. (2012). Feasibility study on plant chili disease detection using image processing techniques. In *Third International Conference on Intelligent Systems Modelling and Simulation* (pp. 291-296). Kota Kinabalu, Malaysia. 10.1109/ISMS.2012.33

Hwang, J. S. (2016). *The fourth industrial revolution (industry 4.0): intelligent manufacturing*. SMT.

Iandola, F. N., Han, S., Moskewicz, M. W., Ashraf, K., Dally, W. J., & Keutzer, K. (2016). *SqueezeNet: AlexNet-level accuracy with 50x fewer parameters and< 0.5 MB model size.* arXiv preprint arXiv:1602.07360

Idbella, M., Iadaresta, M., Gagliarde, G., Mennella, A., Mazzoleni, S., & Bonanomi, G. (2020). AgriLogger: A New Wireless Sensor for Monitoring Agrometeorological Data in Areas Lacking Communication Networks. *Sensors (Basel)*, *20*(6).

ILO. (2020, June 26). Retrieved from International Labour Organization: https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_740893/lang--en/index.htm

Imam, S. A., Choudhary, A., & Sachan, V. K. (2015). Design issues for wireless sensor networks and smart humidity sensors for precision agriculture: A review. *International Conference on Soft Computing Techniques and Implementations (ICSCTI)*. 10.1109/ICSCTI.2015.7489591

India's Agricultural Exports Climb to Record High. (2014).Retrieved from https://www.fas.usda.gov/data/india-s-agricultural-exports-climb-record-high

InfrastructureA. (2011). Retrieved from https://business.mapsofindia.com/india budget/infrastructure/agriculture.html

Ingale, H. T., & Kasat, N. N. (2012). Automated irrigation system. *Int. J. Eng. Res. Dev.*, *4*(11), 51–54.

InsightCb. (2020, May 29). Retrieved from https://www.cbinsights.com/research/agriculture-farm-tech-startup-funding-trends/

Islam, A., Akter, K., Nipu, N. J., Das, A., Rahman, M. M., & Rahman, M. (2018, October). IoT Based Power Efficient Agro Field Monitoring and Irrigation Control System: An Empirical Implementation in Precision Agriculture. In *2018 International Conference on Innovations in Science, Engineering and Technology (ICISET)* (pp. 372-377). IEEE. 10.1109/ICISET.2018.8745605

Ivakhnenko, A. G., Ivakhnenko, A. G., Lapa, V. G., Lapa, V. G. & McDonough, R. N. (1967). *Cybernetics and Forecasting Techniques*. American Elsevier Publishing Company. https://books.google.co.in/books?id=rGFgAAAAMAAJ

Jacob, Prasanna, Sultana, & Helix. (2018). A Comparative Analysis on Smart Farming Techniques using Internet of Things (IoT). Academic Press.

Jagüey, J. G., Villa-Medina, J. F., López-Guzmán, A., & Porta-Gándara, M. Á. (2015). Smartphone irrigation sensor. *IEEE Sensors Journal*, *15*(9), 5122–5127. doi:10.1109/JSEN.2015.2435516

Jain, D., Venkata Krishna, P., & Saritha, V. (2012). A Study on Internet of Things based Applications. Academic Press.

Jaishetty, S. A., & Patil, R. (2016). IoT Sensor Network Based Approach for Agri-Cultural Field Monitoring and ConTrol. *International Journal of Research in Engineering and Technology*, *2*, 45–48.

Jawad, H. M. (2017). Energy-Efficient Wireless Sensor Networks for Precision Agriculture: A Review. Sensors, 17(8). doi:10.339017081781

Jeyalakshmi, S., & Radha, R. (2017). A Review on Diagnosis of Nutrient Deficiency Symptoms in plant leaf image using Digital Image Processing. *ICTACT Journal on Image and Video Processing*, *7*(4), 1515–1524. doi:10.21917/ijivp.2017.0216

Jha, K., Doshi, A., Patel, P., & Shah, M. (2019). Ä comprehensive review on automation in agriculture using artificial intelligence. *Artificial Intelligence in Agriculture*.

Jha, K., Doshi, A., Patel, P., & Shah, M. (2019). A comprehensive review on automation in agriculture using artificial intelligence. *Artificial Intelligence in Agriculture*, *2*, 1–12. doi:10.1016/j.aiia.2019.05.004

Jhuria, M., Kumar, A., & Borse, R. (2013). Image processing for smart farming: Detection of disease and fruit grading. In *IEEE Second International Conference on Image Information* (pp. 521-526). Jaypee, India 10.1109/ICIIP.2013.6707647

Jiménez, A. R., Ceres, R., & Pons, J. L. (2000). A survey of computer vision methods for locating fruit on trees. *Transactions of the ASAE. American Society of Agricultural Engineers*, *43*(6), 1911–1920. doi:10.13031/2013.3096

Jithin, D. V., Sharma, S., & Kaushik, A. (2019). Views of Irish Farmers on Smart Farming Technologies: An Observational Study. *AgriEngineering*, *1*(2), 164–187. doi:10.3390/agriengineering1020013

Jo, R. S., Lu, M., Raman, V., & Then, P. H. (2019, April). Design and Implementation of IoT-enabled Compost Monitoring System. In *2019 IEEE 9th Symposium on Computer Applications & Industrial Electronics (ISCAIE)* (pp. 23-28). IEEE.

Johnson, E. A. J. (1941). Economic History Association. *The Journal of Economic History*, 1941.

Jones, J. W., Tsuji, G. Y., Hoogenboom, G. J., Hunt, L. A., Thorton, P. K., Wilkens, P. W., Immamura, D. T., Bowen, W. T., & Singh, U. (1994). *Systems Approaches for Sustainable Agricultural Development: Decision support system for agrotechnology transfer: DSSAT v3*. Springer.

Jun, Y., Weiwei, C., Yu, L., Jinmin, H., Jiannan, D., & Wenjie, L. (2011). Grey relevant analysis and prediction on agriculture mechanization of china. *IEEE Fourth International Conference on Intelligent Computation Technology and Automation*. 10.1109/ICICTA.2011.315

KAA. (2017). Available: https: //www.kaaproject.org/agriculture/

Kaewmard & Saiyod. (2014). Sensor Data Collection and Irrigation Control on Vegetable Crop using Smart Phone and Wireless Sensor Networks for Smart Farm. IEEE.

Kailas, A., Cecchi, V., & Mukherjee, A. (2012). A survey of communications and networking technologies for energy management in buildings and home automation. *Journal of Computer Networks and Communications*, *2012*, 1–12. doi:10.1155/2012/932181

Kaloxylos, A., Eigenmann, R., Teye, F., Politopoulou, Z., Wolfert, S., Shrank, C., Dillinger, M., Lampropoulou, I., Antoniou, E., Pesonen, L., Nicole, H., Thomas, F., Alonistioti, N., & Kormentzas, G. (2012). Farm management systems and the future internet era. *Computers and Electronics in Agriculture*, *89*, 130–144. doi:10.1016/j.compag.2012.09.002

Kamilaris, A., Gao, F., & Prenafeta-bold, F. X. (2016). *Agri-IoT: A Semantic Framework for Internet of Things-enabled Smart Farming Applications*. doi:10.1109/WF-IoT.2016.7845467

Kamilaris, A., Fonts, A., & Prenafeta-Boldύ, F. X. (2019). The rise of blockchain technology in agriculture and food supply chains. *Trends in Food Science & Technology*, *91*, 640–652. doi:10.1016/j.tifs.2019.07.034

Kamilaris, A., & Prenafeta-Boldú, F. X. (2018). Deep learning in agriculture: A survey. *Computers and Electronics in Agriculture*, *147*(February), 70–90. doi:10.1016/j.compag.2018.02.016

Kamminga, H. (1995). The Science and Culture of Nutrition. Rodopi.

Kapoor, A., Bhat, S., Shidnal, S., & Mehra, A. (2016). Implementation of IoT and Image processing in smart agriculture. *International Conference on Computation System and Information Technology for Sustainable Solutions (CSITSS)*, 21-26. 10.1109/CSITSS.2016.7779434

Karim, Karim, & Frihidab. (2017). Monitoring system using web of things in precision agriculture. *Procedia Computer Science, 110*, 402–409.

Katariya, S. S., Gundal, S. S., Kanawade, M. T., & Mazhar, K. (2015). Automation in agriculture. *International Journal of Recent Scientific Research*, *6*(6), 4453–4456.

Katsigiannis, P., Misopolinos, L., Liakopoulos, V., Alexandridis, T. K., & Zalidis, G. (2016, June). An autonomous multi-sensor UAV system for reduced-input precision agriculture applications. In *2016 24th Mediterranean Conference on Control and Automation (MED)* (pp. 60-64). IEEE. 10.1109/MED.2016.7535938

Kaur, G., Tomar, P., & Singh, P. (2018). Design of cloud-based green IoT architecture for smart cities. In *Internet of Things and Big Data Analytics Toward Next-Generation Intelligence* (pp. 315–333). Springer. doi:10.1007/978-3-319-60435-0_13

Kavianand, G., Nivas, V. M., Kiruthika, R., & Lalitha, S. (2016). *Smart drip irrigation system for sustainable agriculture. In 2016 IEEE Technological Innovations in ICT for Agriculture and Rural Development*. TIAR.

Kendall, H., Naughton, P., Clark, B., Taylor, J., Li, Z., Zhao, C., Yang, G., Chen, J., & Frewer, L. J. (2017). Precision agriculture in China: Exploring awareness, understanding, attitudes and perceptions of agricultural experts and end-users in China. *Advances in Animal Biosciences*, *8*(2), 703–707. doi:10.1017/S2040470017001066

Kennedy, J. (1995). Particle swarm optimization. *IEEE International Conference on Neural Networks*, 4, 1942-1948. 10.1109/ICNN.1995.488968

Kerns, S. C., & Lee, J.-L. (2017). Automated Aeroponics System Using IoT for Smart Farming. *Proceedings of 8th International Scientific Forum, ISF 2017*, 104-110.

Keswani, B., Mohapatra, A. G., Mohanty, A., Khanna, A., Rodrigues, J. J., Gupta, D., & de Albuquerque, V. H. C. (2019). Adapting weather conditions based IoT enabled smart irrigation technique in precision agriculture mechanisms. *Neural Computing & Applications*, *31*(1), 277–292. doi:10.100700521-018-3737-1

Khattab, A. A., & Yelmarthi, K. (2016). Design and implementation of a cloud-based IoT scheme for precision agriculture. *28th International Conference on Microelectronics (ICM)*, 201–204. 10.1109/ICM.2016.7847850

Khirade, S. D., & Patil, A. B. (2015). Plant disease detection using image processing. In *2015 International conference on computing communication control and automation* (pp. 768-771). Pune, Maharashtra, India. 10.1109/ICCUBEA.2015.153

Kim & Jeong. (2015). *Experiences and Emerging Trends Related to ICT, Innovation, and Productivity in Korea, Knowledge Sharing Forum on Development Experiences: Comparative Experiences of Korea and Latin America and the Caribbean*. Academic Press.

Kimle, K. L. (2018). *Building an Ecosystem for Agtech Startups*. Academic Press.

Kim, M. K. (2018). Contactless Palmprint Identification Using the Pretrained VGGNet Model. *Journal of Korea Multimedia Society*, *21*(12), 1439–1447.

Kim, Y. J., Evans, R. G., & Iversen, W. M. (2008). Remote sensing and control of an irrigation system using a distributed wireless sensor network. *IEEE Transactions on Instrumentation and Measurement*, *57*(7), 1379–1387. doi:10.1109/TIM.2008.917198

Kim, Y., Evans, R., & Iversen, W. (2008). Remote Sensing and Control of an Irrigation System Using a Distributed Wireless Sensor Network. *IEEE Transactions on Instrumentation and Measurement*, 1379–1387.

Kingra, P. & Kaur, H. (2017). Microclimatic Modifications to Manage Extreme Weather Vulnerability and Climatic Risks in Crop Production. *Journal of Agricultural Physics*, *17*(1), 1–15.

Kıroğlu, H., Aykaç, K. M., Ergüder, M. T., Çamlıdere, R., Kılıç, M., & Çevik, T. (1992). Karadeniz Bölgesi elma bahçelerinde entegre savaş olanakları üzerine çalışmalar. *Zirai Mücadele Araştırma Enstitüsü Müdürlüğü Yayınları*, *21-22*, 44–46.

Kistler, L., Bieker, V. C., Martin, M. D., Pedersen, M. W., Madrigal, J. R., & Wales, N. (2020). *Smallholders, food security, and the Environment*. Academic Press.

Klerkx, L., Jakku, E., & Labarthe, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS Wageningen Journal of Life Sciences*, *90*, 100315.

Koçak, E. (2006). Süne mücadelesinde zamanlamanın önemi. *Türktarım*, *168*, 42–45.

Kodali, R. (2017). *A low cost smart irrigation system using MQTT protocol*. doi:10.1109/TENCONSpring.2017.8070095

Kodali, R. K., Jain, V., & Karagwal, S. (2016). IoT based smart greenhouse. IEEE Region 10 Humanitarian Technology Conference (R10-HTC), 1–6.

Kodali, R. K., Jain, V., & Karagwal, S. (2016). *IoT based smart greenhouse. In 2016 IEEE Region 10 Humanitarian Technology Conference (R10-HTC)*. IEEE.

Kodali, R. K., & Sahu, A. (2016). An IoT based soil moisture monitoring on Losant platform. *2nd International Conference on Contemporary Computing and Informatics*, 764–768. 10.1109/IC3I.2016.7918063

Kogan, M. (1998). Integrated pest management: Historical perspectives and contemporary developments. *Annual Review of Entomology*, *43*(1), 243–270. doi:10.1146/annurev.ento.43.1.243 PMID:9444752

Kolokotsa, D., Saridakis, G., Dalamagkidis, K., Dolianitis, S., & Kaliakatsos, I. (2010). Development of an intelligent indoor environment and energy management system for greenhouses. *Energy Conversion and Management*, *51*(1), 155–168. doi:10.1016/j.enconman.2009.09.007

Kopytko, V., Shevchuk, L., Yankovska, L., Semchuk, Z., & Strilchuk, R. (2018). Smart home and artificial intelligence as environment for the implementation of new technologies. *Traektoriâ Nauki = Path of Science,4*(9), 2007–2012.

Kozai, T., Niu, G., & Takagaki, M. (Eds.). (2019). *Plant factory: an indoor vertical farming system for efficient quality food production*. Academic Press.

Krishnan, A., Banga, K., & Mendez-Parra, M. (2020). *Disruptive technologies in agricultural value chains*. Academic Press.

Kukuta, A. (2016). *Can Digital farming Deliver on its Promise?* Available: http://www.agnewscenter.com/archives.cfm?news=9903

Kumar, G. (2014). Research paper on water irrigation by using wireless sensor network. *International Journal of Scientific Engineering and Technology*, 123–125.

Kumral, N. A., Kılınc, G., Selvi, A., Ozdemir, B. N., Unveren, B. E., Bozogulları, H. İ., Demirel, H., Balta, P., Pat, S., & Kocak, U. D. (2017). A survey study: pest problems and pest management strategies of farmers in Bursa province (Turkey). In *VIII International Scientific Agriculture Symposium," Agrosym 2017"* (pp. 1421-1426). Jahorina, Bosnia and Herzegovina: Academic Press.

Kumral, N. A., Kovanci, B., & Akbudak, B. (2005). Pheromone trap catches of the olive moth, *Prays oleae* (Bern.) (Lep., Plutellidae) in relation to olive phenology and degree-day models. *Journal of Applied Entomology*, *129*(7), 375–381. doi:10.1111/j.1439-0418.2005.00985.x

Kumral, N. A., Kovanci, B., & Akbudak, B. (2008). Using degree-day accumulations and host phenology for predicting larval emergence patterns of the olive psyllid, *Euphyllura phillyreae. Journal of Pest Science*, *81*(2), 63–69. doi:10.100710340-007-0185-6

Kunjumon, C., Nair, S., Rajan, D., Suresh, P., & Preetha, S. (2018). Survey on weather forecasting using data mining. *IEEE Conference on Emerging Devices and Smart Systems (ICEDSS)*. 10.1109/ICEDSS.2018.8544326

Kürklü, A., & Çağlayan, N. (2005). Sera otomasyon sistemlerinin geliştirilmesine yönelik bir çalışma. *Akdeniz Üniversitesi Ziraat Fakültesi Dergisi*, *18*(1), 25–34.

Kuruczleki, E., Pelle, A., Laczi, R., & Fekete, B. (2016). The Readiness of the European Union to Embrace the Fourth Industrial Revolution. *Manag.*, *11*(4), 2016.

Kwok, J., & Sun, Y. (2018). A smart IoT-based irrigation system with automated plant recognition using deep learning. *ACM International Conference Proceeding Series*, 87–91. 10.1145/3177457.3177506

Kýlavuz, E. (2019). Dünyada Tarim 4.0 Uygulamalari Ve Türk Tariminin Dönüºümü. *Social Sciences, 14*(4), 133-157.

Lakhiar, I. A., Jianmin, G., Syed, T. N., Chandio, F. A., Buttar, N. A., & Qureshi, W. A. (2018). Monitoring and Control Systems in Agriculture Using Intelligent Sensor Techniques: A Review of the Aeroponic System. *Journal of Sensors*, *2018*, 2018. doi:10.1155/2018/8672769

Laksiri, H. G. C. R., Dharmagunawardhana, H. A. C., & Wijayakulasooriya, J. V. (2019). Design and Optimization of IoT Based Smart Irrigation System in Sri Lanka. *2019 14th Conference on Industrial and Information Systems (ICIIS)*, 198-202.

Lamborelle, A. (2020). *Farming 4.0: The Future of Agriculture*. Retrieved from https://www.euractiv.com/section/agriculture-food/infographic/farming-4-0-the-future-of-agriculture/

Land, A., & Doig, A. G. (1960). An Automatic Method of Solving Discrete Programming Problems. *Econometrica*, *28*(3), 497–520. doi:10.2307/1910129

Larkin, R. P., & Fravel, D. R. (1998). Efficacy of various fungal and bacterial biocontrol organisms for control of Fusarium wilt of tomato. *Plant Disease*, *82*(9), 1022–1028. doi:10.1094/PDIS.1998.82.9.1022 PMID:30856829

Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, *6*(4), 239–242. doi:10.100712599-014-0334-4

Le Mouël, C., Lattre-Gasquet, D., & Mora, O. (2018). *Land use and food security in 2050: a narrow road*. Academic Press.

LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, *521*(7553), 436–444. doi:10.1038/nature14539 PMID:26017442

Lee, C. H., & Jhang, J. H. (2019). System design for the internet of things assisted urban aquaponics farming. *2019 IEEE 8th Global Conference on Consumer Electronics, GCCE 2019*, 986–987. 10.1109/GCCE46687.2019.9015214

Lee, J. (2017). The Fourth Industrial Revolution and Future Agriculture (2nd ed.). Science and Technology Policy Institute.

Lee, H., Moon, A., Moon, K., & Lee, Y. (2017). Disease and pest prediction IoT system in orchard: A preliminary study. *Ninth International Conference on Ubiquitous and Future Networks (ICUFN)*, 525–527. 10.1109/ICUFN.2017.7993840

Lee, W. S., Alchanatis, V., Yang, C., Hirafuji, M., Moshou, D., & Li, C. (2010). Sensing technologies for precision specialty crop production. *Computers and Electronics in Agriculture*, *74*(1), 2–33. doi:10.1016/j.compag.2010.08.005

Lele, U., & Goswami, S. (2017). The fourth industrial revolution, agricultural and rural innovation, and implications for public policy and investments: A case of India. *Agricultural Economics*, *48*(S1), 87–100. doi:10.1111/agec.12388

Lerdsuwan, P., & Phunchongharn, P. (2017). An energy-efficient transmission framework for IoT monitoring systems in precision agriculture. In *International Conference on Information Science and Applications*. Springer. 10.1007/978-981-10-4154-9_82

Lesh, R., & Harel, G. (2003). Problem Solving, Modeling, and Local Conceptual Development. *Mathematical Thinking and Learning*, *5*(2-3), 157–189. doi:10.1080/10986065.2003.9679998

Leslie, P., Pearce, J. M., Harrap, R., & Daniel, S. (2012). The application of smartphone technology to economic and environmental analysis of building energy conservation strategies. *International Journal of Sustainable Energy*, *31*(5), 295–311. doi:10.1080/1478646X.2011.578746

Li, Zhang, Zhang, & Langfang. (2014). *A Design of the IOT Gateway for Agricultural Greenhouse*. Academic Press.

Liakos, K. G., Busato, P., Moshou, D., Pearson, S., & Bochtis, D. (2018). Machine learning in agriculture: A review. *Sensors (Basel)*, *18*(8), 2674. doi:10.339018082674 PMID:30110960

Liang, Y., Lu, X. S., Zhang, D. G., Liang, F., & Ren, Z. B. (2003). Study on the framework system of digital agriculture. *Chinese Geographical Science*, *13*(1), 15–19. doi:10.100711769-003-0078-4

Li, G., Hou, Y., & Wu, A. (2017). Fourth Industrial Revolution: Technological drivers, impacts and coping methods. *Chinese Geographical Science*, *27*(4), 626–637. doi:10.100711769-017-0890-x

Li, M., & Lin, H. J. (2015). Design and implementation of smart home control systems based on wireless sensor networks and power line communications. *IEEE Transactions on Industrial Electronics*, *62*(7), 4430–4442. doi:10.1109/TIE.2014.2379586

Lin, Y. P., Petway, J. R., Anthony, J., Mukhtar, H., Liao, S. W., Chou, C. F., & Ho, Y. F. (2017). Blockchain: The evolutionary next step for ICT e-agriculture. *Environments*, *4*(3), 50. doi:10.3390/environments4030050

Li, S. (2012). Application of the internet of things technology in precision agriculture irrigation systems. *IEEE International Conference on Computer Science and Service System*, 1009-1013. 10.1109/CSSS.2012.256

Litvinov, M., Moskovskiy, M., Pakhomov, I., & Smirnov, I. (2019). Interface and software for the system of automatic seeding of grain crops. *IEEE East-West Design & Test Symposium (EWDTS).* 10.1109/EWDTS.2019.8884425

Liu, W., Anguelov, D., Erhan, D., Szegedy, C., Reed, S., Fu, C. Y., & Berg, A. C. (2016). SSD: Single shot multibox detector. Lecture Notes in Computer Science, 9905, 21–37. doi:10.1007/978-3-319-46448-0_2

Liu, H., Meng, Z., & Cui, S. (2007). A wireless sensor network prototype for environmental monitoring in greenhouses. *2007 International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM 2007*, 2344–2347. 10.1109/WICOM.2007.584

Li, Y., Cheng, X., Cao, Y., Wang, D., & Yang, L. (2018). Smart choice for the smart grid: Narrowband internet of things (NB-IoT). *IEEE Internet of Things Journal*, *5*(3), 1505–1515. doi:10.1109/JIOT.2017.2781251

Llewellyn, D. (2018). Does global agriculture need another green revolution. *Engineering*, *4*(4), 449–451. doi:10.1016/j.eng.2018.07.017

MacQueen, J. (1967). *Some methods for classification and analysis of multivariate observations*. Academic Press.

Mainetti, L., Mele, F., Patrono, L., Simone, F., Stefanizzi, M. L., & Vergallo, R. (2013). An RFID-based tracing and tracking system for the fresh vegetables supply chain. *International Journal of Antennas and Propagation*, *2013*, 1–15. doi:10.1155/2013/531364

Ma, L., Feng, S., Reidsma, P., Qu, F., & Heerink, N. (2014). Identifying entry points to improve fertilizer use efficiency in Taihu Basin, China. *Land Use Policy*, *37*, 52–59. doi:10.1016/j.landusepol.2013.01.008

Malavade, V. N., & Akulwar, P. K. (2016). Role of IoT in agriculture. In *National Conference on Changing Technology and Rural Development CTRD* (pp. 56-57). Academic Press.

Manisha, B., & Hingoliwala, H. A. (2015). Smart Farming: Pomegranate Disease Detection Using Image Processing. *Procedia Computer Science*, *58*, 280–288. doi:10.1016/j.procs.2015.08.022

Mankin, R. W., Weaver, D. K., Grieshop, M., Larson, B., & Morrill, W. L. (2004). Acoustic system for insect detection in plant stems: Comparisons of *Cephus cinctus* in wheat and *Metamasius callizona* in bromeliads. *Journal of Agricultural and Urban Entomology*, *21*(4), 239–248.

Manoj Kumar, G., Samuel, D. V. K., & Sirohi, N. P. S. (2010). Decision support system for greenhouse seedling production. *Computers and Electronics in Agriculture*, *73*(2), 133–145. doi:10.1016/j.compag.2010.05.009

Martinelli, F., Scalenghe, R., Davino, S., Panno, S., Scuderi, G., Ruisi, P., & Davis, C. E. (2015). Advanced methods of plant disease detection. A review. *Agronomy for Sustainable Development*, *35*(1), 1–25. doi:10.100713593-014-0246-1

Math, R. K. M., & Dharwadkar, N. V. (2018, August). IoT Based low-cost weather station and monitoring system for precision agriculture in India. In *2018 2nd International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC) I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC), 2018 2nd International Conference on* (pp. 81-86). IEEE. 10.1109/I-SMAC.2018.8653749

Mat, I., Kassim, M. R. M., Harun, A. N., & Yusoff, I. M. (2016, October). IoT in precision agriculture applications using wireless moisture sensor network. In *2016 IEEE Conference on Open Systems (ICOS)* (pp. 24-29). IEEE. 10.1109/ICOS.2016.7881983

McKinion, J. M., & Lemmon, H. E. (1985). Expert systems for agriculture. *Computers and Electronics in Agriculture*, *1*(1), 31–40. doi:10.1016/0168-1699(85)90004-3

McMullen. (2017). *Smart Ag IoT Optimizes Growth in Plant Nursery*. Academic Press.

Mehta, P. (2012). Impending water crisis in India and comparing clean water standards among developing and developed nations. *Archives of Applied Science Research*, *4*(1), 497–507.

Meola. (2020). *Smart farming in 2020: How IoT sensors are creating a more efficient precision agriculture industry*. Academic Press.

Merriam-Webster. (2020). *Phenology*. https://www.merriam-webster.com/dictionary/phenology

Michael, K., McNamee, A., & Michael, M. G. (2006). The emerging ethics of humancentric GPS tracking and monitoring. *International Conference on Mobile Business, ICMB 2006*, 1–10. 10.1109/ICMB.2006.43

Microsoft News Center India. (2015, May). *Digital Agriculture: Farmers in India are using AI to increase crop yields.* https://news.microsoft.com/en-in/features/ai-agriculture-icrisat-upl-india/

Miguel, A. (1998). *Ecological impacts of industrial agriculture and the possibilities for truly sustainable farming*. Retrieved from http://ls-tlss.ucl.ac.uk/course-materials/BENVGDA8_69592.pdf

Miles, R., & Mikolajczyk, K. (2020). *Compression of convolutional neural networks for high performance imagematching tasks on mobile devices.* arXiv preprint arXiv:2001.03102

Miranda, J., Ponce, P., Molina, A., & Wright, P. (2019). Sensing, smart and sustainable technologies for Agri-Food 4.0. *Computers in Industry*, *108*, 21–36. doi:10.1016/j.compind.2019.02.002

Mittal, S., Gandhi, S., & Tripathi, G. (2010). *Socio-economic impact of mobile phones on Indian agriculture* (No. 246). Working paper.

Mkrttchian, V. (2020). Human Capital Management in the Context of the Implementation of Digital Intelligent Decision Support Systems and Knowledge Management: Theoretical and Methodological Aspects. In Knowledge Management, Innovation, and Entrepreneurship in a Changing World (pp.123-148). IGI Global. Doi:10.4018/978-1-7998-2355-1.ch006

Mkrttchian, V. (2019a). New Tools for Cyber Security Using Blockchain Technology and Avatar-Based Management Technique. In *Machine Learning and Cognitive Science Applications in Cyber Security* (pp. 105–122). IGI Global; doi:10.4018/978-1-5225-8100-0.ch004

Mkrttchian, V. (2021a). Avatars-Based Decision Support System Using Blockchain and Knowledge Sharing for Processes Simulation a Natural Intelligence: Implementation of the Multi Chain Open Source Platform. *International Journal of Knowledge Management*, *17*(1), 5. Advance online publication. doi:10.4018/IJKM.2021010105

Mkrttchian, V. (2021b). Digital Intelligent Design of Avatar-Based Control with Application to Human Capital Management. *International Journal of Human Capital and Information Technology Professionals*, *12*(1), 2. Advance online publication. doi:10.4018/IJHCITP.2021010102

Mkrttchian, V., & Aleshina, E. (2017). *Sliding Mode in Intellectual Control and Communication: Emerging Research and Opportunities*. IGI Global., doi:10.4018/978-1-5225-2292-8

Mkrttchian, V., & Belyanina, L. (Eds.). (2018). *Handbook of Research on Students' Research Competence in Modern Educational Contexts*. IGI Global. doi:10.4018/978-1-5225-3485-3

Mokyr, J. (1998). The second industrial revolution, 1870-1914. Stor. Dell economia Mond., 219–245.

Mondal & Rehena. (2018). *IoT Based Intelligent Agriculture Field Monitoring System*. IEEE.

Monitoring Soil Moisture for Optimal Crop Growth. (n.d.). Retrieved from https://observant.zendesk.com/hc/en-us/articles/208067926-Monitoring-Soil-Moisture-for-Optimal-Crop-Growth

Morais, R., Valente, A., & Serôdio, C. (2005). *A wireless sensor network for smart irrigation and environmental monitoring*. Paper presented at the EFITA/WCCA Joint Congress on IT in Agriculture, Portugal.

Morais, R., Valente, A., & Serôdio, C. (2005, July). A Wireless Sensor Network for Smart Irrigation and Environmental Monitoring : A Position Article. *Efita/Wcca*, 845–850.

Murray, M. S. (2008). *Using Degree Days to Time Treatments for Insect Pests*. Utah State University Extension and Utah Plant Pest Diagnostic Laboratory. Retrieved from https://climate.usu.edu/includes/pestFactSheets/degree-days08.pdf

Murray, C., & Chu, A. G. (2015). The flying sidekick traveling salesman problem: Optimization of drone-assisted parcel delivery. *Transportation Research Part C, Emerging Technologies*, *54*, 86–109. doi:10.1016/j.trc.2015.03.005

Na, I. W., Varshney, S., & Khan, E. (2016). An IoT based system for remote monitoring of soil characteristics. *International Conference on Information Technology (InCITe) - The Next Generation IT Summit on the Theme - Internet of Things: Connect your Worlds*, 316–320.

Nagy, Z., Yong, F. Y., & Schlueter, A. (2016). Occupant centered lighting control: A consumer study on balancing comfort, acceptance, and energy consumption. *Energy and Building*, *126*, 310–322. doi:10.1016/j.enbuild.2016.05.075

Nair, C. (2020). *An Inside Look at How Robotic Process Automation in Agribusiness is more Productive & Profitable*. https://blog.accubits.com/robotic-process-automation-in-agribusiness/

Nandurkar, T., & Thool. (2014). Design and Development of Precision Agriculture System Using Wireless Sensor Network. *IEEE International Conference on Automation, Control, Energy and Systems (ACES)*.

Napier, T., Robinson, J., & Tucker, M. (2000). Adoption of precision farming within three Midwest watersheds. *Journal of Soil and Water Conservation*, *55*(2), 135–141.

Nate Dorsey, N., & Precisionag. (2017). *4 important ways precision technology is impacting irrigation - PrecisionAg*. https://www.precisionag.com/in-field-technologies/irrigation/4-important-ways-precision-technology-is-impacting-irrigation/

Nekrasov, V., Ju, J., & Choi, J. (2016). Global deconvolutional networks for semantic segmentation. *British Machine Vision Conference 2016, BMVC 2016,* 124.1-124.14. 10.5244/C.30.124

Nemali, K. S., & Van Iersel, M. W. (2006). An automated system for controlling drought stress and irrigation in potted plants. *Scientia Horticulturae*, *110*(3), 292–297. doi:10.1016/j.scienta.2006.07.009

Nilesh, K., & Raut, C., Patel, & Bherani. (2014). Smart design of microcontroller based monitoring system for agriculture. *International Conference on Circuits, Power and Computing Technologies*.

Nitika & Pateriya. (2016). Development of IoT based Smart Security and Monitoring Devices for Agriculture. *6th International Conference - Cloud System and Big Data Engineering*, 597-602.

O'Grady, M. J., & O'Hare, G. M. P. (2017). Modeling the smart farm. *Information Processing in Agriculture*, *4*(3), 179–187. doi:10.1016/j.inpa.2017.05.001

O'Shaughnessy, S. A., & Evett, S. R. (2010). Canopy temperature based system effectively schedules and controls center pivot irrigation of cotton. *Agricultural Water Management*, *97*(9), 1310–1316. doi:10.1016/j.agwat.2010.03.012

O'Shea, K., & Nash, R. (2015). *An introduction to convolutional neural networks.* arXiv preprint arXiv:1511.08458

OECD. (2016). OECD Science, Technology and Innovation Outlook 2016: Megatrends affecting Science. *Technology and Innovation*.

Ojha, Misra, & Raghuwanshi. (2015). *Wireless Sensor Networks for Agriculture : The State-of-the-Art in Practice and Future Challenges.* Academic Press.

Oksanen, T., Linkolehto, R., & Seilonen, I. (2016). Adapting an industrial automation protocol to remote monitoring of mobile agricultural machinery: A combine harvester with IoT. *IFAC-PapersOnLine*, *49*(16), 127–131. doi:10.1016/j.ifacol.2016.10.024

Olivares, V., Cordova, F., Sepúlveda, J. M., & Derpich, I. (2015). Modeling Internal Logistics by Using Drones on the Stage of Assembly of Products. *Procedia Computer Science*, *55*, 1240–1249. doi:10.1016/j.procs.2015.07.132

Oliver, J. (2019). 済無. *Hilos Tensados*, *1*, 1–476.

Öncüer, C. (2004). Tarımsal Zararlılarla Savaşım Yöntemleri ve İlaçları. *Adnan Menderes Üniversitesi Yayınları*, *19*, 424.

Onfarms. (2017). Available: http://www.onfarm.com/

Onishi, Y., Yoshida, T., Kurita, H., Fukao, T., Arihara, H., & Iwai, A. (2019). An automated fruit harvesting robot by using deep learning. *ROBOMECH Journal*, *6*(1), 2–9. doi:10.118640648-019-0141-2

Otsu, N. (1979). A threshold selection method from gray-level histograms. *IEEE Transactions on Systems, Man, and Cybernetics*, *9*(1), 62–66. doi:10.1109/TSMC.1979.4310076

Ozcan, G. E., Cicek, O., Enez, K., & Yildiz, M. (2014). A new approach to determine the capture conditions of bark beetles in pheromone-baited traps. *Biotechnology, Biotechnological Equipment*, *28*(6), 1057–1064. doi:10.1080/13102818.2014.974015 PMID:26019592

Ozgul, E., & Celik, U. (2018). Design and Implementation of Semiautonomous Anti-pesticide Spraying and Insect Repellent Mobile Robot for Agricultural Applications. *5th International Conference on Electrical and Electronic Engineering*, 233-237.

Palanivel, K., & Suresh Joseph, K. (2020). Robotic Process Automation to Smart Education. *International Journal of Creative Research Thoughts*, *8*(6), 3775–3784.

Palmer, T., & Darabian, N. (2017). M'chikumbe 212 A mobile agriculture service by Airtel Malawi. *GSMA mAgri*.

Panchard, J., Rao, S., & Prabhakar, T.V., Hubaux, J.-P., & Jamadagni, H.S. (2007). COMMONSense Net: A wireless sensor network for resource-poor agriculture in the semiarid areas of developing countries. *Information Technologies and International Development*, *4*(1), 51–67. doi:10.1162/itid.2007.4.1.51

Pang, W. (2004). Modified particle swarm optimization based on space transformation for solving traveling salesman problem. In *Third International Conference on Machine Learning and Cybernetics*, (pp. 2342-2346). Shanghai, China: Academic Press.

Panwar, N. L., Kaushik, S. C., & Kothari, S. (2011). Solar greenhouse an option for renewable and sustainable farming. *Renewable & Sustainable Energy Reviews*, *15*(8), 3934–3945. doi:10.1016/j.rser.2011.07.030

Parasher, Y., Singh, P., & Kaur, G. (2019). Green Smart Security System. *Green and Smart Technologies for Smart Cities*, 165-184.

Parasher, Y., Singh, P., & Kaur, G. (2019). Green Smart Town Planning. *Green and Smart Technologies for Smart Cities*, 19-41. doi:10.1201/9780429454837-5

Parasher, Y., Singh, P., & Kaur, G. (2019a). Green Smart Security System. *Green and Smart Technologies for Smart Cities*, 165-184.

Parasher, Y., Singh, P., & Kaur, G. (2019b). Green Smart Town Planning. *Green and Smart Technologies for Smart Cities*, 19-41.

Parasher, Y., Kaur, G., & Tomar, P. (2019). Green Smart Environment for Smart Cities. In *Green and Smart Technologies for Smart Cities* (pp. 75–89). CRC Press. doi:10.1201/9780429454837-4

Parasher, Y., Kaur, G., Tomar, P., & Kaushik, A. (2020). Development of Artificial Neural Network to Predict the Concrete Strength. In *Smart Systems and IoT: Innovations in Computing* (pp. 379–389). Springer. doi:10.1007/978-981-13-8406-6_36

Parasher, Y., Kedia, D., & Singh, P. (2018). Examining Current Standards for Cloud Computing and IoT. In *Examining Cloud Computing Technologies through the Internet of Things* (pp. 116–124). IGI Global.

Parasher, Y., Kedia, D., & Singh, P. (2018). Examining Current Standards for Cloud Computing and IoT. In *Examining Cloud Computing Technologies Through the Internet of Things* (pp. 116–124). IGI Global. doi:10.4018/978-1-5225-3445-7.ch006

Patil, A., Beldar, M., Naik, A., & Despande, A. (2016). Smart Farming Using Arduino and Data mining. *3rd International Conference on Computing for Sustainable Global Development (INDIA Com)*.

Patil, K. A., & Kale, N. R. (2016). A model for smart agriculture using IoT. In *International Conference on Global Trends in Signal Processing, Information Computing and Communication* (pp. 543-545). Maharasthra, India. 10.1109/ICGTSPICC.2016.7955360

Patil, V. C., Al-Gaadi, K. A., Biradar, D. P., & Rangaswamy, M. (2012). Internet of Things (Iot) And Cloud Computing for Agriculture: An Overview. *Proceedings of AIPA 2012*.

Patrício, D. I., & Rieder, R. (2018). Computer vision and artificial intelligence in precision agriculture for grain crops: A systematic review. *Computers and Electronics in Agriculture*, *153*, 69–81. doi:10.1016/j.compag.2018.08.001

Pecht, M., & Kang, M. (2019). *Machine Learning: Fundamentals*. Wiley-IEEE Press.

Peffer, T., Blumstein, C., Culler, D., Modera, M., & Meier, A. (2015). Software-defined solutions for managing energy use in small to medium sized commercial buildings (No. EE0006351). Berkeley, CA: Regents of the University of California.

Pekoslawski, B., Krasinski, P., Siedlecki, M., & Napieralski, A. (2013). Autonomous wireless sensor network for greenhouse environmental conditions monitoring. *Proceedings of the 20th International Conference Mixed Design of Integrated Circuits and Systems - MIXDES 2013*, 503–507.

Pereira, Feddes, & Gilley. (1996). *Sustainability of irrigated agriculture*. Academic Press.

Petrellis, N. (2017, May). A smart phone image processing application for plant disease diagnosis. In *2017 6th International Conference on Modern Circuits and Systems Technologies (MOCAST)* (pp. 1-4). IEEE. 10.1109/MOCAST.2017.7937683

Phadikar, S., & Sil, J. (2008). Rice disease identification using pattern recognition techniques. In *11th International Conference on Computer and Information Technology* (pp. 420-423). Khulna, Bangladesh. 10.1109/ICCITECHN.2008.4803079

Philips Lighting Catalog. (2014). *Document Number 919002151397*. Amsterdam: Koninklijke Philips Electronics N.V.

Phytec. (2017). Available: https://www.phytech.com/

Piao, S., Ciais, P., Huang, Y., Shen, Z., Peng, S., Li, J., Zhou, L., Liu, H., Ma, Y., Ding, Y., Friedlingstein, P., Liu, C., Tan, K., Yu, Y., Zhang, T., & Fang, J. (2010). The impacts of climate change on water resources and agriculture in China. *Nature*, *467*(7311), 43–51. doi:10.1038/nature09364 PMID:20811450

Pierce, F. J., & Elliott, T. V. (2008). Regional and on-farm wireless sensor networks for agricultural systems in Eastern Washington. *Computers and Electronics in Agriculture*, *6*(1), 32–43. doi:10.1016/j.compag.2007.05.007

Pilli, S., Nallathambi, B., George, S., & Diwanji, V. (2015). eAGROBOT- A Robot for Early Crop Disease Detection using Image Processing. *2nd International Conference on Electronics and Communication System (ICECS)*, 1684-1689. 10.1109/ECS.2015.7124873

Piper, B. (2019). *How technology has changed farming*. Available: monsanto.com/innovations/data-science/articles/agricultural-technology-innovations

Pivoto, D., Waquil, P. D., Talamini, E., Finocchio, C. P. S., Dalla Corte, V. F., & de Vargas Mores, G. (2018). MoresScientific development of smart farming technologies and their application in Brazil. *Information Processing in Agriculture*, *5*(1), 21–32. doi:10.1016/j.inpa.2017.12.002

Ponce, P., Molina, A., Cepeda, P., Lugo, E., & MacCleery, B. (2014). *Greenhouse Design and Control.* CRC Press. doi:10.1201/b17391

Pooja, P., Varsha, T., & Pravin, P. (2016). *Cucumber disease detection using artificial neural network.* Paper presented at the International Conference on Inventive Computation Technologies, Coimbatore, India.

Popp, J., Pető, K., & Nagy, J. (2013). Pesticide productivity and food security. A review. *Agronomy for Sustainable Development*, *33*(1), 243–255. doi:10.100713593-012-0105-x

Potamitis, I., & Rigakis, I. (2015). Smart traps for automatic remote monitoring of *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) Peer J. *PrePrints,* 3:1337v1. doi:10.7287/peerj.preprints.1337v1

Potamitis, I., Ganchev, T., & Kontodimas, D. (2009). On automatic bioacoustic detection of pests: The cases of *Rhynchophorus ferrugineus* and *Sitophilus oryzae. Journal of Economic Entomology*, *102*(4), 1681–1690. doi:10.1603/029.102.0436 PMID:19736784

Potdar, V., Sharif, A., & Chang, E. (2009). Wireless sensor networks: A survey. *Proceedings - International Conference on Advanced Information Networking and Applications, AINA*, 636–641. 10.1109/WAINA.2009.192

Prathibha, S. R., Hongal, A., & Jyothi, M. P. (2017, March). IOT Based monitoring system in smart agriculture. In *2017 International Conference on Recent Advances in Electronics and Communication Technology (ICRAECT)* (pp. 81-84). IEEE. 10.1109/ICRAECT.2017.52

Prem Prakash Jayaraman, A. Y. D. G., & Zaslavsky, A. (2016). *Internet of Things Platform for Smart Farming*. doi:10.339016111884

Preudhomme, M. (2019). *The automated weeding robot for a vegetative crop*. Available: https://www.naio-technologies.com/wp-content/uploads/2019/04/brochure-DINO-ENGLISH

Quarcoo, F., Bonsi, C., & Tackie, N. (2014). Pesticides, the environment, and human health. In *Pesticides-Toxic Aspects*. IntechOpen. doi:10.5772/57553

Radoglou-Grammatikis, P., Sarigiannidis, P., Lagkas, T., & Moscholios, I. (2020). A compilation of UAV applications for precision agriculture. *Computer Networks*, ▪▪▪, 172.

Rafia, R., Dasb, S., Ahmed, N., Hossaind, I., & Reza, S. (2016). Design and Implementation of a Line Following Robot for Irrigation Based Application. *19th International Conference on Computer an Information Technology (ICCIT)*, 480-48. 10.1109/ICCITECHN.2016.7860245

Rains, G. C., & Thomas, D. L. (2009). *Precision Farming: An Introduction*. The University of Georgia Cooperative Extension.

Rajalakshmi, P., & Mahalakshmi, S. D. (2016, January). IoT based crop-field monitoring and irrigation automation. In *2016 10th International Conference on Intelligent Systems and Control (ISCO)* (pp. 1-6). IEEE. 10.1109/ISCO.2016.7726900

Ramachandran, V., Ramalakshmi, R., & Srinivasan, S. (2018). An Automated Irrigation System for Smart Agriculture Using the Internet of Things. *2018 15th International Conference on Control, Automation, Robotics and Vision (ICARCV)*, 210-215. doi:10.1109/ICARCV.2018.858122110.1109/ICARCV.2018.8581221

Ramya, M. G. P. G. (2015). Environment Change Prediction to Adapt Climate Smart Agriculture Using Big Data Analytics. Academic Press.

Rao, R. N., & Sridhar, B. (2018, January). IoT based smart crop-field monitoring and automation irrigation system. In *2018 2nd International Conference on Inventive Systems and Control (ICISC)* (pp. 478-483). IEEE. 10.1109/ICISC.2018.8399118

Ravi Kishore, K., & Nisheeth, R. (2013). *Wireless sensor network in Mango Farming*. Paper presented at the Nirma University International Conference on Engineering, Ahmedabad, India.

Ravi Kishore, K., & Snehashish, M. (2016). *IoT Based Weather Station*. Paper presented at the International Conference on Control, Instrumentation, Communication and Computational Technologies, Kumarakoil, India.

Recio, B., Rubio, F., & Criado, J. A. (2003). A decision support system for farm planning using AgriSupport II. *Decision Support Systems*, *36*(2), 189–203. doi:10.1016/S0167-9236(02)00134-3

Rekha, P., Rangan, V. P., Ramesh, M. V., & Nibi, K. V. (2017, October). High yield groundnut agronomy: An IoT based precision farming framework. In *2017 IEEE Global Humanitarian Technology Conference (GHTC)* (pp. 1-5). IEEE. 10.1109/GHTC.2017.8239287

Retief, F., Bond, A., Pope, J., Morrison-Saunders, A., & King, N. (2016). Global megatrends and their implications for environmental assessment practice. *Environmental Impact Assessment Review*, *61*, 52–60. doi:10.1016/j.eiar.2016.07.002

Robertson, G. P., & Swinton, S. (2005). Reconciling agricultural productivity and environmental integrity: A grand challenge for agriculture. *Frontiers in Ecology and the Environment*, *3*(1), 38–46. doi:10.1890/1540-9295(2005)003[0038:RAPAEI]2.0.CO;2

Robertson, M., Carberry, P., & Brennan, L. (2007). The Economic Benefits of Precision Agriculture: Case Studies from Australian Grain Farms. *Controlled Traffic and Precision Agriculture Conference*, 1–7.

Robinson, A. (2019). Smart Farming Uses Driverless Tractors, and Weed-Killing Robots. Academic Press.

Roman, R., Zhou, J., & Lopez, J. (2013). On the features and challenges of security and privacy in distributed internet of things. *Computer Networks*, *57*(10), 2266–2279. doi:10.1016/j.comnet.2012.12.018

Rose, D. C., & Chilvers, J. (2018). Agriculture 4.0: Broadening responsible innovation in an era of smart farming. *Frontiers in Sustainable Food Systems*, *2*, 87. doi:10.3389/fsufs.2018.00087

Rose, D. C., & Chilvers, J. (2019). *Agriculture 4.0: Broadening Responsible Innovation in an Era of Smart Farming, Science, Society, and Sustainability (3S) Research Group*. School of Environmental Sciences, University of East Anglia.

Rostow, W. W. (1983). Technology and unemployment in the Western world. *The Challenge (Karachi)*, *26*(1), 6–17. doi:10.1080/05775132.1983.11470821

Rotz, S., Duncan, E., Small, M., Botschner, J., Dara, R., Mosby, I., Reed, M., & Fraser, E. D. (2019). The politics of digital agricultural technologies: A preliminary review. *Sociologia Ruralis*, *59*(2), 203–229. doi:10.1111oru.12233

Roy, S., & Bandyopadhyay, S. (2013). A Test-bed on real-time monitoring of agricultural parameters using wireless sensor networks for precision agriculture. *First international conference on intelligent infrastructure the 47th annual national convention at computer society of India CSI*.

Roy, S., & Bandyopadhyay, S. (2013). A Test-Bed on Real-Time Monitoring of Agricultural Parameters Using Wireless Sensor Networks for Precision Agriculture. *International Conference on Intelligent Infrastructure*.

Rupanagudi, S., Ranjani, B., Nagaraj, P., Bhat, V., & Thippeswamy, G. (2015). A novel cloud computing based smart farming system for early detection of borer insects in tomatoes. *International Conference on Communication, Information and Computing Technology (ICCICT)*. 10.1109/ICCICT.2015.7045722

Ryu & Yun. (2015). Design & implementation of a Connected Farm for Smart Farming System. IEEE.

Sabir, N., Balraj, S., Hasan, M., Sumitha, R., Deka, S., Tanwar, R. K., Ahuja, D. B., Tomar, B. S., Bambawale, O. M., & Khah, E. M. (2010). Good Agricultural Practices (GAP) for IPM in protected cultivation. *Technical Bulletin, 23*, 1-14.

Sabri, F., Hanif, N., & Janin, Z. (2018). Precision crop management for Indoor Farming. *IEEE 5th International Conference on Smart Instrumentation, Measurement and Application (ICSIMA)*. 10.1109/ICSIMA.2018.8688791

Sadik, N. (1991). *Population growth and the food crisis.* http://www.fao.org/3/U3550t/u3550t02.htm

Sahu, C. K., & Behera, P. (2015). A low cost smart irrigation control system. *2015 2nd International Conference on Electronics and Communication Systems (ICECS)*, 1146–1152. 10.1109/ECS.2015.7124763

Salman, T., & Jain, R. (2017). Networking protocols and standards for internet of things. *Internet of Things and Data Analytics Handbook*, 215–238. doi:10.1002/9781119173601.ch13

Sawant, S., Mohite, J., Sakkan, M., & Pappula, S. (2019, July). Near Real Time Crop Loss Estimation using Remote Sensing Observations. In *2019 8th International Conference on Agro-Geoinformatics (Agro-Geoinformatics)* (pp. 1-5). IEEE. 10.1109/Agro-Geoinformatics.2019.8820217

Scherm, H. (2004). Climate change: Can we predict the impacts on plant pathology and pest management? *Canadian Journal of Plant Pathology*, *26*(3), 267–273. doi:10.1080/07060660409507143

Schieffer, J., & Dillon, C. (2015). The economic and environmental impacts of precision agriculture and interactions with agro-environmental policy. *Precision Agriculture*, *16*(1), 46–61. doi:10.100711119-014-9382-5

Schneider, U., & Kumar, P. (2008). Greenhouse gas mitigation through agriculture. *Choices*, *23*(1), 19–23.

Schönfeld, M., Heil, R., & Bittner, L. (2018). *Big Data on a Farm—Smart Farming*. doi:10.1007/978-3-319-62461-7_12

Schwab, K. (2016). The fourth industrial revolution. Geneva, Switzerland. *World Economic Forum*.

Sciforce. (2019). *Smart Farming: The Future of Agriculture*. Academic Press.

Scott Ramsay, S., & South Africa, W. W. F. (2019). *Climate smart smallholder farming - WWF South Africa.* https://www.wwf.org.za/our_work/initiatives/climate_smart_smallholder_farming.cfm

Seckler, D., Barker, R., & Amarasinghe, U. (1999). Water Scarcity in the Twenty-First Century. *International Journal of Water Resources Development*, *15*(1-2), 29–42. doi:10.1080/07900629948916

Semios. (2017). Available: https://semios.com/

Seth, A. N. K. U. R., & Ganguly, K. A. V. E. R. Y. (2017). Digital technologies transforming Indian agriculture. *The Global Innovation Index*, 105-111.

Shade, R. E., Furgason, E. S., & Murdock, L. L. (1989). *Ultrasonic insect detector*. U.S. Patent No. 4,809,554. Washington, DC: U.S. Patent and Trademark Office. Retrieved from https://patents.google.com/patent/US4809554A/en

Shade, R. E., Furgason, E. S., & Murdock, L. L. (1990). Detection of hidden insect infestations by feeding-generated ultrasonic signals. *American Entomologist (Lanham, Md.)*, *36*(3), 231–235. doi:10.1093/ae/36.3.231

Shahzadi, R., Tausif, M., Ferzund, J., & Suryani, M. A. (2016). Internet of things based expert system for smart agriculture. *Int. J. Adv. Comput. Sci. Appl.*, *7*(9), 341–350. doi:10.14569/IJACSA.2016.070947

Shaikh, F. K., Zeadally, S., &Exposito, E. (2017). Enabling technologies for green internet of things. *IEEE Systems Journal, 11*(2), 983–994.

Shamshiri, R. (2018). Research and development in agricultural robotics: A perspective of digital farming. *International Journal of Agricultural and Biological Engineering*, *11*, 1–14. doi:10.25165/j.ijabe.20181104.4278

Sharma Subedi, J. R. (2018). *Design and Implementation of IoT Based Smart Greenhouse Monitoring System* (Doctoral dissertation). Université d'Ottawa/University of Ottawa.

Shepherd, M., Turner, J. A., Small, B., & Wheeler, D. (2018). Priorities for science to overcome hurdles thwarting the full promise of the 'digital agricultural revolution. *Journal of the Science of Food and Agriculture*.

Shie, M. C., Lin, P. C., Su, T. M., Chen, P., & Hutahaean, A. (2014). Intelligent energy monitoring system based on ZigBee-equipped smart sockets. In *Proceedings of IEEE international conference on intelligent green building and smart grid (IGBSG)* (pp. 1–5). IEEE. 10.1109/IGBSG.2014.6835281

Shimoda, N., Kataoka, T., Okamoto, H., Terawaki, M., & Hata, S. I. (2006). Automatic pest counting system using image processing technique. *Nogyo Kikai Gakkaishi*, *68*(3), 59–64.

Shirsath, P. D. O., Kamble, P., Mane, R., Kolap, A., & More, P. R. S. (2017). IoT based smart greenhouse automation using Arduino. *International Journal of Innovative Research in Computer Science & Technology*, *5*(2), 234–238. doi:10.21276/ijircst.2017.5.2.4

Simon, J. Y. (2014). *The toxicology and biochemistry of insecticides*. CRC press.

Singh, P., Dixit, V., & Kaur, J. (2019). Green Healthcare for Smart Cities. *Green and Smart Technologies for Smart Cities*, 91-130.

Singh, O. V., Ghai, S., Paul, D., & Jain, R. K. (2006). Genetically modified crops: Success, safety assessment, and public concern. *Applied Microbiology and Biotechnology*, *71*(5), 598–607. doi:10.100700253-006-0449-8 PMID:16639559

Singh, P. P., Khosla, P. K., & Mittal, M. (2019). Energy conservation in IoT-based smart home and its automation. In M. Mittal, S. Tanwar, B. Agarwal, & L. M. Goyal (Eds.), *Energy conservation for IoT devices. Studies in systems, decision and control* (Vol. 206, pp. 155–177). Springer. doi:10.1007/978-981-13-7399-2_7

Singh, S., Burks, T., & Lee, W. (2005). Autonomous robotic vehicle development for greenhouse spraying. *Transactions of the ASAE*, 48. 10.13031/2013.20074

Singla, A., Yuan, L., & Ebrahimi, T. (2016, October). Food/non-food image classification and food categorization using pre-trained googlenet model. In *Proceedings of the 2nd International Workshop on Multimedia Assisted Dietary Management* (pp. 3-11). 10.1145/2986035.2986039

Skolnik, H. (1968). History, Evolution, and Status of Agriculture and Food Science and Technology. *Journal of Chemical Documentation*, *8*(2), 95–98. doi:10.1021/c160029a011

Skvortcov, E., Skvortsova, E., Sandu, I., & Iovlev, G. (2018). Transition of agriculture to digital, intellectual and robotics technologies. *Economy of Region, 1*(3), 1014-1028.

Smith, M. J. (2020). Getting value from artificial intelligence in agriculture. *Animal Production Science*, *60*(1), 46–54. doi:10.1071/AN18522

SpecPage. (2019). *Food Industry 4.0 – Revolution or Evolution?* Available: https://www.specpage.com/food-industry-4-0-revolution-evolution/

Spoorthi, S., Shadaksharappa, S., Suraj, S., & Manasa, V. (2017). Freyr Drone Pesticide/Fertilizers Spraying Drone – An Agricultural Approach. *2nd International Conference on Computing and Communications Technologies (ICCCT)*, 252-255. 10.1109/ICCCT2.2017.7972289

Srbinovska, Gavrovski, Dimcev, Krkoleva, & Borozan. (2014). *Environmental parameters monitoring in precision agriculture using wireless sensor networks*. Elsevier.

Sreekantha, D. K., & Kavya, A. M. (2017, January). Agricultural crop monitoring using IOT-a study. In *2017 11th International Conference on Intelligent Systems and Control (ISCO)* (pp. 134-139). IEEE.

Srinivasan, A. (Ed.). (2006). *Handbook of precision agriculture: principles and applications*. CRC press. doi:10.1201/9781482277968

Srisruthi, S., Ros, G., & Elizabeth, E. (2016). Sustainable Agriculture using Eco-friendly and Energy Efficient Sensor Technology. *IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT),* 1442-1446. 10.1109/RTEICT.2016.7808070

Srivastava, A. (2018). *Technology-Assisted Knowledge Agriculture for Sustainable Development Goals Advances in Crop Science and Technology*. doi:10.4172/2329-8863.1000391

Stehr, N. J. (2015). Drones: The Newest Technology for Precision Agriculture. *Natural Sciences Education*, *44*(1), 89–91. doi:10.4195/nse2015.04.0772

Stojkoska, B. L. R., & Trivodaliev, K. V. (2017). A review of Internet of Things for smart home: Challenges and solutions. *Journal of Cleaner Production*, *140*, 1454–1464. doi:10.1016/j.jclepro.2016.10.006

Suchithra, Asuwini, Charumathi, & Lal. (2018). Monitoring Of Agricultural Crops Using Cloud and IoT with Sensor Data Validation. *International Journal of Pure and Applied Mathematics*.

Sujatha, R., & Anitha Nithya, R. (2017). A Survey on Soil Monitoring and Testing In Smart Farming Using IoT And Cloud Platform. *International Journal of Engineering Research and Applications*, *7*(11), 55–59.

Sujjaviriyasup, T., & Pitiruek, K. (2013). Agricultural Product Fore-casting Using Machine Learning Approach. *Int. Journal of Math. Analysis*, *7*(38), 1869–1875. doi:10.12988/ijma.2013.35113

Sung, J. (2018). The Fourth Industrial Revolution and Precision Agriculture. *Autom. Agric. Secur. Food Supplies Futur. Gener.*, 1.

Sung, J. (2018). The Fourth Industrial Revolution and Precision Agriculture. *Autom. Agric. Security. Food Supplies Futur. Gener.*, 1.

Sureephong, P., Wiangnak, P., & Wicha, S. (2017). The comparison of soil sensors for integrated creation of IoT-based wetting front detector (WFD) with an efficient irrigation system to support precision farming. *International Conference on Digital Arts, Media and Technology (ICDAMT)*, 132–135. 10.1109/ICDAMT.2017.7904949

Swanson, B. E. (2008). *Global review of good agricultural extension and advisory service practices.* Rome: Food and Agriculture Organization of the United Nations. USA, Research and Extension Unit (NRRR). Retrieved from http://www.fao.org/nr/gen/gen_081001_en.htm

Syngenta. (2018). *Syngenta Crop Challenge In Analytics*. https://www.ideaconnection.com/ Syngenta-crop-challenge/challenge.php/

Szegedy, C., Ioffe, S., Vanhoucke, V., & Alemi, A. A. (2017, February). Inception-v4, inception-resnet and the impact of residual connections on learning. *Thirty-first AAAI conference on artificial intelligence*.

Tang, S., Zhu, Q., Yan, G., Zhou, X., & Wu, M. (2002). About Basic Conception of Digital Agriculture. *Nongye Xiandaihua Yanjiu*, *3*(005).

Tan, L. (2016). Cloud-based decision support and automation for precision agriculture in orchards. *IFAC-PapersOnLine*, *49*(16), 330–335. doi:10.1016/j.ifacol.2016.10.061

Targ, S., Almeida, D., & Lyman, K. (2016). *Resnet in resnet: Generalizing residual architectures.* arXiv preprint arXiv:1603.08029

Taylor, J., & Whelan, B. (2016). *A General Introduction to Precision Agriculture*. www.usyd.edu.au/su/agric/acpa

Tevel-tech. (2020, July 4). Retrieved from www.tevel-tech.com/

Tian, H., Wang, T., Liu, Y., Qiao, X., & Li, Y. (2020). Computer vision technology in agricultural automation, A review. *Information Processing in Agriculture*, *7*(1), 1–19. doi:10.1016/j.inpa.2019.09.006

Tian, Y., Li, T., & Niu, Y. (2008). The Recognition of Cucumber Disease Based on Image Processing and Support Vector Machine. *Congress on Image and Signal Processing*, *2*, 262–267.

Timilsina, B., Adhikari, N., Kafle, S., Paudel, S., Poudel, S., & Gautam, D. (2020). Addressing Impact of COVID-19 Post Pandemic on Farming and Agricultural Deeds. *Asian Journal of Advanced Research and Reports*, 28-35.

Tirelli, P., Borghese, N. A., Pedersini, F., Galassi, G., & Oberti, R. (2011). Automatic monitoring of pest insects traps by Zigbee-based wireless networking of image sensors. In *IEEE International Instrumentation and Measurement Technology Conference* (pp. 1-5). Binjiang, Hangzhou, China. 10.1109/IMTC.2011.5944204

Togelius, J., Juul, J., Long, G., Uricchio, W., & Consalvo, M. (2018). *What is "(Artificial) Intelligence?"*. MIT Press.

Tokekar, P., Vander Hook, J., Mulla, D., & Isler, V. (2016). Sensor planning for a symbiotic UAV and UGV system for precision agriculture. *IEEE Transactions on Robotics*, *32*(6), 1498–1511. doi:10.1109/TRO.2016.2603528

Tomás, J. P. (2017). *Three precision agriculture IoT case studies*. Available: https://enterpriseiotinsights.com/20170516/smart-farm/20170516smart-farmthree-precision-agriculture-iot-case-studies-tag23-tag99

Tongke, F. (2013). *Smart Agriculture Based on Cloud Computing and IOT*. Retrieved from https://pdfs.semanticscholar.org/62ee/b701c40626811a1111ca5d1db37650f1ea0b.pdf

Tran, D. V., & Nguyen, N. V. (2006). The concept and implementation of precision farming and rice integrated crop management systems for sustainable production in the twenty-first century. *Int. Rice Comm. News.*, *55*, 91–102.

Trendov, N.M., Varas, S., & Zeng, M. (2019). *Digital Technologies in Agriculture and Rural Areas – Status Report*. Academic Press.

Trendov, N. M., Varas, S., & Zeng, M. (2019). *Digital Technologies in Agriculture & Rural Areas Status Report*. Food and Agriculture Organization of the United Nations Rome.

Trendov, N. M., Varas, S., & Zeng, M. (2019). *Digital Technologies in Agriculture and Rural Areas*. Food and Agriculture Organization of the United Nations Rome.

Tripathy, A. K., Adinarayana, J., Merchant, S. N., & Desai, U. B. (2013). *Data mining and wireless sensor network for groundnut pest/disease precision protection*. Paper presented at the National Conference on Parallel Computing Technologies, Bangalore, India. 10.1109/ParCompTech.2013.6621399

Tripathy, A. K., Adinarayana, J., Sudharsan, D., Vijayalakshmi, K., Merchant, S. N., & Desai, U. B. (2013). Data mining and wireless sensor network for groundnut pest/disease interaction and predictions – a preliminary study. *Int. J. Comput. Inform. Syst. Ind. Manage. Appl.*, *5*, 427–436.

Tsai, K. L., Leu, F. Y., & You, I. (2016). Residence energy control system based on wireless smart socket and IoT. *IEEE Access: Practical Innovations, Open Solutions*, *4*, 2885–2894. doi:10.1109/ACCESS.2016.2574199

Tzounis, A., Katsoulas, N., Bartzanas, T., & Kittas, C. (2017). Internet of Things in agriculture, recent advances and future challenges. *Biosystems Engineering*, *164*, 31–48. doi:10.1016/j.biosystemseng.2017.09.007

UNICEF, OGAC, LSHTM, & MSF. (2018). *USAID. Key considerations for introducing new HIV point-of-care diagnostic technologies in national health systems*. Author.

University of Stellenburg Business School. (2017). The Future Of The Western Cape Agricultural Sector In The Context Of The 4th Industrial Revolution, Review. *The Fourth Industrial Revolution (4IR),* 1–21.

University of Stellenburg Business School. (2017a). The Future Of The Western Cape Agricultural Sector In The Context Of The 4th Industrial Revolution, Review. *The Fourth Industrial Revolution (4IR),* 1–21.

University of Stellenburg Business School. (2017b). The Future of the Western Cape Agricultural Sector in the Context Of The 4th Industrial Revolution, Review. In *Agriculture in 4IR & its drivers – A global perspective*. Author.

US Food and Drug. (2018). *FDA Investigated Multistate Outbreak of E. coli O157: H7 Infections Linked to Romaine Lettuce from Yuma Growing Region*. Author.

USAID. (2018). *Digital Farmer Profile: Reimagining Smallholder Agriculture*. USAID.

Varma, Mulla, Raut, & Pawar. (2017). Fertigation & Irrigation System for Agricultural Application along with Soil Monitoring Using IoT. *Vishwakarma Journal of Engineering Research, 1*(2), 241–45. www.vjer.in

Vatari, S., Bakshi, A., & Thakur, T. (2016). Green house by using IOT and cloud computing. In *2016 IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)* (pp. 246-250). IEEE. 10.1109/RTEICT.2016.7807821

Verified Market Intelligence. (2020, May 26). Retrieved from https://www.verifiedmarketresearch.com/product/global-agriculture-robots-market-size-and-forecast-to-2025/

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, *28*(2), 118–144. doi:10.1016/j.jsis.2019.01.003

Viani, F., Bertolli, M., Salucci, M., & Polo, A. (2017). Low-cost wireless monitoring and decision support for water saving in agriculture. *IEEE Sensors Journal*, *17*(13), 4299–4309. doi:10.1109/JSEN.2017.2705043

Vinnikov, K. Y., Liu, S., Speranskaya, N. A., Hollinger, S. E., Namkhai, A., Entin, J. K., ... Srinivasan, G. (2002). The Global Soil Moisture Data Bank. *Bulletin of the American Meteorological Society*, *81*(6), 1281–1299. doi:10.1175/1520-0477(2000)081<1281:tgsmdb>2.3.co;2

Vishwa, G., Venkatesh, J., & Geetha, C. (2019). Crop Variety Selection Method using. *Machine Learning*, *12*(4), 35–38.

Vishwakarma, R., & Choudhary, V. (2011). Wireless solution for irrigation in agriculture. *IEEE International Conference on Signal Processing, Communication, Computing and Networking Technologies*.

Vossen, P. (2006). Changing PH in Soil. *University of California Cooperative Extension, 11*, 1–2. https://vric.ucdavis.edu/pdf/Soil/ChangingpHinSoil.pdf

Vyas, D., Borole, A., & Singh, S. (2016). Smart Agriculture Monitoring and Data Acquisition System. *International Research Journal of Engineering and Technology*, *3*(3), 1823–1826.

WalchK. (2020, June 26). Retrieved from Forbes: https://www.forbes.com/sites/cognitiveworld/2019/07/05/how-ai-is-transforming-agriculture/#3e36b1f84ad1

Walter, A., Finger, R., Huber, R., & Buchmann, N. (2017). Smart farming is key to Developing Sustainable Agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, *114*(24), 6148–6150. doi:10.1073/pnas.1707462114 PMID:28611194

Wang & Liu. (2014). The application of internet of things in agricultural means of production supply chain management. *Journal of Chemical and Pharmaceutical Research, 6*(7), 2304-2310.

Wang, L., Guo, S., Huang, W., & Qiao, Y. (2015). Places205-vggnet models for scene recognition. *arXiv preprint arXiv:1508.01667*.

Wang, N., Zhang, N., & Wang, M. (2006). *Wireless sensors in agriculture and food industry — Recent development and future perspective.* doi:10.1016/j.compag.2005.09.003

Wang, X., & Liu, N. (2014). The application of internet of things in agricultural means of production supply chain management. *Journal of Chemical and Pharmaceutical Research, 6*(7), 2304-2310.

Wang, H. H., Wang, Y., & Delgado, M. S. (2014). The transition to modern agriculture: Contract farming in developing economies. *American Journal of Agricultural Economics*, *96*(5), 1257–1271. doi:10.1093/ajae/aau036

Wang, Q., Terzis, A., & Szalay, A. (2010). A Novel Soil Measuring Wireless Sensor Network. *IEEE Transactions on Instrumentation and Measurement*, 412–415.

Wang, X. (2016). The vehicle routing problem with drones: Several worst-case results. *Optimization Letters*, *11*, 1–19.

Wang, X., Yang, W., Wheaton, A., Cooley, N., & Moran, B. (2010). Efficient registration of optical and IR images for automatic plant water stress assessment. *Computers and Electronics in Agriculture*, *74*(2), 230–237. doi:10.1016/j.compag.2010.08.004

Weiser, M. (1991). *The Computer For The 21st Century*. Retrieved from https://www.ics.uci.edu/~corps/phaseii/Weiser-Computer21stCentury-SciAm.pdf

Welch, S. M. (1984). Developments in computer-based IPM extension delivery systems. *Annual Review of Entomology*, *29*(1), 359–381. doi:10.1146/annurev.en.29.010184.002043

Weller, S., Culbreath, A., Gianessi, L., Godfrey, L., Jachetta, J., Norsworthy, J., & Madsen, J. (2014). The contributions of pesticides to pest management in meeting the global need for food production by 2050. *Issue Paper - Council for Agricultural Science and Technology*, (55), 1–28.

Weltzien, C. (2016). Digital agriculture or why agriculture 4.0 still offers only modest returns. *Landtechnik*, *71*(2), 66–68.

Wognum, P. M. N., Bremmers, H., Trienekens, J. H., van der Vorst, J. G. A. J., & Bloemhof, J. M. (2011). Systems for sustainability and transparency of food supply chains—Current status and challenges. *Advanced Engineering Informatics*, *25*(1), 65–76. doi:10.1016/j.aei.2010.06.001

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M.-J. (2017). Big Data in Smart Farming – A review. *Agricultural Systems*, *153*, 69–80. doi:10.1016/j.agsy.2017.01.023

Works, I. C. T. (2019). *5 Problems with 4th Industrial Revolution – Your Weekend Long Reads*. Available: https://www.ictworks.org/problems-fourth-industrial-revolution

World Bank Group. (2016). *The World Bank Group A to Z 2016*. World Bank Publications.

World Economic Forum. (2018). System Initiative on Shaping the Future of Food Security and Agriculture: Innovation with a purpose, the role of technology innovation in accelerating food systems transformation. Author.

World Economic Forum. (2019a). *System Initiative on Shaping the Future of Food, Innovation with a purpose, Improving Traceability in Food Value Chains through Technology Innovations*. Author.

World Economic Forum. (2019b). *The fourth industrial revolution food systems are ripe for technology disruption*. Available: https://www.fodnavigator.com/article/2019/01/23/

Wu, J. (2017). Introduction to convolutional neural networks. National Key Lab for Novel Software Technology. Nanjing University.

WWAP (World Water Assessment Programme). (2012). *The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk*. Paris: UNESCO. Retrieved from http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/WWDR4%20Volume%201-Managing%20Water%20under%20Uncertainty%20and%20Risk.pdf

Xavier, L. J., & Boyetchko, S. M. (2004). Arbuscular mycorrhizal fungi in plant disease control. *Fungal biotechnology in agricultural, food, and environmental applications*, 183-194.

Yadav, E. P., Mittal, E. A., & Yadav, H. (2018). IoT: Challenges and Issues in Indian Perspective. *Proceedings - 2018 3rd International Conference On Internet of Things: Smart Innovation and Usages, IoT-SIU 2018*, 1–5. 10.1109/IoT-SIU.2018.8519869

Yaghoubi, S., Akbarzadeh, N. A., Bazargani, S. S., Bazargani, S. S., Bamizan, M., & Asl, M. I. (2013). Autonomous robots for agricultural tasks and farm assignment and future trends in agro robots. *International Journal of Mechanical and Mechatronics Engineering*, *13*(3), 1–6.

Yahya, N., (2018). Agricultural 4.0: Its implementation toward future sustainability. In *Green Urea*. Springer.

Yalcin, H. (2018). Phenology recognition using deep learning: DeepPheno. *26th IEEE Signal Processing and Communications Applications Conference, SIU 2018*, 1–4. 10.1109/SIU.2018.8404165

Yan-e, D. (2011). Design of intelligent agriculture management information system based on IoT, *Fourth International Conference on Intelligent Computation Technology and Automation*, 1, 1045–1049. 10.1109/ICICTA.2011.262

Yang, Y., & Miao, Y. (2017). A path planning method for mobile sink in farmland wireless sensor network. *IEEE 2nd Information Technology, Networking, Electronic and Automation Control Conference (ITNEC)*. 10.1109/ITNEC.2017.8284957

Yao, Y., & Yao, Y. (2019). Design and Research of Intelligent Irrigation Things Cloud System. *2019 International Conference on Information Technology and Computer Application (ITCA)*, 167-170. doi:10.1109/ITCA49981.2019.0004310.1109/ITCA49981.2019.00043

Yaqoob, I., Ahmed, E., Hashem, I. A. T., Ahmed, A. I. A., Gani, A., Imran, M., & Guizani, M. (2017). Internet of things architecture: Recent advances, taxonomy, requirements, and open challenges. *IEEE Wireless Communications*, *24*(3), 10–16. doi:10.1109/MWC.2017.1600421

Ye, J., Chen, B., Liu, Q., & Fang, Y. (2013, June). A precision agriculture management system based on Internet of Things and WebGIS. In *2013 21st International Conference on Geoinformatics* (pp. 1-5). IEEE. 10.1109/Geoinformatics.2013.6626173

Yong, W., Shuaishuai, L., Li, L., Minzan, L., Arvanitis, K. G., Georgieva, C., & Sigrimis, N. (2018). Smart sensors from ground to cloud and web intelligence. *IFAC-PapersOnLine*, *51*(17), 31–38. doi:10.1016/j.ifacol.2018.08.057

Yoo, S., Kim, J., Kim, T., Ahn, S., Sung, J., & Kim, D. (2007). A2S: Automated agriculture system based on WSN. In *ISCE 2007. IEEE International Symposium on Consumer Electronics*. https://agribotix.com/wp-content/uploads/2016/04/WhatFarmersNeedToKnow_web.pdf

Yu, H., Sun, Q., Sheng, K., & Wang, Z. (2016). Intelligent street lamp control system using ZigBee and GPRS technology. *International Journal of Simulation-Systems, Science & Technology, 17*(35), 36.1–36.13.

Yuan, G., Luo, Y., Sun, X., & Tang, D. (2004). Evaluation of a crop water stress index for detecting water stress in winter wheat in the North China Plain. *Agricultural Water Management*, *64*(1), 29–40. doi:10.1016/S0378-3774(03)00193-8

Zaidan, A. A., Zaidan, B. B., Qahtan, M. Y., Albahri, O. S., Albahri, A. S., Alaa, M., Jumaah, F. M., Talal, M., Tan, K. L., Shir, W. L., & Lim, C. K. (2018). A survey on communication components for IoT-based technologies in smart homes. *Telecommunication Systems*, *69*(1), 1–25. doi:10.100711235-018-0430-8

Zaier, R., Zekri, S., Jayasuriya, H., Teirab, A., Hamza, N., & Al-Busaidi, H. (2015). Design and implementation of smart irrigation system for groundwater use at farm scale. *7th International Conference on Modeling, Identification and Control (ICMIC)*, 1–6. 10.1109/ICMIC.2015.7409402

Zambon, I., Cecchini, M., Egidi, G., Saporito, M. G., & Colantoni, A. (2019). A. Revolution 4.0: Industry vs. Agriculture in a Future Development for SMEs. *Processes (Basel, Switzerland)*, *2019*(7), 36. doi:10.3390/pr7010036

Zhang, P., Zhang, Q., Liu, F., Li, J., Cao, N., & Song, C. (2017). The construction of the integration of water and fertilizer smart water saving irrigation system based on big data. *IEEE International Conference on Computational Science and Engineering (CSE) and IEEE International Conference on Embedded and Ubiquitous Computing (EUC), 2*, 392–397.

Zhang, M., Crocker, R. L., Mankin, R., Flanders, K., Hickling, R., & Brandhorst-Hubbard, J. (2000). Inferring activities and incidental soil-borne sounds of white grubs. In *Proceedings of the XXI International Congress of Entomology* (Vol. 1, p. 238). Londrina, Brazil: Academic Press.

Zhang, Q., Yang, X., Zhou, Y., Wang, L., & Guo, X. (2007). A wireless solution for greenhouse monitoring and control system based on zigbee technology. *Journal of Zhejiang University. Science A*, *8*(10), 1584–1587. doi:10.1631/jzus.2007.A1584

Zhang, S., Chen, X., & Wang, S. (2017). Research on the monitoring system of wheat diseases, pests and weeds based on IoT. *9th International Conference on Computer Science Education*, 981–985.

Zhu, N., Liu, X., Liu, Z., Hu, K., Wang, Y., Tan, J., Huang, M., Zhu, Q., Ji, X., Jiang, Y., & Guo, Y. (2018). Deep learning for smart agriculture: Concepts, tools, applications, and opportunities. *International Journal of Agricultural and Biological Engineering*, *11*(4), 21–28. doi:10.25165/j.ijabe.20181104.4475

Zhu, N., Marais, J., Betaille, D., & Berbineau, M. (2018). GNSS Position Integrity in Urban Environments: A Review of Literature. *IEEE Transactions on Intelligent Transportation Systems*, *19*(9), 2762–2778. doi:10.1109/TITS.2017.2766768

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