distal sensing techniques. The utilization of high-resolution data is of utmost importance in the context of soil testing. In contrast to remote sensing, which necessitates the installation of sensors in aerial or satellite systems, proximity sensing only necessitates the placement of sensors in close proximity to the ground. This facilitates the characterization of the sub-surface soil in a specific geographical region. The implementation of data-collecting software and robotics has facilitated the development of hardware solutions such as Rowbot, which focuses on optimizing fertilizer application for corn cultivation in order to enhance crop yield.

Image-Based Insight Generation

Precision farming has emerged as a highly debated topic within the realm of agriculture. The utilization of drone-captured imagery has the potential to facilitate comprehensive crop monitoring and field surveys by providing detailed information. Farmers will possess the capability to promptly react due to the integration of computer vision technologies, drone data, and the Internet of Things. The utilization of drone imagery data has the potential to elicit immediate alerts, thereby expediting the precision farming procedure. Large-scale drone designers like aerialtronics, have implemented IBM's Watson Visual Recognition APIs and IoT Platform to facilitate real-time analysis of images. The subsequent instances illustrate potential applications for computer vision technology:

Disease Detection

Convolutional Neural Networks (CNNs) have demonstrated notable efficacy in the field of plant disease classification in recent times. As a result of consistently achieving superior results, scholars have increasingly shown a preference for the multi-layered supervised network. CNN architecture has undergone significant revolutionary advancements since the initial publication of LeNet in [4]. Contemporary building design frequently incorporates complex features, such as ReLu nonlinearity and overlapping pooling. These technological advancements have contributed to a reduction in the duration of training as well as the error rate. The advent of the 21st century has brought about the need for a redesign in response to the increasing size and complexity of datasets. Recent architectural advancements, exemplified by ResNet, have integrated additional pioneering elements. Both the dynamic skip connections and extensive batch normalization are integral components of this system. As a result, the rate of learning during training may advance notably. In a study conducted by Victor Ikechukwu, Murali, Deepu, and Shivamurthy [5], it was found that ResNet exhibited superior performance compared to VGGNet, GoogLeNet, and DenseNet in the context of disease diagnosis in grape leaves.

AlexNet, LeNet, and GoogleNet are among the prominent contemporary architectures commonly employed as the foundation for customized constructions. In [6], on the classification of Soybean diseases, Jadhav, Udupi, and Patil introduced a framework inspired by the LeNet architecture. The proposed framework, integrating 3 convolutional layers: max-pooling layer, completely linked MLP (multi-layer perception) with ReLU (Rectified Linear Unit) activation, achieved a high accuracy of 99% in predicting labels. Plant leaf images are partitioned into distinct components, namely the background, diseased region, and healthy area, through the utilization of image sensing and analysis techniques to extract relevant information. The process of excising the impaired or polluted tissue involves its surgical removal, followed by its subsequent transfer to a laboratory for further examination and analysis. This methodology proves advantageous not only in identifying insufficiencies in vitamins but also in pinpointing the presence of pests. **Fig 2** illustrates a comprehensive sequence.

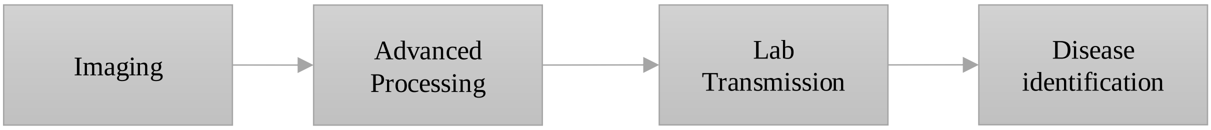

Fig 2. Disease Detection

Identify the Readiness of the Crop

In order to assess the level of ripeness of their unripe fruits, agricultural practitioners capture images of their produce under two distinct lighting conditions: white light and ultraviolet A (UVA) light. This data could be utilized by farmers to categorize their crops based on different stages of maturity. Subsequently, prior to their distribution to the market, it is advisable to thoroughly intermingle the items into diverse assortments.

Field Management

By utilizing aerial imagery obtained from unmanned aerial vehicles (UAVs) and helicopters, agricultural practitioners have the capability to generate precise field maps. These maps enable farmers to identify specific areas within their fields that require immediate attention for the application of water, fertilizer, or pesticides. This real-time analysis allows for targeted interventions to optimize crop growth and productivity. This significantly contributes to the optimization of resources.

Identification of Optimal Mix for Agronomic Products

Several factors, such as soil condition, weather prediction, seed type, and insect infestation, can influence the recommendations provided by cognitive solutions for determining the optimal crops and hybrid seeds to be utilized in a specific location. A customized recommendation that considers the unique requirements of the farm, the regional climate, and historical data on agricultural productivity. Farmers can make a well-informed decision by taking into account market and crop price trends, customer preferences and demands, as well as aesthetic considerations.

Crop Health Monitoring

The development of agricultural metrics for extensive agricultural areas necessitates the utilization of remote sensing (RS) techniques, including hyper spectral photography and 3D laser scanning. From the perspectives of temporal and labor considerations, this technology holds the capacity to bring about a transformative shift in the manner in which farmers oversee their land. This technology will be utilized to monitor the lifespan of crops, enabling the identification and reporting of anomalies at their origin.

In order to enhance agricultural productivity and effectiveness, Dessales, Richard, Poussard, Vauzelle, and Martinsons [7] proposed the development of a wireless sensor network system for monitoring field conditions. Sensors can be employed to monitor various parameters such as water level, humidity, temperature, and other factors within environments. The system was developed utilizing the ZigBee protocol, incorporating processors such as IC-S8817 BS and ATMEGA8535, analog-to-digital conversion, and wireless sensor nodes equipped with a wireless transceiver module. Data is retrieved and stored through the utilization of a database in conjunction with a web application. In this experimental study, we implement measures to account for the potential failure of individual sensor nodes and to optimize energy efficiency. Arunkumar, Ramaswamy, and Murugesh [8] conducted experiments on a monitoring system for intelligent agricultural greenhouses based on ZigBee technology. The system has the capability to collect data, analyze it, transmit it, and receive it.

Liu, Shao, and Sun [9] aim to develop a greenhouse system capable of effectively managing the ambient conditions, reducing agricultural costs, and conserving energy. The IoT technology is built upon the B-S architecture, wherein the cc2530 chip is utilized as the processor for both the wireless sensor node and coordinator. The device is equipped with a Linux operating system and a central cortex A8 CPU, which contribute to its robust capabilities. In general, the concept enables the remote and intelligent monitoring and management of the greenhouse, thereby eliminating the requirement for expensive human labor and wired technology.

The experiment that suggested the utilization of wireless sensor networks (WSN) for the purpose of automating irrigation was conducted by Kavra, Gupta, and Kansal [10]. The utilization of automatic communication for the purpose of acquiring information on soil moisture conditions in irrigation design has led to the development of wireless sensor network (WSN)-based irrigation control and rescheduling, which have proven to be effective tools for enhancing water management efficiency. This method employs a calculation technique to determine the most optimal watering frequency and timing, with the aim of conserving water, promoting crop health, and reducing losses resulting from delays in detection and load. OPNET offers agricultural simulation services.

The utilization of a distinct wireless sensor network (WSN) design within the Zigbee protocol for the irrigation system will have an impact on the duration of battery life. Given the nascent stage of wireless sensor networks (WSNs), it is pertinent to acknowledge the presence of several limitations in this domain, encompassing sluggish connection speeds, susceptibility to security breaches, elevated power consumption, and communication breakdowns within the agricultural sector. Wireless sensor networks are employed for the purpose of automating the irrigation system and its scheduling. Wireless Sensor Networks (WSNs) exhibit energy efficiency due to their inherent characteristics of low data rate and power consumption [11]. The operation of all systems is governed by the data obtained from sensors that are strategically embedded within the ground. Farmers have the ability to assess the functionality of the system and determine whether any remedial actions are necessary.

The study conducted by Ochepo [12] investigated the endeavors of the rural agricultural community to embrace novel approaches over traditional ones. The sensor nodes are furnished with a variety of supplementary sensors, encompassing those that gauge soil moisture, soil pH, air pressure, and the moisture content of the adjacent foliage. The soil moisture sensor integrated into the mote device initiates the activation of the watering system in periods of low soil moisture, and subsequently deactivates it once the appropriate quantity of water has been dispensed. The pH level of the soil is transmitted to the central base station, and the farmer is notified of the soil's pH via SMS utilizing the Global System for Mobile Communications (GSM) framework, leading to water conservation. Farmers have the potential to utilize this data in order to reduce their reliance on fertilizer. In order to facilitate real-time monitoring of rice harvests and optimize productivity for farmers, it is proposed to develop a rice crop monitoring system based on Wireless Sensor Networks (WSNs). Wireless sensor networks are employed for the purpose of automating the control of water sprinklers and facilitating the dissemination of information.

Automation Techniques in Irrigation and Enabling Farmers

The process of irrigation in agriculture is characterized by its requirement of significant time and labor investment. Automated irrigation systems, enabled by artificial intelligence (AI), can optimize agricultural output by leveraging machine learning algorithms to identify patterns in weather, soil conditions, and crop preferences. Approximately 70% of the global freshwater resources are allocated for irrigation purposes. Consequently, any technological advancements aimed at enhancing water management for agricultural purposes are highly sought after by farmers.

The greenhouse monitoring system for smart agriculture was developed by Kochhar, Kumar, and Aneja [13], utilizing ZigBee technology. The system performed a range of tasks including data capture, processing, transmission, and reception. The selected approach proved to be a favorable decision in terms of effectively managing the surrounding ecosystem, reducing agricultural expenditures, and promoting energy conservation. The wireless sensor node and coordinator utilized the B-S architecture and the cc2530 as its processor chip. The core components of the system consist of the Linux operating system and the Cortex A8 processor. The architectural design enables remote monitoring and control of intelligent greenhouse systems. The implementation of wireless technology eliminates the requirement for expensive wired infrastructure and reduces labor costs.

Furthermore, the security concerns pertaining to the Internet of Things (IoT) have been examined by [14]. The authors underscore the correlation between the extensive utilization of the system and the emergence of these issues. The Internet of Things (IoT) presents a number of security concerns that arise from its initial design and persist throughout its various functionalities. The individuals formulated solutions to address these issues and implemented protective measures to mitigate their occurrence. The prominence of algorithm and key management, secure routing systems, and data fusion technologies is evident through the perception layers. Authentication and other access control measures were implemented by the individuals. A proposal has been put forth by [15] for the implementation of a remote observation system. This system utilizes ZigBee modules to enable real-time monitoring of farmland and facilitate informed decision-making based on the collected data. The integration of data is facilitated through the utilization of a high-performance ARM microcontroller.

Following the data collection process, GPRS modules facilitate the transmission of gathered information to a distant computer system, which subsequently enables the utilization of such data for informed decision-making in management contexts. This approach not only enhances agricultural productivity but also reduces labor costs.

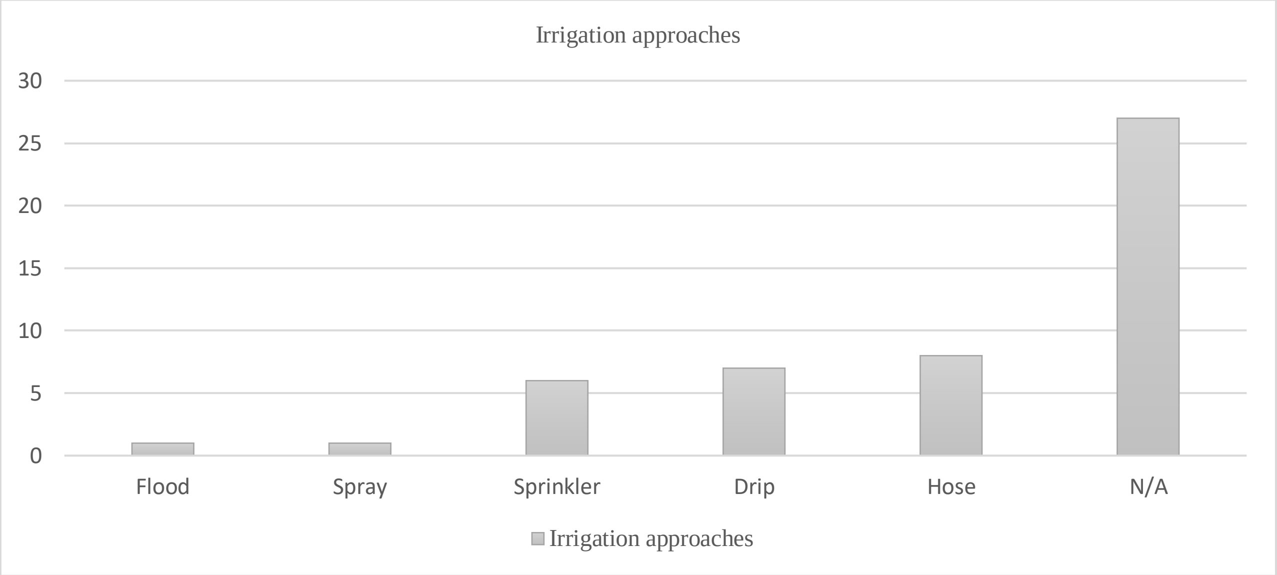

Fig 3. Different Irrigation Approaches

Fig 3 displays publications that have conducted analyses on irrigation methods. The abbreviation "N/A" is used to indicate cases where the specific irrigation method utilized is not discernible. Additionally, **Fig 3** includes publications that propose the use of modeling or simulations for irrigation analysis. In scholarly literature, papers that introduce minimal prototypes frequently allude to hoses within the framework of irrigation. The majority of articles provide a brief mention of the utilization of solenoid valves or water pumps, as depicted in **Fig 3**, without explicitly specifying the particular irrigation method employed.

IV. DRONE TECHNOLOGY

According to recent research conducted by PWC (Price Water House Coopers), there exists a global market for drone-based solutions estimated to be valued at $127.3 billion [16]. The agricultural industry has a market value of $32.4 billion. Such The agricultural industry has found numerous applications for drone-based solutions, including mitigating the impact of adverse weather conditions, enhancing production levels, implementing more accurate farming techniques, and managing crop yields. Unmanned aerial vehicles (UAVs), also referred to as unmanned airframes (UAS), are aircraft that are operated remotely and do not require the presence of a human pilot. They engage in collaboration with the Global Positioning System (GPS) and other integrated sensors. Drones are increasingly employed in agricultural contexts for a diverse range of applications, such as monitoring crop conditions and irrigation infrastructure, identifying and addressing invasive plant species, surveilling livestock and wildlife populations, and facilitating emergency response efforts. The utilization of unmanned aerial vehicles (UAVs) in the context of remote sensing, encompassing activities such as image acquisition, processing, and analysis, is significantly impacting the agricultural sector. The agricultural industry has demonstrated a strong inclination towards embracing novel innovations, particularly through the adoption of propelled devices to modify traditional farming methods.

Based on an ongoing study conducted by [17], it has been determined that the total addressable estimate of automation-driven arrangements in various industries exceeds USD 127 billion. In order to obtain high-quality images, one may draw a comparison between them and a conventional, easily-operated camera. Nevertheless, although a conventional camera can offer certain insights into plant growth, inclusion, and related aspects, the incorporation of a multispectral sensor enhances the efficacy of the procedure and allows farmers to observe phenomena that are imperceptible to the unaided human eye, such as soil moisture levels and the monitoring of plant health. These strategies have the potential to effectively mitigate the numerous challenges associated with agricultural productivity. Unmanned Aerial Vehicles (UAVs) incorporate Wireless Sensor Networks (WSN) during their design and implementation processes. The utilization of Wireless Sensor Network (WSN) data enables Unmanned Aerial Systems (UAS) to enhance their operational efficiency, such as by restricting the application of synthetic substances exclusively to specific regions. Given the unpredictable and continuous fluctuations in environmental conditions, it is imperative for the governing body to respond with utmost expediency.

The act of reconciling with Wireless Sensor Networks (WSN) may be considered a positive and progressive measure in addressing the matter at hand. Nevertheless, the hardware implementations of UAVs are predominantly focused on crucial factors such as weight, flight range, payload capacity, configuration, and costs. This emphasis on these aspects imposes limitations on the effectiveness of UAVs in precision agriculture applications, specifically in tasks like field and soil analysis, crop height determination, pesticide spraying, and crop monitoring. The field of UAV research encompasses the examination of various aspects related to UAVs, including their systems, technologies, methodologies, and limitations. To facilitate the selection of the most suitable UAVs for agricultural applications, a comprehensive compilation and examination of more than 250 models is conducted. According to projections, the agricultural drone market is anticipated to witness a growth rate exceeding 38% over the forthcoming years. The projected rise in populations and changing weather patterns is anticipated to augment the demand for the implementation of sustainable agricultural practices.

Crop spraying

To facilitate the operation of unmanned vehicles and their autonomous functioning in the absence of a pilot, unmanned aerial vehicles (UAVs), commonly referred to as drones, heavily rely on advancements in sensor technology and microcontroller systems that have been specifically designed for this application. For several years, farmers have employed unmanned aircraft systems (UAS) to carry out substance spraying activities. These devices are commonly acknowledged as being highly effective and of significant importance, particularly in regions with overcast weather conditions and for accessing areas of tall crops such as maize that were previously difficult to reach. According to Cho et al. [18], it is widely believed that they possess a significant edge in comparison to high-resolution imaging sensors mounted on satellites. Abd El-Hamid [19] made adaptations to air-carriers plantation sprayer equipped with a sprayer control framework based on microcomputer technology. Control calculations were performed using a personal computer that was connected to a foliage volume estimation system utilizing ultrasonic range transducers. The calculations were based on the amount of spray deposited.

Zou, Li, Cai, and Lin [20] employed unmanned aerial vehicles (UAVs), commonly known as drones, to administer synthetic compounds onto agricultural crops. Specifically, the drones were programmed to fly in a coordinated manner, forming a circular pattern to establish a controlled environment. The drones utilized remote sensor networks (WSN) sensors to facilitate the application of synthetic chemicals to crops in the field. The data collected by the remote sensors restricted the drones' ability to apply synthetic chemicals exclusively to the specified regions. Huang, Hoffman, Lan, BFritz, and Thomson [21] constructed a sprayer with a low volume capacity for an autonomous aircraft. The helicopter employed in this investigation possesses a maximum payload capacity of 22.7 kilograms and a primary rotor span measuring 3 meters. Over the course of approximately 45 minutes, consuming approximately one gallon of gasoline. The methodology and its methodical outcomes establish a basis for the advancement of unmanned aerial vehicle (UAV) flight application frameworks, with a focus on enhancing productivity. This includes achieving a higher success rate and increasing the size of the visual marker detection (VMD) droplets.

Hafeez et al. [22] developed a sprayer framework that utilizes an automated flying system, employing an unmanned aerial vehicle as its foundation. The utilized system incorporated a cost-effective and functional module designed specifically for the MSP430 single-chip microcontroller, characterized by its compact form factor and efficient power management capabilities. The designated pathway was developed to facilitate the coordination of UAV in the targeted application of pesticides or desired substances to specific areas of agricultural fields. During the UAV testing, it was observed that the spray consistency exceeded the minimum threshold for the variation coefficient of ultra-low volume spraying. In the year 2010, Zhu et al. [23] designed a precision spraying controller for UAV utilizing Pulse Width Modulation (PWM) technology. This study utilizes a TL494 fixed-recurrence modulator of the pulse width, data collecting board, and custom software to design a pulse width modulation (PWM) controller specifically tailored for an agricultural UAVsprayer. The utilization of pre-modified flight plans enables the remote command or automation of UAV.

The analysis by Prodic, Maksimovic, and Erickson [24] demonstrates that the PWM controller undergoes a significant transformation, rendering it a highly accurate system for various spraying applications. The evaluation of the powerful swath measurement and bead rotation of aeronautical sprinkling models was conducted by Pan, Jiang, Li, and Qinu [25] sing M-18B and Thrush 510G aircraft. In this study, a comparison was conducted to assess the droplet dispersal power and swath breadth of two agricultural aircraft models, namely the M-18B and the Thrush 510G. The aircraft were evaluated while flying at altitudes of 5 m and 4 m, respectively. The implications of this analysis suggest that the discrepancy in swath widths between the two agricultural aircraft can be attributed to their distinct flying characteristics.

The sprayer is the apparatus accountable for the fragmentation of the liquid being dispersed, encompassing suspensions, emulsions, or solutions, into minute droplets and subsequently discharging them with minimal force to achieve uniform dispersion. Furthermore, it is incumbent upon the regulatory body to oversee and control the appropriate dosage of pesticides, thereby mitigating the occurrence of excessive or superfluous applications. The excessive utilization of pesticides could potentially exert detrimental impacts on both soil quality and agricultural output. Dusters are additionally employed for the dissemination of information pertaining to pesticide residue. Sprayers are categorized into four distinct groups based on the type of energy employed for the atomization and propulsion of the liquid shower. These groups include gaseous energy, hydraulic energy, kinetic energy, and centrifugal energy.

Crop Monitoring

The utilization of advanced sensors and imaging technologies in agriculture has presented a wide range of possibilities for enhancing crop productivity and reducing yield losses. In recent years, there has been a notable shift in the practical application of unmanned aircraft. Continuous advancements are consistently enhancing the techniques employed in surveying, data collection, and analysis. Furthermore, novel sensors are being integrated into UAV to effectively function as the client's visual apparatus on the field. Aerial surveys have been a well-established practice within the agriculture industry for a considerable period of time. Satellites have been utilized for the past ten years to survey extensive croplands and forests; however, UAVs have introduced a heightened level of precision and adaptability to this undertaking. UAV flights can be carried out irrespective of the satellite's positioning or prevailing weather conditions. Additionally, operating at an altitude of 400 to 500 feet above the ground provides distinct advantages in terms of enhanced image quality and precise spatial accuracy.

V. PRECISION FARMING

Precision farming is an advanced agricultural approach characterized by enhanced precision and regulation, which reduces the reliance on manual labor and instead employs automation and strategic guidance, particularly in the context of crop rotation. Technologies that enable precision farming encompass a range of applications, including variable-rate technology, high-precision positioning systems, remote sensing, geological mapping, water resource management, integrated electronic communication, estimators for determining optimum planting and harvesting times, plant and soil nutrient management, and mitigation of pest and rodent attacks, among others. The objectives of precision agriculture are outlined in **Table 1**.

Table 1. Objectives of Precision Agriculture

Profitability	This aims to strategically analyze the selection of crops and markets, as well as estimate the Return on Investment (ROI) through the utilization of cost and gross profit projections.
Efficiency	By employing a precise algorithm, agricultural practitioners can leverage accelerated and cost-effective cultivation. Consequently, resources can be utilized in a more efficient manner universally.
Sustainability	Enhanced environmental and socioeconomic management ensures consistent and cumulative benefits for all stakeholders, year after year.

Cases of Precision Farming Management

The utilization of high-resolution imagery and diverse sensor data enables artificial intelligence (AI) to discern and evaluate the stress level of a plant. The compilation of diverse sources of information is imperative for the utilization of training data in AI systems. The fusion of identifying criteria and data is facilitated for the purpose of plant stress detection (see **Fig. 4**). AI machine learning models were developed using a diverse range of plant photographs to accurately detect and classify different indicators of plant stress. In order to enhance decision-making capabilities, it is advisable to deconstruct this all-encompassing strategy into four distinct phases: identification, classification, quantification, and prediction (as illustrated in **Fig 4**).

Yield management using AI

A smart, efficient, and sustainable farming ecosystem is currently under development, incorporating advanced technologies such as artificial intelligence (AI), cloud-based machine learning (ML), satellite imagery, and sophisticated analytics. The convergence of these technologies enables farmers to enhance their average output per hectare and exert greater influence on the price of grain. Microsoft has initiated a collaboration with farmers in the Indian state of Andhra Pradesh to offer agricultural advisory services. This collaboration utilizes the Cortana Intelligence Suite, which integrates Machine Learning and Power BI technologies, enabling the conversion of data into actionable insights.

The implementation of an artificial intelligence (AI) based sowing application in this pilot project resulted in a notable 30% increase in the average crop yield per hectare. This application offered farmers valuable recommendations pertaining to various aspects of farming, including, land preparation, sowing date, fertigation based on soil analysis, FYM application and requirement, seed selection and treatment, as well as optimization of sowing depth. Artificial intelligence models have the potential to be employed for the purpose of ascertaining the optimal timing for seed planting, taking into consideration various factors such as prevailing weather conditions, average precipitation levels, and soil moisture levels.

Microsoft and United Phosphorus Limited are collaborating on the development of a Pest Risk Prediction Application Programming Interface (API) that aims to provide advance warning regarding the probability of an imminent pest infestation (see **Fig 5**). The application programming interface (API) will leverage artificial intelligence (AI) and machine learning (ML) methodologies. Pest attacks are classified into high, medium, or low categories, taking into account various factors such as anticipated weather conditions and the stage of crop growth in the field.

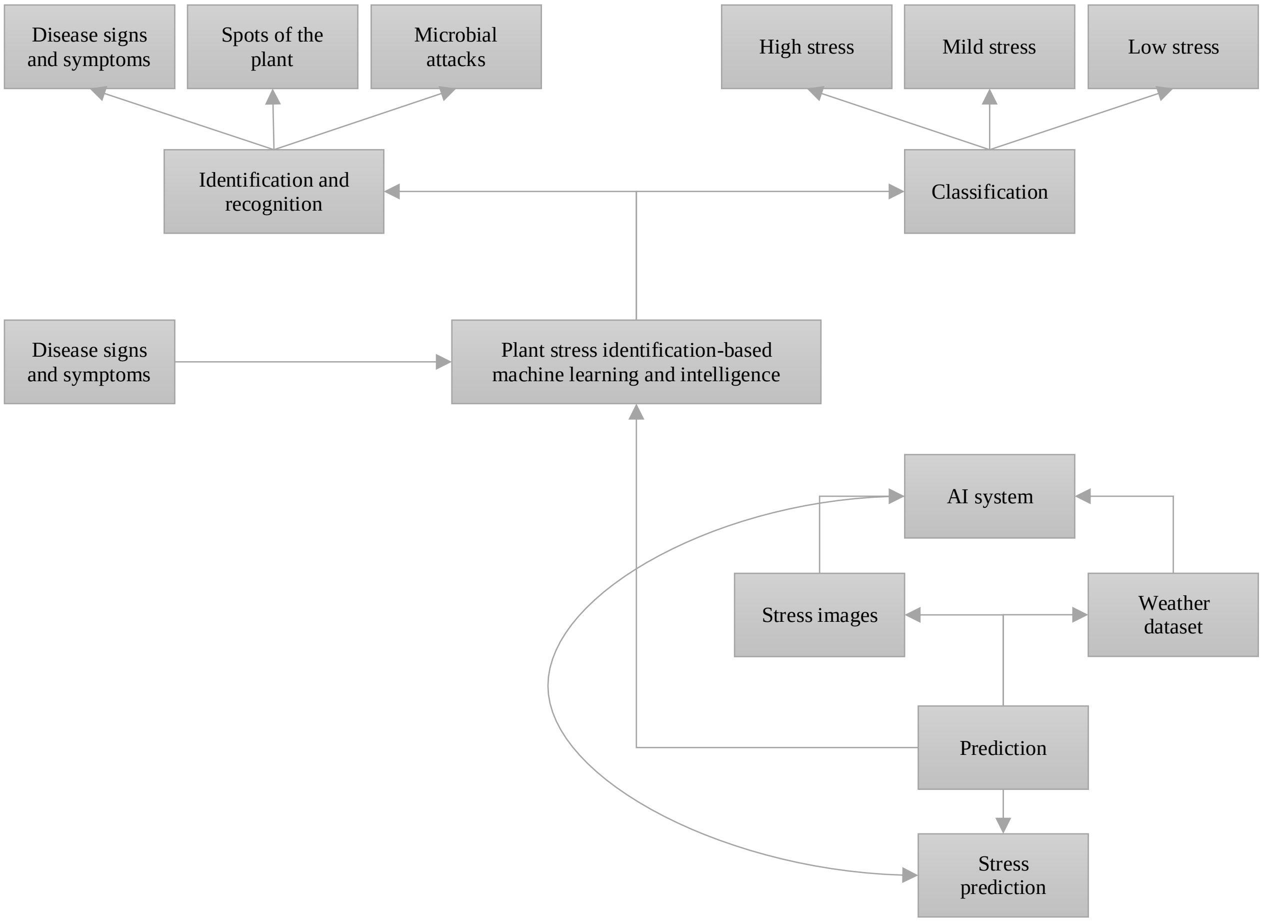

Fig 4. Plant Stress Recognition Using Machine Learning and Artificial Intelligence

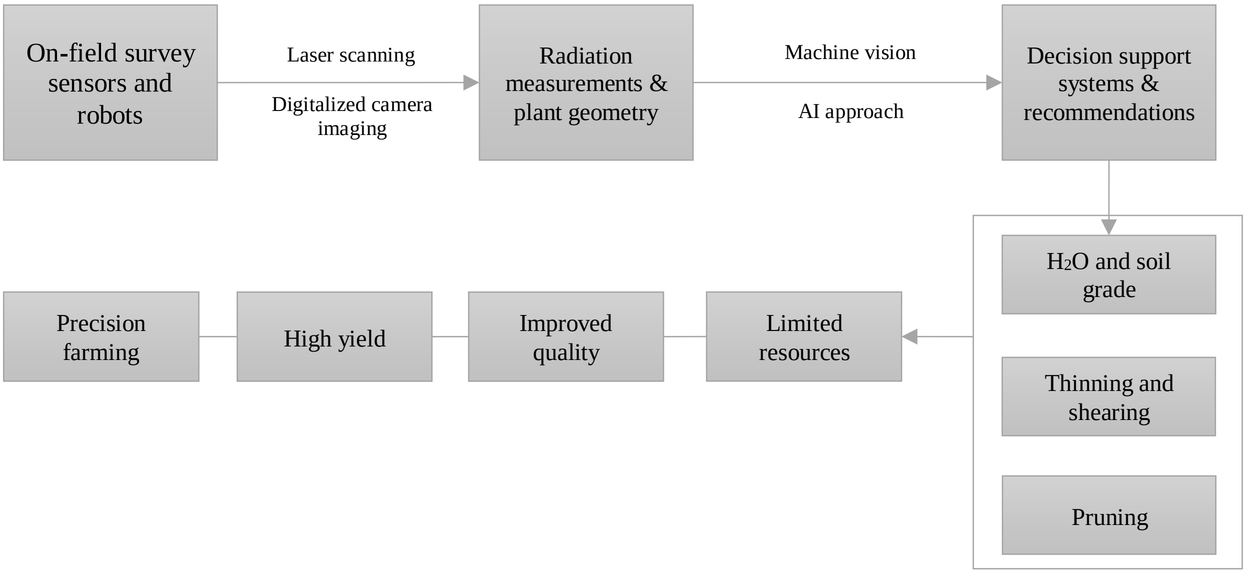

Fig 5. Robotics in Digitalized Farming

VI. CHALLENGES IN AI ADOPTION IN AGRICULTURE

There exists a notable dearth of knowledge regarding advanced and innovative machine learning solutions in the agricultural sector worldwide, despite the substantial potential that artificial intelligence (AI) holds for various agricultural applications. The agricultural sector is highly susceptible to the impacts of environmental factors, including climate conditions, soil quality, and pest infestations. The efficacy of an initially well-conceived crop cultivation strategy may be compromised during the harvesting phase as a result of external factors. Similarly, AI systems require a substantial volume of data for training in order to achieve accurate predictive capabilities. Obtaining time data can pose challenges, whereas acquiring geographical data is typically more accessible, particularly when dealing with extensive agricultural land. The crop-specific data was exclusively accessible during the duration of the growth period. The time required to develop a dependable AI machine learning model is prolonged due to the delayed advancement of databases. This is the reason why artificial intelligence (AI) is increasingly employed in agronomic products like pesticides, seeds, and fertilizers, instead on on-field precision approaches.

Farmers face a multitude of challenges, including inadequate irrigation infrastructure, escalating temperatures, diminishing groundwater resources, food scarcity, and waste management concerns. The outcome of a cultivation endeavor is significantly influenced by the adoption of diverse cognitive strategies. Despite the ongoing research efforts and the availability of certain applications, it is evident that the market remains significantly underserved. The agricultural industry is currently in its early stages of addressing practical difficulties encountered by farmers and applying digital predictive and decision-making approaches to mitigate these issues. In order to comprehensively explore the extensive possibilities of artificial intelligence in the field of agriculture, it is imperative to enhance the quality of applications. Only in that circumstance will it possess the capability to proficiently adjust to evolving external circumstances, facilitate on-time decision making, and implement effective models and platforms for the retrieval of contextual information and data. The exorbitant cost associated with the majority of cognitive solutions currently available in the agricultural industry represents a significant factor to be taken into account.

In order to optimize the widespread applicability of technology, it is imperative to reduce solution costs. The accessibility and adoption rates of the solutions could be enhanced if they were developed on an open source platform. This new technology is expected to yield increased agricultural productivity and enhance the quality of seasonal crops, thereby providing farmers with substantial benefits. Farmers in various countries, such as India, depend on the yearly monsoon precipitation for agricultural cultivation. Official weather forecasts are highly valued in the context of rain-fed agriculture. The utilization of artificial intelligence technologies would greatly facilitate the weather patterns forecasting and other agriculturally significant factors like groundwater levels, soil quality, crop cycles, and insect infestations. The implementation of AI technology enables farmers to benefit from accurate projections and forecasts, thereby mitigating a significant portion of their concerns.

The utilization of sensors powered by artificial intelligence holds the potential to assist farmers in the acquisition of vital information across various domains. The data collected will contribute to the enhancement of productivity. The utilization of these sensors in the agricultural industry holds significant promise. To enhance the cultivation process, agricultural scientists may gather data pertaining to various factors such as weather conditions, soil quality, groundwater levels, and other relevant parameters. The application of AI technology on robotic harvesting machinery enables the integration of sensors for data collection purposes. The utilization of AI-based expert advice has the potential to enhance productivity by up to 30%. The primary challenge faced by farmers is the detrimental impact on crops resulting from natural disasters or the invasion of insects. The primary cause of agricultural failures is attributed to farmers' deficiency in crucial knowledge. In the contemporary era of digitalization, this technological advancement has the potential to assist farmers in protecting their crops from unauthorized access. The utilization of artificial intelligence will facilitate the process of image identification.

An escalating number of enterprises are employing unmanned aerial vehicles (UAVs), commonly known as drones, for the purpose of monitoring production processes and identifying instances of insect infestations. The existence of multiple previous achievements serves as a driving force for the development of a comprehensive system aimed at monitoring and protecting agricultural production. The robotic lens amplifies the appearance of a golden bloom on a tomato seedling. The computer vision system utilizes image analysis techniques to ascertain the optimal time for harvesting a tomato by examining the plant's images. This enables the identification of a ripe tomato, which is good for packaging and placement in the fresh produce section of a supermarket.

The initiative being established and studied by the NatureFresh Farms, a firm with a 20-year history in vegetable cultivation spanning 185 acres across Ontario and Ohio, is currently under investigation. In accordance with the statements made by Keith Bradley, the IT Manager at NatureFresh Farms, having accurate knowledge of the projected quantity of tomatoes available for purchase in the future simplifies the tasks of the sales personnel and promptly enhances the financial performance of the company [26]. Artificial intelligence (AI) is significantly transforming the agricultural sector, exemplifying one of the numerous avenues through which it is revolutionizing the industry. Despite the observed impacts of climate change, such as altered growing seasons, desertification of arable land, and inundation of previously fertile deltas by seawater, the utilization of artificial intelligence presents a potential solution for humanity to confront a significant challenge: providing sustenance for an additional 2 billion individuals by the year 2050.

According to projections made by the United Nations [27], it is anticipated that there will be a need to augment food production by 49.9% in the middle of the 21st century. The exponential growth of the global population from 3 billion in 1960 to 7 billion in 2015 resulted in a proportional increase in agricultural output, which multiplied by a factor of 3. The success of agricultural development can be attributed to a combination of technological advancements, including the use of pesticides, fertilizers, and machineries, as well as the expansion of cultivated land through activities such as deforestation and the redirection of freshwater resources to agricultural areas such as farms, orchards, and rice paddies. In this instance, it is imperative that we exercise our creative faculties.

In the forthcoming years, it is highly probable that artificial intelligence (AI) will exert a significant influence on the agricultural sector and the overall economy. Farmers have derived advantages from technological advancements through the acquisition of enhanced understanding pertaining to hybrid crops, which have the potential to generate greater financial returns within a shorter timeframe. The appropriate utilization of artificial intelligence (AI) within the agricultural sector has the potential to enhance crop productivity and lay the foundation for economic advancement. Data derived from reputable institutions reveals that a significant amount of food is lost or wasted on a global scale. Implementing appropriate algorithms to tackle this issue would not only result in time and cost savings but also make a valuable contribution to long-term economic development.

The utilization of technological advancements such as AI enhances the prospects of achieving digital transformation within the agricultural sector. Nevertheless, the success of this endeavor heavily relies on the extensive collection of data, a task that proves to be challenging due to the sporadic occurrence of the yearly production cycle. Farmers, on the other hand, demonstrate their ability to adjust to the emerging circumstances by employing AI to facilitate a transformative shift in the agricultural sector. AI is transforming the agricultural sector in various ways, and the aforementioned example serves as a testament to its revolutionary impact on farming. In this instance, it is imperative that we employ our creative faculties.

VII. CONCLUSION AND FUTURE RESEARCH

The development of adaptive cognitive approaches will play a pivotal role in ensuring the enduring viability of agriculture in the forthcoming years. Despite the current abundance of ongoing research and the availability of numerous applications, the agricultural industry remains underserved. Nevertheless, the current state of agricultural AI is still in its early stages when it comes to addressing the practical difficulties encountered by farmers in implementing AI-driven decision-making systems and predictive solutions. The realization of the immense potential of artificial intelligence (AI) in the agricultural sector necessitates the development and deployment of increasingly robust and advanced applications. Only under such circumstances will it possess the capacity to acclimate to the perpetually fluctuating external environment. This approach would facilitate enhanced decision-making in real-time scenarios and the consecutive utilization of the most advantageous model or program for efficiently obtaining contextual information. An additional crucial aspect pertains to the exorbitant cost associated with the existing cognitive solutions available for the agricultural sector. To facilitate the adoption of this technology within the agricultural community, it is imperative to enhance the commercial viability of AI solutions. Possible outcomes of implementing AI cognitive solutions through an open source platform include a reduction in cost, increased accessibility, and enhanced comprehension among farmers.

In the forthcoming era, AI technology is anticipated to offer innovative and precise resolutions to the prevailing agricultural challenges encountered by farmers worldwide. AI has the potential to address a wide range of challenges, encompassing areas such as pest management, weather forecasting, and agricultural automation. In forthcoming years, researchers in the field of AI are anticipated to achieve significant advancements that will directly influence the agricultural sector. The integration of AI technology holds the potential to empower future farmers with scientific thinking capabilities, enabling them to leverage data-driven approaches to optimize crop yield on individual plots of land. AI enterprises are currently engaged in the development of user-friendly robots specifically designed for application in agricultural contexts. The purpose of this machine is to enhance the efficiency and precision of crop harvesting in comparison to human labor. The aforementioned robots have been programmed with the capability to perform tasks such as harvesting, packing, and inspecting for both weeds and crop quality. The robots easily overcome the challenges associated with manual farm work. Artificial intelligence systems have the capability to detect insects, such as grasshoppers and locusts, through the analysis of satellite photographs and the utilization of preexisting data. AI-assisted pest control has the potential to provide farmers with benefits by employing mobile phone notifications to prompt them to take necessary actions.

By leveraging AI, farmers can effectively automate their agricultural practices, thereby advancing precision cultivation techniques. This technological integration enables farmers to enhance crop yield and quality, while simultaneously reducing water and fertilizer consumption. As advancements in technology continue to emerge, there is growing optimism that the global food supply challenges associated with a burgeoning population can be effectively addressed. Specifically, the development of new technologies holds promise in supporting businesses seeking to enhance their offerings through the utilization of AI. This includes the provision of training data for agricultural purposes, the utilization of drones, and the implementation of automated machinery in manufacturing processes. Given that the majority of advanced technological applications are currently limited to large-scale, interconnected agricultural operations, it is imperative that substantial endeavors be undertaken to ensure universal accessibility in order to ascertain the future prospects of AI in the realm of agriculture. Ensuring the future projection of ML-assisted agriculture products and data engineering in farming globally necessitates the expansion of accessibility and connection to small-scale farms situated in remote areas. The utilization of AI in the agricultural industry holds promise for enhancing productivity and addressing challenges related to limited resources and labor scarcity. By optimizing resource allocation and improving operational efficiency, AI has the potential to deliver significant benefits to the agricultural business sector. The significance of this technology in the realm of horticultural research and development cannot be overstated.

Data Availability

No data was used to support this study.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

Funding

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Ethics Approval and Consent to Participate

The research has consent for Ethical Approval and Consent to participate.

Competing Interests

There are no competing interests.

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