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Exploring Artificial Intelligence Applications in the Agricultural Sector

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Abstract – This study conducts a comprehensive review and critical analysis of scholarly articles pertaining to the use of Artificial Intelligence (AI) within the agricultural industry. Subsequently, it delves into an examination of the possible utilization of AI in various agricultural contexts. Farmers are now able to use advanced data and analytics solutions driven by AI, enabling them to optimize crop yields and reduce inefficiencies in the cultivation of biofuels and food. The sectors of agriculture are now seeing a transformative impact from the integration of AI and Machine Learning (ML), which have already shown significant advancements in several domains. Several emerging technologies are now being developed to facilitate the process of crop and soil monitoring for farmers, hence enhancing its simplicity. The cutting-edge techniques used in the monitoring of crop health include 3D laser scanning and hyperspectral imaging, which are based on AI. The use of AI-enhanced advancements enables the collection of more comprehensive data pertaining to the health of crops, surpassing previous levels of detail. The research focused on the significance of AI inside the agricultural sector. This article provides a brief overview of the functioning of AI in the agricultural sector, as well as the many elements that may be monitored via the use of AI technology. Ultimately, we have successfully examined the primary applications of artificial intelligence within the agricultural sector.

Keywords – Artificial Intelligence, Machine Learning, Internet of Things, Precision Farming, Crop Monitoring, Plant Diseases.

I.INTRODUCTION

One of the world's earliest and most consequential economic activities is farming. The rising global population has a multiplicative effect on the needs of the economy. Babcock gives a study and prediction of the total food demand stemming from a combination of three separate factors: population expansion, caloric intake, and feed grain equivalents, illustrating the relevance of a changing consumption profile on the overall need for food. **Fig. 1** displays, from 1966 to 2050, the varied trends of these three variables. If global food consumption remained at its 1966 level, as shown at the bottom of the graph, the resulting demand for food due to population increase would be enormous.

To enhance productivity, fields or greenhouses are subjected to pesticide application. In the context of administering pesticides and fertilizers to crops, farmers may use machine learning techniques as a component of precision agriculture management. To optimize profitability and eliminate inefficiencies, farmers want dependable techniques for discerning and classifying crop quality attributes. Machines using data have the potential to uncover and unveil novel aspects that significantly enhance the quality of crops. The management of water in agricultural practices significantly impacts the balance of agronomy, climate, and hydrology. ML-based applications have the capability to provide estimations of evapotranspiration on a daily, weekly, or monthly basis, hence enhancing the efficiency of irrigation systems.

Precise forecast of daily dew point temperatures enhances the detection of anticipated weather phenomena and the evaluation of evaporation and evapotranspiration processes. The food technology sector has seen significant advantages as a result of the heightened use of machine learning and artificial intelligence models by farmers. Currently, the tasks of crop management, monitoring, and data collecting are being carried out by autonomous robots and advanced sensor systems. The potential applications of Machine Learning (ML) in the field of digital agriculture are increasingly broadening. ML has the potential to assist farmers in enhancing their agricultural productivity while minimizing their environmental footprint, therefore ensuring both safety and efficacy. The collection of agricultural data enables farmers to get a more comprehensive comprehension of their crops, including their genetic makeup and potential diseases.

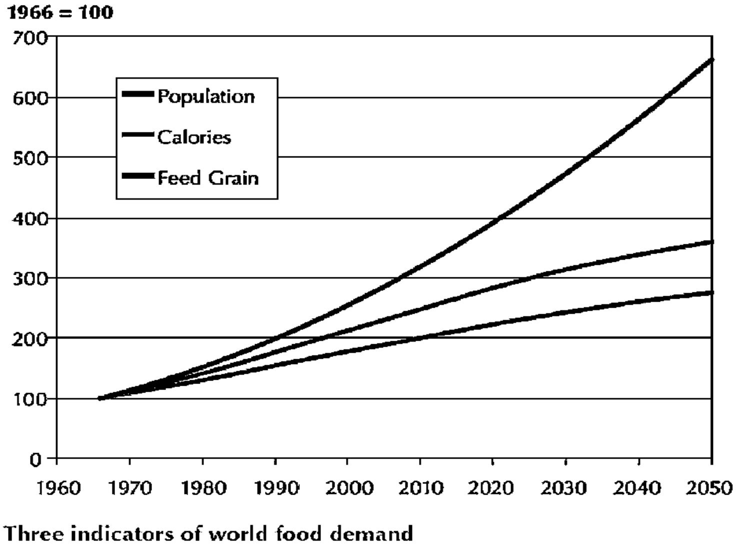

Fig 1. Global Food Demand, Calorie Intake, and the Corresponding Requirements for Feed Grain (from 1966 to 2050)

Given the insufficiency of traditional farming operations in meeting the global need for food and providing employment for the world's population of 7.5 billion, there is a growing focus on the development of automated alternatives. Due to the diminishing labor pool, more stringent rules, more global populations, and a stagnant agricultural workforce, farmers are actively seeking alternate solutions. The use of sophisticated technological advancements such as Machine Learning, Artificial Intelligence, Big Data & Data Analytics, and Internet of Things is prevalent. Research efforts are now being considered to boost the quantity and quality of agricultural products via the use of "smart farming," which aims to integrate connectivity and intelligence into agricultural practices.

The benefits of Artificial Intelligence (AI) are being realized in an increasing number of industries within the global economy, owing to developments in processing power and the growing use of cloud services. The agricultural sector is increasingly recognizing the advantages of AI. Examples of agricultural applications include soil and crop health monitoring, yield forecasting, and weed control. In the last decade, several enterprises have extensively tested the capabilities of AI and ML as prospective tools for advancement. The recognition of AI's potential to help agricultural decision-making has just emerged. The use of artificial intelligence has promise in enhancing agricultural and animal production via its capacity to assist farmers in making well-informed decisions. The application of AI technology to enhance the process of making decisions in the agricultural industry has garnered significant attention due to many factors. There has been an undeniable increase in the quantity and availability of accessible data, and this phenomenon has been a prominent focus of attention.

The efficacy of AI inside the agriculture industry is indisputable. Smart farming technologies and vertical farming systems have the potential to alleviate human cognitive load by delegating tedious and repetitive tasks, so enabling individuals to focus on more strategic goals. It is important to note that, in contrast to a tractor, the acquisition and activation of AI systems is not a straightforward process. Artificial intelligence has intangibility. The term refers to a collection of computerized technology. AI refers to a computational model that emulates human intelligence via the use of data-driven learning and problem-solving techniques. AI represents a significant advancement in the progression of intelligent agriculture; yet, its operational efficacy is contingent upon the integration of complementary technological components. It might be argued that in order to fully harness the benefits of AI, farmers must first develop a technologically sound basis. The implementation of such infrastructure might potentially require a significant amount of time, perhaps spanning many years. Nevertheless, by this action, farmers have the potential to create a sustainable technological ecosystem.

Currently, it is essential for technology businesses to prioritize the improvement of their tools, providing support to farmers in surmounting challenges, and effectively articulating the ways in which machine learning contributes to resolving significant issues, such as reducing reliance on human labor. The application of AI within the agricultural sector exhibits promising prospects. This study conducts a comprehensive review and critical analysis of scholarly articles pertaining to the use of AI in the agricultural sector. Subsequently, it delves into an examination of the possible utilization of AI in various agricultural contexts. The subsequent parts of the paper are organized in the following manner: Section II provides a review of the artificial intelligence (AI) concept. Section III discusses the relevance of the concept within the agricultural sector, while Section IV discusses the applications of AI in agriculture. Section V focusses on the limitations of AI in agriculture and provides prospects for future research. Lastly, Section VI provides final remarks to the research.

II.A REVIEW OF ARTIFICIAL INTELLIGENCE

For centuries, scholars from ancient Greek civilization and other intellectual communities situated around the Mediterranean coast have engaged in deep contemplation over the true nature of intelligence. In contemporary scholarship, Hsiao and Galazyuk [1] asserted that there exists a fundamental connection between synaptic and neuronal activity and the phenomenon of intelligence. The first "Checkers" program and the Turing Test developed by Strachey in 1952, subsequently improved by Samuel in 1959 to surpass top human players, exemplify the natural progression of these concepts into the field of artificial intelligence during the emergence of computing in the 1950s [2]. Through a process of comparing and contrasting several versions of the software, researchers saw the emergence of the concept of an evolving program.

The phrase "Artificial Intelligence" was officially introduced at a symposium that took place in July 1956 at Dartmouth College. This event is largely seen as the seminal moment that marked the inception of the field of AI. Scientists have built research laboratories focused on AI at renowned institutions such as Carnegie Mellon, MIT, Stanford, and Edinburgh [3]. In the field of general artificial intelligence, two prominent methodologies have been identified: the "top-down" technique that involves first implementing higher-level functionalities and thereafter progressing towards the cellular level, and the "bottom-up" approach, which entails starting at the cellular level and gradually advancing towards the neuron level. In 1956, Gargani [4] developed a computer program known as "Logic Theorist" for the purpose of theorem proving. Subsequent years witnessed the development of a multitude of programs and methodologies, such as the "General Problem Solver", "Geometry Theorem Prover", "STRIPS", "Virtual Mall" by Oettinger, "Eliza", "SHRDLU", "expert systems" (which ultimately culminated in Deep Blue in 1997), "Herbert", "Toto", and "Genghis".

Researchers in the area of artificial intelligence came to the realization of the significant problems that lied ahead throughout the 1980s. Given these circumstances, Brooks arrived to the determination that the trajectory of research on consciousness hinges on the advancement of discrete modules that emulate certain components of the human brain, like memory module, planning module, and so forth, which may potentially be amalgamated to generate intelligence. In recent years, there has been a notable surge in endeavors to develop embodied intelligences, mostly driven by developments in computer and robotics technology. The distinctive nature of this region, however, has resulted in a profusion of individual endeavors. The pursuit of physical robot creation has faced significant challenges, including a formidable entrance barrier and a limited pace of achievement. Consequently, there has been a notable transition towards the development of "Artificial General Intelligence" (AGI) computer simulations. These simulations include virtual agents operating inside a virtual reality setting, while they endeavor to exhibit intelligent behavior.

Although AI has been a prominent theme in science fiction for many years, it is presently being actively researched and developed by firms of all sizes throughout the globe. AI has the capability to replicate human behavior by virtue of its capacity to evaluate vast quantities of data, identify underlying patterns within this data, and then generate appropriate responses. Scholars have used this technology to develop autonomous automobiles and chess-playing computers; however, it is currently being employed in the agricultural sector as well. The implementation of more rigorous supervision in the field of AI research and development has the potential to yield enhanced agricultural practices, therefore contributing to the amelioration of climate change.

III.RELEVANCE OF AI IN AGRICULTURE

The potential for cross-disciplinary uses of AI to revolutionize farming practices is significant. The use of AI-driven solutions enables farmers to enhance productivity and efficiency, resulting in increased output within reduced timeframes. Additionally, these solutions contribute to the production of superior-quality agricultural products and expedite the time required to bring them to market. The distribution of digital IT solutions across several sectors is being propelled by recent advancements in AI, big data (DB), and the internet of things (IoT). Therefore, it is recommended that we use digital solutions bolstered by AI in order to enhance the living circumstances of marginalized farmers, concurrently establishing a novel market segment for business proprietors and innovators.

Growth Driven By Internet of Things (IoT)

The agricultural sector is seeing the impacts of the digital revolution. The integration of structured and unstructured data via the use of Internet of Things (IoT) devices has the potential to shed light on several aspects of the agricultural business. On a daily basis, a substantial volume of data, including both structured and unstructured formats, is generated. These include data collected from meteorological stations, soil analyses, contemporary research, precipitation records, insect prevalence, aerial drone imagery, photographic documentation, and several other resources. Cognitive systems inside the Internet of Things have the capability to gather such data and provide significant insights that might enhance agricultural output. Intelligent data fusion often incorporates the use of both proximity sensing and distant sensing technologies. The use of high-resolution data may be advantageous in the context of soil testing.

In contrast to remote sensing, proximity sensing does not need the placement of sensors in aerial or satellite systems. Instead, these sensors are positioned in direct contact with the ground or at a close proximity. The use of this method becomes advantageous in the characterization of the soil composition within a certain geographical area. To optimize the fertilizer composition for corn cultivation and use other measures to improve crop yield, agricultural practices have included hardware solutions such as corn-specific robots that are integrated with data-collecting software. The use of Internet of Things (IoT) enabled sensors at critical locations within the field is crucial. These transducers are used to assess several factors like climate conditions, soil moisture and nutrient levels, root and shoot development rates, abundant leaf growth, monitoring of photoperiods, blooming and seed setting processes, grain and fruit production, identification of pest and disease signs, and determination of harvest readiness.

The sensor responsible for measuring the aforementioned environmental and agricultural factors is integrated inside the Internet of Things (IoT) device. The protected mini board has the capability to accommodate many components such as the CPU, low-cost VGA image sensor, tiny battery, and micro solar panel. The installation of a sufficient number of WiFi-enabled hot spot towers to provide comprehensive field coverage facilitates the collecting of data at regular intervals. Drones connected with a WiFi hotspot have the potential to perform dual functions of scanning and collecting data from Internet of Things devices, while concurrently shooting aerial video footage of the whole region.

Image-Based Insight Generation
Precision farming has emerged as a highly discussed subject within the realm of contemporary agriculture. Drone-based imaging has the potential to provide significant benefits in several agricultural applications, such as in-depth field evaluation, field scanning, and crop monitoring. The integration of Internet of Things (IoT), computer vision and drone data technologies has the potential to facilitate prompt decision-making for farmers. The expeditiousness of precision farming may be enhanced by the generation of real-time alerts using data obtained from drone photos. Companies such as Aerialtronics are integrating real-time image analysis capabilities into their operations by using the Visual Recognition APIs and IBM Watson IoT Platform. The following are examples of applications using computer vision technology.

Disease Detection
In the context of leaves, it is important to ensure that the photographs are appropriately segmented into distinct components, such as the background, unaffected region, and sick area, prior to doing any analysis. After the affected region has been harvested, it is sent to distant labs for examination. Moreover, it may be used for the purpose of identifying nutritional deficits, pests, and several other issues.

Crop Readiness Identification
The task at hand involves the cropping of photos captured under white and UV illumination.In order to determine the level of maturity of the unripe fruits, a photometric measurement is conducted. Farmers have the practice of categorizing their crops and fruits into different stages of readiness and arranging them into distinct groups prior to transporting them to the market.

Field Management
During the cultivation season, real-time estimates may be generated by creating a field map and using high-definition aerial pictures obtained from drone orcopters to identify specific areas inside the field that need water, fertilizer, or pesticides. This approach proves to be quite beneficial in the optimization of existing resources.

Identification of Optimal Mix for Agronomic Products
Cognitive solutions provide recommendations to farmers for optimal crop selection and hybrid seed use, taking into account several criteria such soil quality, weather projections, seed characteristics, and pest frequency within certain geographical areas. The final, personalized recommendations may include several factors such as the farm's requirements, the surrounding ecological context, and historical data pertaining to the farm's past performance. Farmers may also consider external factors such as market trends, price, and client preferences while making informed decisions.

Health Monitoring of Crops
The acquisition of agricultural data across vast expanses of land requires the use of remote sensing techniques, hyper spectral imaging technology, and three-dimensional laser scanning methods. Due of its potential time and resource efficiency, this technology has the capacity to substantially transform the methods used for farm management. Furthermore, this technology will be used to monitor crops during their whole development cycle, collecting data and generating reports in the case of any anomalies.

Automation Techniques in Irrigation and Enabling Farmers
The process of irrigation requires a significant amount of work in the agriculture sector. The use of automated irrigation systems has the potential to enhance agricultural productivity via the utilization of data pertaining to historical weather patterns, soil conditions, and intended crop yields. Approximately 70% of the global freshwater supply is allocated for irrigation purposes. Consequently, the implementation of automated water management systems has the potential to provide significant cost and resource savings for farmers.

IV.APPLICATION OF ARTIFICIAL INTELLIGENCE IN AGRICULTURE

The agriculture industry offers several potential uses for AI. This area encompasses consulting, the Internet of Things (IoT), data analytics, and the application camera system, and various sensors. Through the examination of diverse datasets including weather patterns, soil composition, crop productivity, and temperature variations, the integration of AI within the agricultural sector is poised to enhance the precision of future prognostications. The study focused on examining the potential hazards linked to the use of machine learning models for the purpose of optimizing agricultural production. The aforementioned factors included data dependability, security and safety, interoperability, and unplanned socio-ecological impacts. The promise of AI lies in its ability to swiftly diagnose plant illnesses and efficiently administer agrochemicals, hence augmenting crop management practices and increasing agricultural yield. The use of ML has the potential to provide significant advantages in several agricultural applications, such as soil composition analysis, farm monitoring, rapid plant phenotyping, and harvest and weather prediction. An increasing number of agricultural practitioners are using sophisticated technological advancements such as the internet of things (IoT), AI, and other innovative solutions to enhance agricultural productivity. In the following discussion, we will explore the primary applications of AI within the agriculture industry.

Weather Forecast

Supercomputers have been used in the field of weather forecasting for several decades, facilitating the processing of vast quantities of oceanic and atmospheric data. Weather predicting firms gather data from weather stations and incorporate it with data from other sources, such as ocean buoys and independent weather trackers, as part of their specialized operations. The process of collecting and evaluating this data necessitates substantial computational resources, a significant amount of time for completion, and substantial financial investment, since it relies on models that simulate the intricate mechanics of fluid dynamics in weather phenomena. The current need for both expediency and precision in weather forecasting is placing significant challenges on even the most sophisticated meteorological systems.

Weather monitors located in observatories, on land, and at sea provide a vast amount of climate and weather data from many regions throughout the world. Due to its considerable magnitude and intricate nature, the efficient analysis or scanning for similarities of the subject matter is unattainable using conventional computer networks or human efforts. If the extensive volume of information cannot be comprehensively analyzed, it becomes an inefficient use of time and resources, hence presenting a challenge. Scholars are using machine learning, neural networks, and deep learning techniques due to the aptitude of artificial intelligence in pattern recognition tasks. Significant quantities of data may be inputted into the algorithms, enabling them to acquire knowledge about the identification of weather patterns that have the capacity to generate lightning or tornadoes. The system has the capability to detect patterns that may indicate the imminent occurrence of severe weather events, such as hurricanes or blizzards.

Effective Achievement of Results by Farmers

Artificial Intelligence (AI) has the capacity to transform the agriculture industry by enabling farmers to enhance productivity while reducing labor requirements and offering other advantages. Nevertheless, AI cannot function in isolation. The integration of AI may provide valuable assistance in facilitating the adoption of novel farming practices, hence aiding the transition from conventional agricultural methods. Many farmers see AI as a concept that is only present in the digital realm. It is possible that individuals may lack awareness about the potential of contemporary agricultural instruments to enhance farming efficiency. Cognitive Internet of Things (IoT) technologies, including proximity sensing, imaging, soil testing, and remote sensing, contribute to the development of AI-enabled growth-driven crops. Artificial intelligence has the capability to efficiently analyze, retain, and acquire large quantities of data, hence enabling it to react to this data in manners that enhance productivity. The application of AI in the analysis of data from the Cognitive Internet of Things has the potential to provide valuable insights aimed at enhancing agricultural output. The integration of data gathering software and robots into hardware solutions enables the optimization of fertilizer application to specific locations.

By using Agriculture 4.0 technologies, farmers have the ability to use trend analysis in order to predict forthcoming weather patterns and crop yields. The integration of Internet of Things (IoT) technology in the agricultural sector has promise for boosting agricultural productivity and yield outcomes. By using IoT capabilities, farmers can effectively monitor and optimize soil fertility and crop health, so facilitating improvements in both the amount and quality of their harvests. Enhanced decision-making may be facilitated by the use of gathered data and advancements in technology. The use of Internet of Things (IoT) devices enables the acquisition of sensor data, which may provide timely and accurate information on the present state of agricultural crops. The use of predictive analytics might potentially facilitate more optimal decision-making in the realm of harvesting practices.

The expansion of the agricultural sector is facilitated by the use of scientific planting techniques, utilization of automated farm equipment, and adoption of improved production systems. The use of intelligent technology has the potential to catapult the region towards the era of Agriculture 4.0. The use of photographs and sensor data has the potential to be employed in precision farming for the purpose of monitoring plants, soil, and air conditions in real-time. This enables farmers to get timely notifications on localized variations, allowing them to make appropriate adjustments as necessary. The implementation of precision farming is contingent upon the use of Internet of Things (IoT) solutions, such as crop management systems.

The use of predictive data analytics plays a pivotal role in the implementation of precision agriculture. Data analytics plays a crucial role in enabling farmers to make significant predictions about optimal harvesting periods, potential disease and insect threats, crop yield quantities, and several other elements. This is achieved by effectively analyzing the extensive quantities of pertinent real-time data made available via the use of Internet of Things (IoT) and smart sensor technologies. Data analytics tools boost the management and predictability of farming, a sector that heavily depends on weather conditions. Similar to the deployment of weather stations for the purpose of gathering meteorological data, these devices will be strategically positioned in agricultural fields to get information pertaining to crop production.

In prospective scenarios, it is plausible that weather stations may autonomously modify the atmospheric conditions to align with specified parameters, alongside their primary function of collecting environmental data. The implementation of precision farming is contingent upon the use of Internet of Things (IoT) solutions, such as crop management systems. Similar to the deployment of weather stations for the purpose of gathering meteorological data, these devices will be strategically positioned in agricultural fields to get information pertaining to crop production.

Help Harvest Healthier Crops

The absence of information and decision support is a significant obstacle to achieving increased productivity in developing agricultural economies. Therefore, it is essential to provide assistance to the agriculture industry in order to effectively navigate these issues. Over the last several decades, there has been a progressive development of automated solutions aimed at addressing agricultural challenges. The field of agriculture is characterized by its dynamic nature, necessitating the absence of a universally applicable answer. By using artificial intelligence techniques, it is possible to effectively simulate complex systems. The gradual resolution of complicated issues is being facilitated by the advancement of diverse artificial intelligence methodologies.

In order to enhance the overall standard of food production, it is important to focus on several aspects such as pest control, soil and environmental monitoring, organization of farmer data, labor reduction, and other duties related to the agricultural supply chain. The use of AI is becoming more prevalent within the agricultural sector. Farmers have growing challenges in selecting the optimal timing for seed sowing due to the unpredictable nature of weather patterns and the escalating levels of pollution. Through the integration of AI with weather forecasting, agricultural practitioners are empowered to assess meteorological factors, enabling them to make informed decisions on suitable crop selection and ideal timing for seed sowing. The use of AI has the potential to assist farmers in optimizing their financial gains via streamlining the decision-making process involved in crop selection. By using forecasting techniques and predictive analytics, farmers have the potential to mitigate the potential risks of crop failure and mitigate operational issues. The use of artificial intelligence has the potential to assist farmers in cultivating crops that are more resilient to diseases and climatic variations via the collection and analysis of plant development data. The use of AI systems enables the conduction of chemical analysis on soil, hence facilitating the generation of precise estimations pertaining to the deficient nutrients.

Predict Plant Diseases

The use of machine learning methods in the agriculture business has been shown for soil fertility evaluation. The agricultural sector has always been regarded as the primary subject of scholarly investigation. The analysis of soil data in this study is based on many constraints, which enhance the precision of each representation. Additionally, several clustering algorithms are used to further refine the analysis. The use of technological breakthroughs such as data mining and automation has shown to be beneficial in the field of agricultural research. Although data mining is widely used in many sectors and there are many readily available techniques for extracting data and applying data mining software to particular fields, the exploration of data mining in agricultural soil datasets is still at an early stage of development.

Fig 2(a). Representative Images of a Leaf Afflicted with Illness And 2(b). A Leaf in a State of Good Health

Fig. 2 presents an illustration of leaf inflicted with diseases (determined using machine learning methods), and another with good health. The illustration aimed at defining accuracy machine learning in plant disease identification. This paper offers a comprehensive account of the machine learning approach used for the purpose of categorizing symptoms associated with plant diseases. Nevertheless, the aforementioned study failed to include all the potential factors that may influence the identification of illnesses. The current abundance of data collected in agricultural settings necessitates the need for efficient analysis and use to fully harness its potential. The method of preparing the input image is shown in **Fig. 3**. In order to get precise outcomes, it is necessary to eliminate extraneous signals prior to extracting the relevant characteristics. After the conversion of the RGB image to grayscale, a Gaussian filter is used to provide a smoothing effect. The use of various strategies in agricultural production, including disease detection and crop selection, serves to underscore the impact of several environmental factors on precipitation patterns.

Automated techniques for the detection of plant diseases provide significant advantages, since they streamline monitoring efforts in large-scale agricultural operations and facilitate timely identification of disease symptoms. There are many photo segmentation algorithms that may be used in combination with deep learning systems for the automated identification and categorization of plant diseases. A comprehensive evaluation and ranking of machine learning methodologies for the prediction of crop borders using geographic information system (GIS) data was conducted. The approach outlined in this study aims to assist coffee, cocoa, and technical rice cultivators in making well-informed choices about crop selection, insect prevention, disease control, and fertilizer selection. These decisions are based on valuable feedback obtained from customers and the surrounding ecological context.

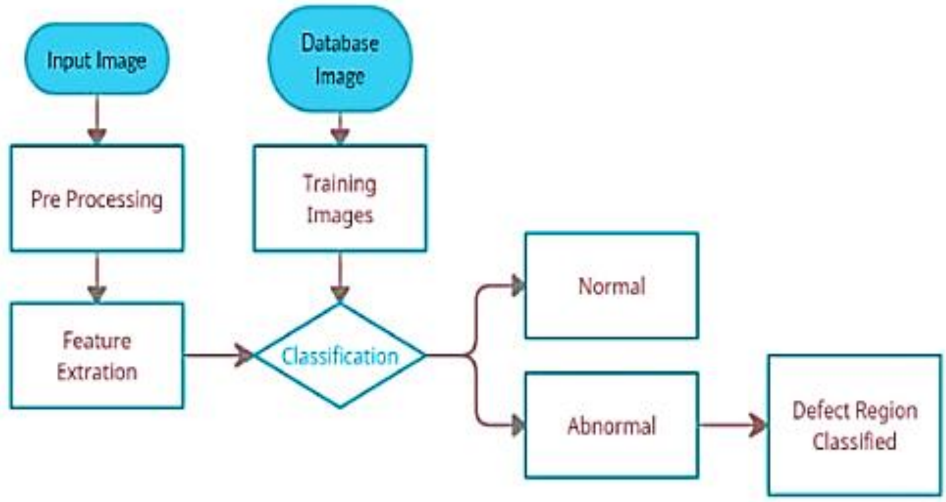

Fig 3. General Steps for Crop Detection

Self-Driving Tractors

The application of AI, autonomous agricultural machinery, and the interconnectedness of devices, often referred to as the internet of things, holds promise in tackling a significant challenge faced by the agricultural industry, namely the scarcity of manpower. These technologies have the potential to be more cost-effective while also offering improved accuracy and reduced errors. The combination of AI, autonomous tractors, and the IoT is crucial for achieving precision farming. Robotics is an emerging technological field that remains relatively uncommon. Agricultural robots are now engaged in the execution of labor-intensive activities such as crop harvesting and lettuce trimming. There are many benefits that human farmhands possess in comparison to their robotic counterparts.

Autonomous systems exhibit enhanced reliability, reduced susceptibility to mistakes, and the possibility for extended operational durations. The agricultural sector presents a myriad of complexities in practice, resulting in a wealth of data that is both copious and challenging to evaluate. The advancements in AI possess the capacity to significantly transform the industry by facilitating novel forms of data analysis and interpretation. Businesses may have difficulties in keeping up with advancements in their respective industries. The use of AI has the potential to enhance the efficiency of decision-making inside businesses. The integration of data with machine learning techniques has the potential to assist organizations in effectively navigating complex environments and generating predictions with enhanced accuracy.

Currently, the majority of fully autonomous tractors use laser technology for navigation, using the reflection of signals from a distributed network of mobile transponders positioned throughout the field. The use of 150 MHz radios, in conjunction with lasers, may potentially resolve line-of-sight issues. The tractors are operated with the use of remote control technology. The primary responsibility of the controllers is to monitor the tractors from a secure proximity. These controllers provide the centralized administration of a multitude of agricultural fields' worth of tractors. The capacity to provide commands to a tractor or other agricultural machinery through its internal electrical system, often referred to as the Controller Area Network (CAN bus), is a significant advancement in the pursuit of fully autonomous tractors. The automation software utilizes GPS tracking and radio input to oversee the trajectory of the truck and control the agricultural equipment.

The control of many aspects of the vehicle, including as steering, acceleration, braking, transmission, and implement control, is often achieved via the use of radio signals. These signals are received by a retrofitted radio receiver and then processed by an on-board computer. Sensor technologies, such as lidar, enhance security measures by effectively detecting and mitigating potential threats that could otherwise remain unnoticed. At the 2022 Consumer Electronics Show, John Deere, a prominent producer in the tractor industry, unveiled its intentions to introduce the world's first autonomous tractor. The 8R 410 tractor will be equipped with a combination of 12 stereo cameras and an Nvidia GPU that can be controlled using a smartphone.

Soil and Crop Monitoring

The proliferation of sensing and imaging technologies has provided farmers with a wide array of instruments that may enhance crop productivity and mitigate losses. In recent times, unmanned aircraft with practical applications have taken an unconventional trajectory. Continuous advancements are consistently enhancing the efficacy of surveying, data collection, and analysis techniques, while novel sensors are being integrated into unmanned aerial vehicles (UAVs) to function as the client's visual apparatus on the terrain. Aerial surveys are often conducted within the agricultural business. While the use of satellites for the last decade has enabled the surveying of extensive agricultural and forest regions, the introduction of Unmanned Aerial Vehicles (UAVs) has introduced a heightened level of precision and adaptability to this undertaking. UAV images, acquired at an altitude of 400-500 ft. above ground level, exhibit enhanced quality and precision. Furthermore, UAV flights may be done independently of satellite positioning or the availability of ideal weather conditions.

Hütt, Bolten, Hüging, and Bareth [5] conducted a study whereby they examined digital images captured from model aircraft to evaluate their potential for remote sensing applications in assessing crop biomass and nitrogen status. A custom-designed digital camera was used in conjunction with an aerobatic model airplane to capture shots. The resultant images were afterwards altered using colored canvases. Significant discrepancies in DN values were observed for similar reflectances as due to changes in the startup settings utilized by the sophisticated camera. The researchers also used the Normalized Green-Red Difference Index (NGRDI) and observed a positive connection between the NGRDI and the relative luminosity of the red and green reflectances. The results of this research indicate a positive linear relationship between the Net Growth Rate Diversity Index (NGRDI) and dry biomass for soybeans, horse feed, and maize within the range of 0 to 120 gm^2. However, the NGRDI reaches a plateau at 150 gm^2 and beyond for corn and soybean, respectively. Hunt Jr, Cavigelli, Daughtry, Mcmurtrey III, and Walthall [6] demonstrated the feasibility of accurately delineating the extent of transplanted column crops by the application of RTK (real-time kinematic) GPS (global positioning systems).

In the area of transplant mapping, a customized vegetable harvest equipment was used, which was outfitted with an RTK GPS receivers, tendency, plant, and odometry sensors, including on-board continuous data logger. The findings from the field experiments indicate that about 96% of the projected plant field were found to be within a deviation of 5.1 mm from their actual areas. Moreover, there is a mean error of approximately 2 cm between anticipated plant map field according to planting data and the observed fields after the process of planting. Zou, Li, Cai, and Lin [7] demonstrated the efficacy of using unmanned aerial vehicles (UAVs) equipped with multispectral sensors for the purpose of accurately guiding soil and crop management practices. To establish precise ground goals and provide accurate statistical data, multi-temporal and multi-spectral orthomosaics were acquired for a designated test field. The test field, measuring 100 m by 200 m, was located inside a larger maize field. Younas et al. [8] developed a cost-effective multispectral imaging system with the objective of facilitating crop monitoring. The drone is equipped with an internal configuration that comprises a CPU and two cameras. Both the infrared-sensitive camera and the ordinary RGB camera are used. The photos and data obtained by this technology are used by software algorithms to calculate the Normalized Difference Vegetation Index (NDVI) of the crop, therefore assessing its overall health.

Proper Data on Crop

In recent years, much discourse has emerged around the potential use of AI for addressing a diverse range of challenges within the agricultural domain. One may experience confusion within the heightened enthusiasm around this subject, provided that sufficient effort has not been dedicated to acquiring a deeper understanding of it. The application of AI in agriculture encompasses various areas such as machine control, image analysis for tasks like weed or disease identification, and the utilization of "big data" to gain deeper insights into crop responses to specific environmental conditions or product applications. These are merely a few examples of the wide range of potential applications of AI in the agricultural sector.

AI technology may be used to anticipate several agronomic aspects, including soil quality, weather patterns, and groundwater levels, among others. Advisories using AI technologies have the potential to enhance productivity. The primary challenge faced by farmers is the significant reduction in agricultural yield resulting from either natural disasters or infestations by insects. The primary cause of most crop failures may be traced to a lack of appropriate knowledge on the side of the farmer. The use of artificial intelligence to assist with image recognition might be advantageous in the aforementioned case. The results of the study will also contribute to enhancing productivity. By using Internet of Things (IoT) and AI technologies, farmers have the potential to enhance food production and profitability while minimizing the depletion of natural resources. This enables them to effectively address the needs of both the current and future global populations.

Various companies are now using AI technology to create agricultural robots capable of performing a diverse array of tasks. The management of weeds and the harvesting of crops will be carried out by these robotic devices. Furthermore, the participants will get instruction in the techniques and practices of agricultural harvesting and storage. Artificial intelligence in the field of agriculture has the potential to use satellite imagery to detect instances of animal or human invasions by using a comparative analysis of present circumstances with historical data. This mitigates the likelihood of agricultural damage caused by any kind of animal, whether domestic or wild.

Student Research on Agriculture

It is essential to provide agricultural students with comprehensive instruction on the application of AI in the agricultural sector, in order to effectively harness the potential benefits offered by AI. In order to cultivate students' interest and enhance their understanding of the rapid developments in this domain, it is advisable to include the study of AI in agriculture within the undergraduate curriculum. The creation of effective AI applications in agriculture necessitates the imperative collaboration of machine learning experts [9], data specialists, and agricultural scientists. The use of high-resolution multispectral imaging and advanced remote sensing techniques enables a thorough monitoring of crop and soil health. Numerous enterprises have already used cognitive computing and AI techniques to scrutinize sensor data for the purpose of monitoring agricultural operations. Technological solutions based on AI have the potential to mitigate the temporal and energetic demands associated with farmers' assessment of crop health throughout various developmental phases. Furthermore, AI-driven systems have the capability to monitor soil flaws and nutritional deficiencies, in addition to their role in crop surveillance. The control of plant diseases and the improvement of crop yields may be achieved by a comprehensive comprehending of the soil's inherent capabilities and constraints.

Determining Wasteful Resource Consumption Sequences

The occurrence of overproduction in several sectors has led to a surplus of waste materials. The use of waste reduction strategies in the processes of production and distribution is of paramount importance in safeguarding the environment. According to the World Bank, the global quantity of industrial trash created surpasses that of municipal solid waste by a factor of 18.

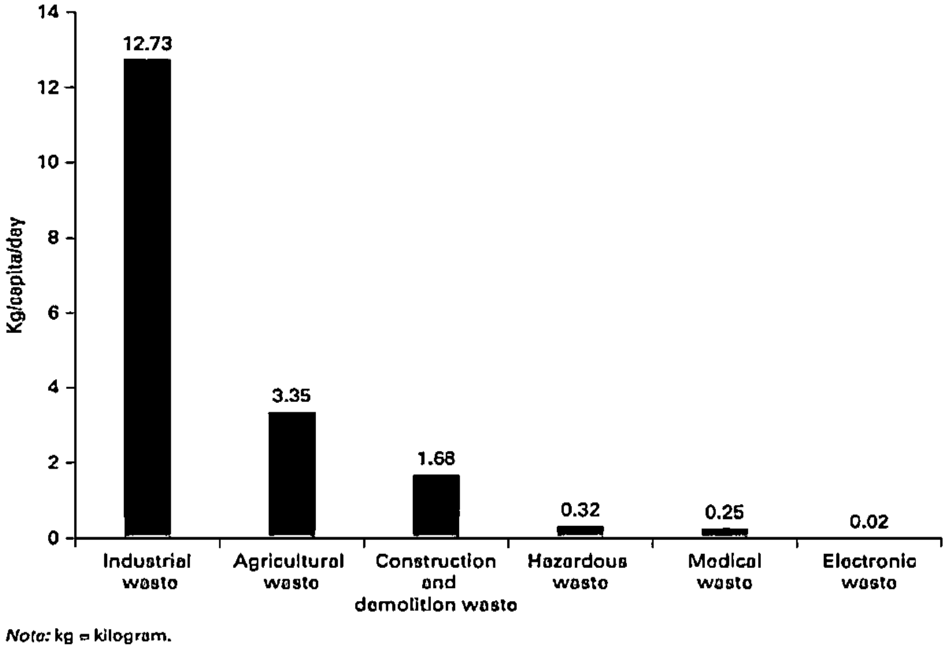

Fig 4. Global Critical Waste Generation

A significant proportion, no less than 50%, of the total waste generated may be attributed to the industrial sector see **Fig. 4**. The manufacturing industry is accountable for the most substantial and rapidly expanding proportion of industrial waste. The challenge of accommodating the projected global population increase to 9.7 billion individuals over a span of less than three decades poses a formidable obstacle to the expansion of our businesses, since doing so would entail significant environmental degradation. The significant role of substandard quality in generating preventable production waste is also readily apparent. The combination of advancements in machine learning and artificial intelligence, together with human ingenuity, has significantly enhanced the feasibility of addressing the mathematical challenge of enhancing production quality.

Identify the trends pertaining to suboptimal use of resources. Artificial intelligence systems has the capability to identify patterns of excessive resource consumption and propose optimization strategies via the analysis of data pertaining to resource distribution and utilization. The use of preventive measures, such as diligent monitoring of cattle health and equipment efficiency, may result in cost savings for farmers in terms of veterinarian services and equipment maintenance. The use of AI in agriculture has been seen to enhance crop yields without necessitating additional resource consumption, hence resulting in reduced costs associated with different stages of agricultural operations. Consequently, this technological advancement inherently contributes to the overall profitability of farming practices. The primary objective of sustainable agriculture is to meet the immediate demands for food and clothing while ensuring the preservation of natural resources, therefore preventing their depletion to an extent that would compromise the needs of future generations. Through the use of AI, farmers are able to enhance their comprehension of optimal strategies for the sustainable utilization of water and land resources. AI, an expansive domain encompassing diverse technological applications, has the potential to provide agriculture a plethora of algorithmic and programmatic alternatives in the future.

Assist Food Supply Chain

In view of the increasing need for transparency within the food sector, it is imperative that all food companies prioritize supply chain management as a fundamental aspect of their operations. The use of AI in the food sector to improve supply chains is shown by the practice of conducting food safety monitoring and testing across every level of the supply chain. This ensures adherence to industry and consumer standards. Improved pricing and inventory management need more accurate projections. AI-based image identification technologies provide more efficient and enhanced food purchasing practices [10]. Furthermore, with the aid of artificial intelligence, the task of monitoring the origins and purchasers of fruits and vegetables has been more convenient.

The use of AI-powered solutions in the agricultural business has the potential to deliver significant benefits, such as the augmentation of crop yields and the improvement of various agricultural tasks throughout the whole food supply chain. These technological advancements not only increased the need for sustenance but also generated employment opportunities for a significant global population. The advent of AI has sparked a transformative revolution in the field of agriculture. The agricultural sector has effectively mitigated the impacts of population growth, climate change, heightened labor requirements, and concerns over food safety, therefore safeguarding its production. Nevertheless, it is important to note that there are significant threats linked to the integration of emerging AI advancements, which are currently being disregarded, despite the potential of AI to enhance crop management and agricultural output. The use of AI applications is facilitating the creation of novel models that include effective scale management tactics and technology, therefore supporting farm, forest, and ranch managers in enhancing economic efficiency and sustainability. Scholars are currently examining the impacts and contributions of AI in order to gain a deeper comprehension of the organization and efficacy of agricultural markets, agricultural production, global trade, resource utilization, food safety, consumer behavior, food loss and waste, farm immigration and labor, policy formulation related to agriculture, the design and consequences of agricultural policies, technological advancements and adoption, as well as science and innovation policy.

V.LIMITATIONS AND FUTURE SCOPE

A significant challenge hindering the extensive application of AI within the agriculture sector is the lack of readily implementable solutions that seamlessly integrate the technology into farming practices. Most farmers do not have the necessary time and technical expertise to independently explore AI alternatives. In order to achieve comprehensive integration and implementation of AI in the agricultural sector, it is necessary to establish connections between the novel AI solutions and the existing legacy infrastructure and systems used by farmers. The limited capacity of AI to depart from preprogrammed activities constrains its efficacy inside agricultural contexts. A significant number of farmers, particularly those residing in geographically isolated areas, lack awareness of the existence of these technologies. The potential for semi-autonomous agriculture, facilitated by AI, is increasingly being recognized as more individuals become awareness of its prospects and as technological advancements become more accessible to farmers. AI systems need a substantial volume of data in order to facilitate machine learning and achieve accurate prediction capabilities. When dealing with mostly agricultural terrain, the availability of geographical data is abundant, whereas the collection of temporal data poses challenges. The collection of specific crop-related data is often limited to an annual occurrence, namely during the harvest period. Constructing an efficient ML model may be a time-consuming process, since it requires the gradual development of data infrastructure.

The forthcoming advancements in AI technology have the potential to provide innovative and accurate solutions to the prevailing agricultural challenges now encountered by farmers worldwide. AI will enable the realization of many applications such as insect control, weather forecasting, and automated agriculture equipment. It is anticipated that there will be a proliferation of noteworthy advancements in the field of agricultural artificial intelligence in the forthcoming years. In forthcoming years, the integration of AI is anticipated to facilitate a transition for farmers into the realm of agricultural science. This transition will be achieved via the use of AI technologies to optimize crop yields in particular plant rows, using data that has been gathered and analyzed. The use of robots developed by artificial intelligence companies is increasingly proving to be advantageous in agricultural contexts. The purpose of this equipment is to enhance the efficiency and effectiveness of agricultural harvesting in comparison to human labor. The robots have been trained to do the tasks of harvesting, packing, and inspecting crops for the purpose of identifying flaws and removing weeds. These robots demonstrate exceptional performance in the domain of agricultural work. AI systems have the capability to analyze satellite imagery and historical data in order to ascertain the presence and specific species of insects, such as grasshoppers or locusts. AI assists farmers in the control of pests by providing timely notifications to their mobile devices, prompting them to initiate appropriate measures.

The use of AI has facilitated the automation of farming practices, enabling farmers to progress towards precision agriculture. This technological advancement has resulted in enhanced agricultural output and quality, while simultaneously reducing input costs. The global capacity to address food supply challenges in the face of population growth is expected to increase with the advent of emerging technologies that support enterprises in enhancing AI-driven goods and services. These technologies include advancements in agricultural training data, drone technology, and automated machine manufacturing. The use of cutting-edge equipment is mostly limited to large-scale and well-established agricultural operations. Consequently, it is essential to prioritize the enhancement of accessibility to such technology in order to ensure the future advancement of AI in the domain of agriculture. By enhancing the level of connection to geographically distant farms, it is possible to guarantee the sustained viability of machine learning-driven automated agricultural products and the use of data science in the field of farming. The use of AI in the agriculture industry has promise for enhancing resource utilization and efficiency, as well as addressing the prevailing challenges of resource scarcity and labor shortages. This approach will significantly contribute to the progress of horticulture science.

VI.CONCLUSION

The utilization of AI-enabled technologies enables the anticipation of weather patterns, assessment of crop viability, and examination of farms for the prevalence of pests or diseases and poor plant nourishment. This is achieved through the amalgamation of various data sets, including precipitation, temperature, solar radiation, and wind speed alongside the application of machine learning algorithms and the analysis of satellite and drone imagery. Farmers who have the ability to connect to wireless internet may use artificial intelligence applications to get a personalized farm plan generated by AI technology. Farmers has the potential to address the increasing global need for food by using artificial intelligence-based solutions that enhance production and provide higher profitability, all while safeguarding valuable natural resources. Through the use of AI, agricultural practitioners are able to actively observe their cultivated plants in a timely manner, enabling them to accurately identify specific areas that need irrigation, fertilization, or pest control measures. Vertical farming and other innovative agricultural techniques have potential for enhancing food production while minimizing environmental repercussions.

As a result of this, a reduced quantity of herbicide is used, leading to improved crop yields of superior quality, increased economic profits, and significant cost savings. AI technologies are used to collect high-resolution aerial pictures and obtain information pertaining to irrigation systems for application in agricultural settings. The identification of soil issues like as clogs and leaks may be facilitated with the use of AI technology. The use of artificial intelligence contributes to the enhancement of agricultural productivity via the assessment and prioritization of soil conditions. Automated and autonomous agricultural activities, as well as AI-enabled yield management and productions, contribute to the enhancement of total field productivity. AI-assisted packing, sorting, and picking processes significantly enhance the efficiency and effectiveness of food production, packaging, and sorting operations. Agricultural data may provide valuable insights into weather patterns, precipitation levels, wind conditions, and solar radiation. This information plays a crucial role in assisting farmers in comprehending and interpreting these factors. Farmers have two significant challenges, namely climate change and infestations of insects and plants, both of which have detrimental effects on agricultural productivity. The integration of AI inside the agricultural sector is anticipated to provide significant advancements in several aspects.

CRediT Author Statement

The author reviewed the results and approved the final version of the manuscript.

Data Availability

The datasets generated during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interests

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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Competing Interests

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