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CULTIVATING AGRICULTURAL EVOLUTION: REVOLUTIONIZING FARMING THROUGH THE POWER OF AI AND TECHNOLOGY

[1]Punam Rattan

ABSTRACT

Objective: The objective of this study is to explore the current and potential role of Artificial Intelligence (AI) in the agricultural sector. We aim to analyze the adoption and impact of AI solutions in farming, identify challenges, and discuss the prospects for its future integration.

Method: We conducted a comprehensive review of existing literature and ongoing research projects related to AI applications in agriculture. We also examined case studies, technological developments, and AI pioneers in the field.

Results: Our analysis reveals that while AI solutions are being researched and applied in agriculture, there is a gap in widespread industry adoption. Large-scale research projects are underway, and some AI applications are available in the market. However, the development of predictive solutions to address real farming challenges is in the early stages. AI's influence extends across various sectors, contributing to the advancement of technologies such as big data, robotics, and the Internet of Things.

An illustrative example is the styrofoam container device, which utilizes machine learning and computer vision to detect and categorize "safety occurrences." Although not all-encompassing, this technology gathers significant data, such as driver behavior, speed, and surroundings. IFM's system promptly alerts supervisors to safety breaches, enhancing both safety and productivity.

Conclusion: The future of AI in agriculture hinges on the widespread adoption of AI solutions. The agricultural industry remains underserved in terms of AI integration, and the development of predictive solutions is in its early stages. However, AI's impact across sectors underscores its importance. Pioneers like IFM and IBM's patent statistics demonstrate the expanding scope of AI innovation.

Keywords: AI in Agriculture, Technology Adoption, Predictive Solutions, Environmental Sustainability, Global Food Demands

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[1] Lovely professional University, Jallandhar https://orcid.org/0000-0002-1965-0703

REVOLUÇÃO DA INTELIGÊNCIA ARTIFICIAL (IA) NA AGRICULTURA: TRANSFORMANDO A AGRICULTURA COM TECNOLOGIA

RESUMO

Objetivo: Este estudo explora o atual e potencial papel da Inteligência Artificial (IA) no setor agrícola. Nosso objetivo é analisar a adoção e o impacto das soluções de IA na agricultura, identificar desafios e discutir as perspectivas para sua futura integração.

Método: Realizamos uma revisão abrangente da literatura existente e de projetos de pesquisa em andamento relacionados a aplicações de IA na agricultura. Também examinamos estudos de caso, desenvolvimentos tecnológicos e pioneiros da IA no campo.

Resultados: Nossa análise revela que, embora soluções de IA sejam pesquisadas e aplicadas na agricultura, há uma lacuna na adoção generalizada pela indústria. Grandes projetos de pesquisa estão em andamento e algumas aplicações de IA já estão disponíveis no mercado. No entanto, o desenvolvimento de soluções preditivas para enfrentar desafios reais da agricultura está em estágios iniciais. A influência da IA se estende por vários setores, contribuindo para o avanço de tecnologias como big data, robótica e Internet das Coisas.

Um exemplo ilustrativo é o dispositivo de recipiente de isopor, que utiliza aprendizado de máquina e visão computacional para detectar e categorizar "ocorrências de segurança". Embora não seja abrangente, essa tecnologia reúne dados significativos, como comportamento do motorista, velocidade e arredores. O sistema da IFM alerta prontamente os supervisores sobre violações de segurança, melhorando tanto a segurança quanto a produtividade.

Conclusão: O futuro da IA na agricultura depende da adoção generalizada de soluções de IA. A indústria agrícola ainda não está plenamente integrada à IA, e o desenvolvimento de soluções preditivas está em estágios iniciais. No entanto, o impacto da IA em vários setores destaca sua importância. Pioneiros como a IFM e as estatísticas de patentes da IBM demonstram o escopo em expansão da inovação em IA.

No contexto da agricultura, a IA possui um potencial transformador para o século XXI. Ela pode otimizar a alocação de recursos, melhorar a eficiência e contribuir para a sustentabilidade ambiental. Essa transformação exige a tradução do conhecimento dos agricultores para o treinamento de IA. Ao adotar tecnologias como visão computacional e robótica agrícola, a indústria pode atender às demandas globais de alimentos e reforçar a segurança alimentar, adaptando-se às mudanças climáticas e às crescentes necessidades.

Palavras-chave: IA na Agricultura, Adoção de Tecnologia, Soluções Preditivas, Sustentabilidade Ambiental, Demanda Global de Alimentos.

1. INTRODUCTION

> "Farming is not an easy job, you have to be wearing a lot of hats," said Tara Sawyer, chair of the Alberta Barley Commission. " To me, it takes a special sort of person and mindset that makes a really good farmer that cares about farm stewardship and understands the business side. It's a high risk for entry, the high land value, the high cost of equipment, the high cost of inputs."

The primary industry for employment is agriculture in several nations throughout the world. Over time, technology has changed how farming is done, and this has had a wide range of implications on the agriculture sector. Only an additional 4% of the planet's surface will be cultivated by 2050, when the population is projected to rise from 7.5 billion to 9.7 billion, adding to the pressure on the land. Farmers will therefore need to work more while utilising fewer resources. According to some estimates, a 60% increase in food production would be required to feed an additional two billion people.

Yet, traditional methods fall short of fulfilling this colossal requirement. Artificial Intelligence (AI) is consequently increasingly contributing to the technical development of the agriculture industry. By the year 2050, the goal is to increase the world's food production by 50% in order to feed an additional two billion people. Farmers will be able to work more productively while also improving crop quality and quantity and assuring a speedier time to market with the aid of AI-powered technologies. For human existence, agriculture is essential. A large fraction of the global population relies on agriculture for livelihood.

Also, it provides citizens with a wide range of employment options. Low yields are a result of conventional farming methods, which are preferred by many farmers. The long-term expansion and development of the economy depend heavily on agriculture and allied businesses. The decision-making process, crop selection, and supporting systems for enhancing crop yield are the main problems in agricultural production. Natural factors including temperature, soil fertility, water volume, water quality, season, and crop prices have an impact on agriculture forecasts. A plethora of tools and apps for quick knowledge acquisition have emerged as a result of growing developments in agricultural automation. For efficient irrigation and crop management, it is necessary to maintain real-time monitoring and precise predictive models due to the changing dynamics, non-linearity of soil moisture content, and other weather and plant variables.

Future prospects are bright for artificial intelligence, one of the intriguing and all-encompassing areas of computer science. In the present era, technology is advancing quickly, and new innovations are made daily. Artificial intelligence, which is currently undergoing rapid development and is already poised to bring about a brand-new global revolution through the development of intelligent machines, is one of the computer science disciplines that is experiencing this development.

Our world is now filled with artificial intelligence. Self-driving cars, chess play, theorem proving, music performance, art, etc. are just a few of the diverse subdisciplines it is currently involved in, ranging from the general to the specialised. AI has a tendency to make machines behave like humans. Precision agriculture, often known as artificial intelligence systems, is assisting in enhancing harvest quality and accuracy. Artificial intelligence (AI) technology aids in the detection of pests, plant diseases, and undernutrition in farms. AI sensors can identify and target weeds, then choose which pesticide to spread across the area.

AI's key contributions to various transdisciplinary domains. In particular, "narrow AI," which implements optimization methods utilising data algorithms and typically falls under the categories of deep learning or machine learning, has already had an effect on nearly every large organisation. In the past few years, data collection and analytics have increased significantly due to the proliferation of connected devices, robust IoT connectivity, and ever-improving computational capabilities. Other industries are seasoned travellers while some are just starting out on their AI voyage. They both have a long way to go. In any event, it's tough to ignore how AI is affecting our daily lives.. The following are few examples

- Transportation: Although it would take some time for automated cars to evolve, they could one day transport us all from place to place.
- Manufacturing: Intelligent robotics perform a limited range of tasks including assembling and stacking with others, while powerful analytics detectors maintain equipment operating properly.
- Healthcare: In the still-emerging field of AI-based health insurance, disorders are recognised more quickly and precisely, drug research is sped up, and virtual nursing assistants keep a watch on patients. Big data analysis also contributes to more individualised care experiences.

- **In the field of education,** artificial intelligence (AI) is being used to digitise books, value human teachers slightly earlier than virtual tutors, and measure learner moods through facial analysis to better identify students who are struggling or bored and better tailor the learning experience to meet individual needs.
- **The media:** Journalism is utilising AI as well and will continue to do so. In order to assist readers quickly understand complicated accounting reports, Bloomberg utilizes Cybernetic technologies. The News Agency now generates approximately four times as many earnings reporting pieces every year (3,700) using Artificial Insight' natural language processing capabilities.
- **Customer service**: Lastly but again not least, Google is developing an AI assistant that really can phone calls which sound like they were made by a human to schedule appointments at, say, your local hair salon. The technology is capable of comprehending nuances and context as additional just speech.

Combining artificial intelligence and agriculture can be beneficial for the following processes:

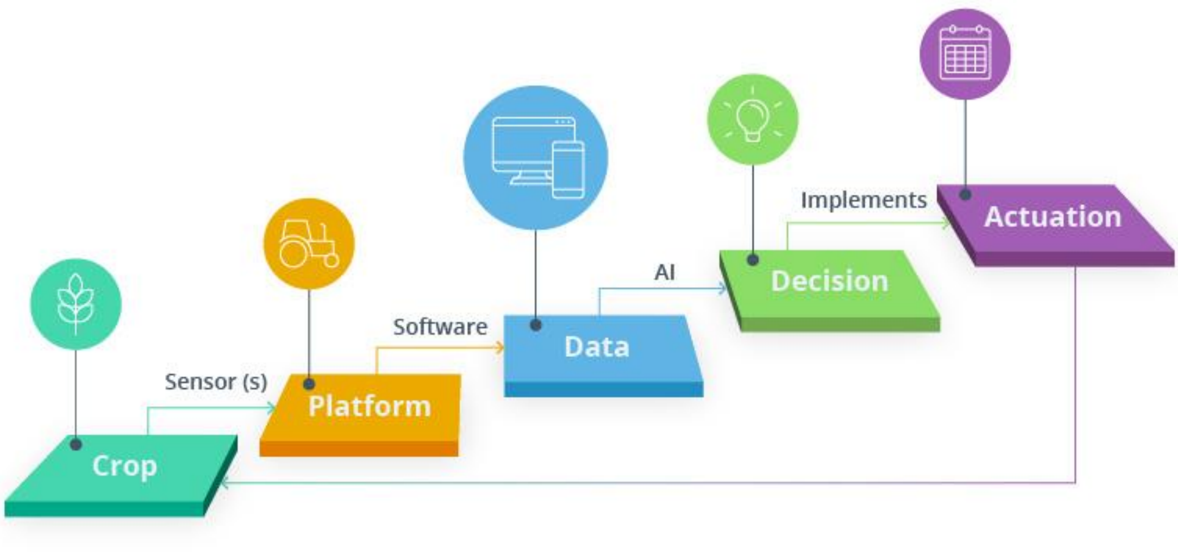

Figure 1 Role of AI in Agriculture Sector

- **Analysing market demand** AI can simplify crop selection and help farmers identify what produce will be most profitable.
- **Managing risk** Farmers can use forecasting and predictive analytics to reduce errors in business processes and minimize the risk of crop failures.

- Breeding seeds By collecting data on plant growth, AI can help produce crops that are less prone to disease and better adapted to weather conditions.
- Monitoring soil health AI systems can conduct chemical soil analyses and provide accurate estimates of missing nutrients.
- Protecting crops AI can monitor the state of plants to spot and even predict diseases, identify and remove weeds, and recommend effective treatment of pests.
- Feeding crops AI is useful for identifying optimal irrigation patterns and nutrient application times and predicting the optimal mix of agronomic products.
- Harvesting With the help of AI, it's possible to automate harvesting and even predict the best time for it

2. LIFE CYCLE OF AGRICULTURE

It is possible to think of agriculture as a system with inputs that include aspects of the physical, cultural, economic, and behavioural worlds. Physical controls are typically more critical in regions where farming is less developed than they are when human inputs rise. Any sort of farming, regardless of size or location, can use this system paradigm. It is the variations in the inputs which are responsible for the different types and patterns of

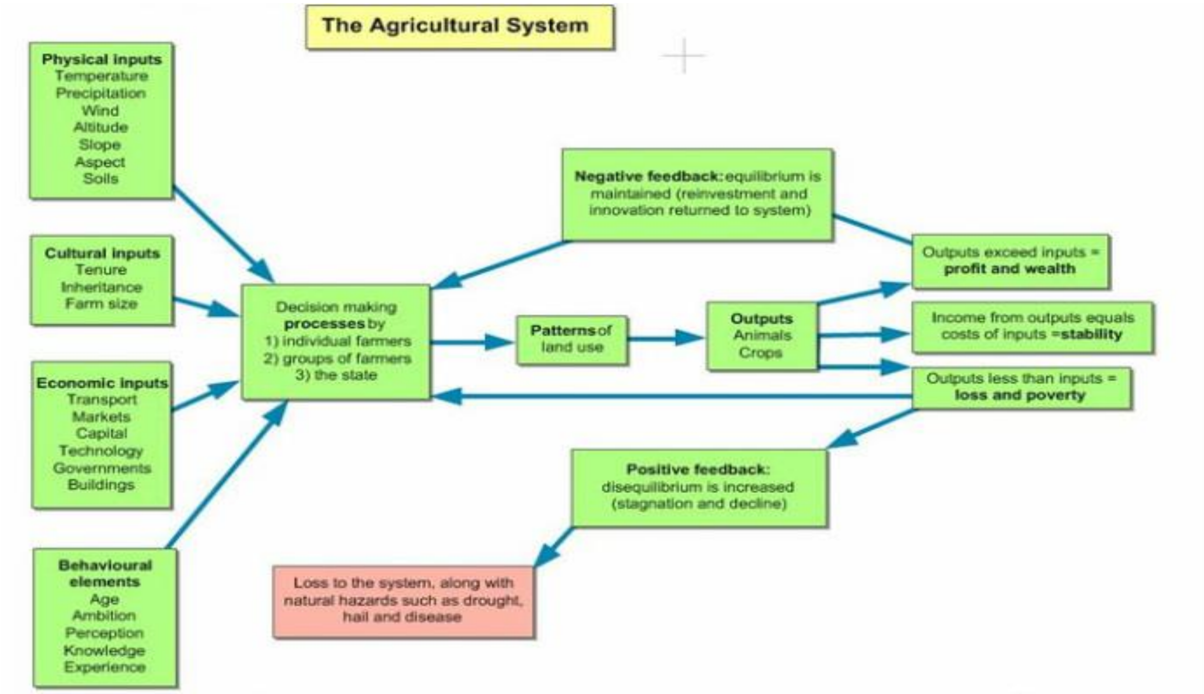

Figure 2 Life cycle of agriculture

agriculture around the world as shown in the following figure 2. The leads to classifications of agriculture in which contrasts between the different types of farming are clear.

3. PROBLEMS FACED BY MANUAL FARMING

- The effects of several meteorological variables, including temperature, humidity, and rainfall, are significant in agriculture.
- For a better crop, it is essential that the soil should be productive and have the necessary nutrition, such as Nitrogen, Phosphorous, and Potassium. Due to pollution, the climate can occasionally change abruptly, making it challenging for farmers to make the right decisions for harvesting, sowing seeds, and soil preparation.
- Poor quality crops may result if these nutrients are not effectively present in the soil. Yet, these soil qualities are challenging to determine using conventional methods. In the agriculture lifecycle, it is required that we save our crops from weeds. Else it may increase the production cost, and it also absorbs nutrients from the soil. But by traditional ways, identification and prevention of crop from weeds is not efficient.

4. LIFECYCLE OF ARTIFICIAL INTELLIGENCE

Computer systems now have the ability to automatically learn without being explicitly programmed thanks to machine learning. How does a machine learning system function, though? Thus, the machine learning life cycle can be used to describe it. Building an effective machine learning project involves a cycle known as the machine learning life cycle. The life cycle's primary goal is to find a solution for the issue or undertaking. Machine learning life cycle involves seven major steps, which are given below:

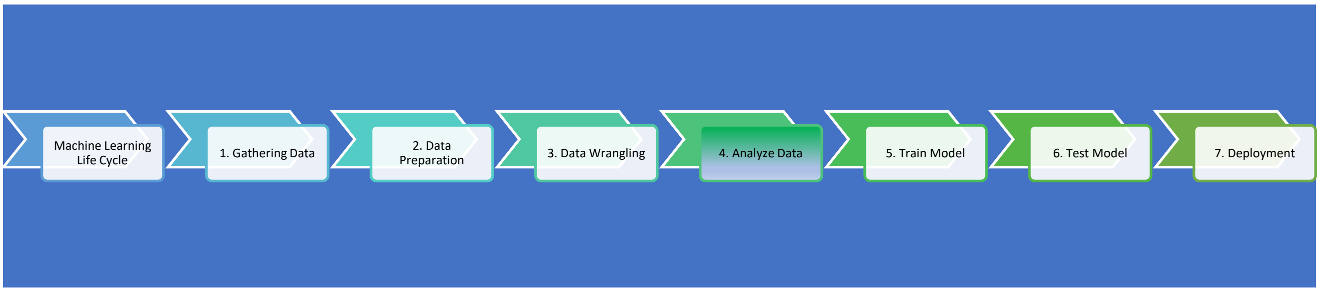

Figure 3 Life Cycle of AI

The most important thing in the complete process is to understand the problem and to know the purpose of the problem. Therefore, before starting the life cycle, we need to understand the problem because the good result depends on the better understanding of the problem. In the complete life cycle process, to solve a problem, we create a machine learning system called "model", and this model is created by providing "training". But to train a model, we need data, hence, life cycle starts by collecting data.

1. Gathering Data: Data Gathering is the first step of the machine learning life cycle. The goal of this step is to identify and obtain all data-related problems. In this step, we need to identify the different data sources, as data can be collected from various sources such as files, database, internet, or mobile devices. It is one of the most important steps of the life cycle. The quantity and quality of the collected data will determine the efficiency of the output. The more will be the data, the more accurate will be the prediction. This step includes the below tasks:

- Identify various data sources
- Collect data
- Integrate the data obtained from different sources

By performing the above task, we get a coherent set of data, also called as a dataset. It will be used in further steps.

2. Data preparation After collecting the data, we need to prepare it for further steps. Data preparation is a step where we put our data into a suitable place and prepare it to use in our machine learning training. In this step, first, we put all data together, and then randomize the ordering of data. This step can be further divided into two processes:

- Data exploration: It is used to understand the nature of data that we have to work with. We need to understand the characteristics, format, and quality of data. A better understanding of data leads to an effective outcome. In this, we find Correlations, general trends, and outliers.
- Data pre-processing: Now the next step is pre-processing of data for its analysis.

3. Data Wrangling Data wrangling is the process of cleaning and converting raw data into a useable format. It is the process of cleaning the data, selecting the variable to use, and transforming the data in a proper format to make it more suitable for analysis in the next step. It is one of the most important steps of the complete process. Cleaning of data is required to address the quality issues. It is not necessary that data we have collected is always of our use as some of the data may not be useful. In real-world applications, collected data may have various issues, including: Missing Values, Duplicate data, Invalid data, Noise. So, we use various filtering techniques to clean the data. It is mandatory to detect and remove the above issues because it can negatively affect the quality of the outcome.

4. Data Analysis Now the cleaned and prepared data is passed on to the analysis step. This step involves: Selection of analytical techniques, building models, Review the result. The aim of this step is to build a machine learning model to analyse the data using various analytical techniques and review the outcome. It starts with the determination of the type of the problems, where we select the machine learning techniques such as Classification, Regression, Cluster analysis, Association, etc. then build the model using prepared data, and evaluate the model. Hence, in this step, we take the data and use machine learning algorithms to build the model.

5. Train Model Now the next step is to train the model, in this step we train our model to improve its performance for better outcome of the problem. We use datasets to train the model using various machine learning algorithms. Training a model is required so that it can understand the various patterns, rules, and, features.

6. Test Model Once our machine learning model has been trained on a given dataset, then we test the model. In this step, we check for the accuracy of our model by providing a test dataset to it. Testing the model determines the percentage accuracy of the model as per the requirement of project or problem.

7. Deployment The last step of machine learning life cycle is deployment, where we deploy the model in the real-world system. If the above-prepared model is producing an accurate result as per our requirement with acceptable speed, then we deploy the model in the real system. But before deploying the project, we will check whether it is improving its performance using available data or not. The deployment phase is similar to making the final report for a project.

5. APPLICATION OF AI IN AGRICULTURE

There's no doubt that crop yields, quality, and labor practices are more efficient now than they were 50 years ago. However, there's still a major need (and *field*) for improvements. The global human population is exploding, with an estimated 9.9 billion of us on the planet by 2050 and with food demand projected to leap 35%—56% in that time. And that's not to mention climatic changes that make resources like water and farmable land scarcer. Luckily, technology provides us with yet another solution: AI. From leveraging computer vision technology for crop and soil monitoring to disease detection and predictive analytics, the agriculture industry is entering a whole new phase of evolution—thanks to AI. Agriculture is one of the most important sectors for the economy of our country, India. It is the foundation on which the economy of our country stands. The use of artificial intelligence technology in agriculture can increase productivity and efficiency. Artificial Intelligence is being used for identification and detection of diseases, precision farming and many other applications. Machine learning, a kind of artificial intelligence, allows computers to learn and make decisions on their own. In the field of agriculture, machine learning is being used to improve crop yields, reduce costs, and increase efficiency, not only is there potential, but also rapidly growing interest and investment shown by forbes reports that global spending on "smart" agriculture, including AI and machine learning, is projected to triple to $15.3 billion by 2025. Ongoing research suggests that the market size of AI in agriculture should expect a compound annual growth rate (CAGR) of 20%, reaching $2.5 billion by 2026. The following are various applications of AI in the field of agriculture.

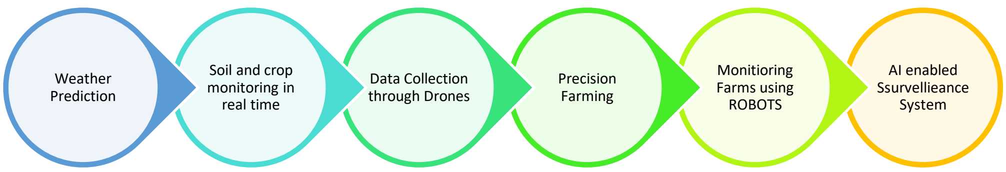

Figure 4 Application of AI in Agriculture Sector

5.1. **Weather Prediction** Smart management of weather data is an essential step toward implementing sustainability and precision in agriculture. It represents an important input for numerous tasks, such as crop growth, development, yield, and irrigation scheduling, to name a few. Advances in technology allow collecting this weather data from heterogeneous sources with high temporal resolution and at low cost. Generating and using these data in their raw form makes no sense, and therefore implementing adequate infrastructure and tools is necessary

5.2. **Soil and crop monitoring in real time** AI can be used for crop and soil monitoring through the use of sensors and machine learning algorithms. Sensors placed in the field can collect data on various parameters such as temperature, moisture levels, soil nutrient levels, and sunlight intensity.

5.3. **Data Collection through Drones** AI-based drones rely largely on computer vision. This technology enables drones to detect objects while flying and allows the analysis and recording of information on the ground. Computer vision works through high-performance, onboard image processing performed with a neural network

5.4. **Precision Farming** There has been an increase in the use of data to make more informed decisions and to produce better products. The basic idea of artificial intelligence in precision farming is that it can reduce complexity and perform the necessary tasks that only a human could perform.

5.5. **Monitoring Farms using ROBOTS** Redefining agriculture through artificial intelligence: Predicting the unpredictable Drones or unmanned aerial vehicles (UAVs) are being predominantly used in the agriculture sector. Kisan drones are likely to bring change through accurate weather forecasts and secure, precise crop analytics which are AI enabled and accessible. Multi-spectral and imaging features of drones can aid crop stress monitoring, assess a plant's growth stage, yield prediction and help in delivering fertilisers, herbicides and water. Drones can also help assess crop health, weed infliction, pests and infections status, and suggest judicious use of chemicals to address these issues. Hence, drone technology can help enhance the efficiency and consistency of crop management along with making it cost effective. There has been considerable development in the usage of drones in the agriculture sector. The Government of India (GoI) has also made a few important announcements towards the use of drones in the agriculture sector, and the notification of Drone Rules, 2021, launch of the drone Production Linked Incentive (PLI) scheme and introduction of a single-window Digital Sky Platform are some of the important steps taken by the GoI.

As the agriculture sector of the country develops further, the usage of drones in farming methods is predicted to grow with many start-ups investing in low-cost drones which can support farmers, enhance their knowledge and generate employment for the rural youth.

5.6. **Use of IOT devices in Agriculture** Artificial intelligence combined with autonomous tractors and IoT can solve one of the most common problems in farming: a shortage of labor. These technologies are also potentially cost-effective because they're more accurate and thus reduce errors. Taken together, AI, autonomous tractors, and IoT are the key to precision agriculture. Another less common but rapidly growing technology is robotics. Agricultural robots are already being used for manual work, such as picking fruits and vegetables and thinning lettuce. The advantages of robots over farmworkers are considerable. They can work longer, are more precise, and are less prone to error.

5.7. **Intelligent spraying** There are different AI companies that are building robots with AI and computer vision, which can precisely spray on weeds. The use of AI sprayers can widely reduce the number of chemicals to be used on fields, and hence improves the quality of crops and also saves money.

5.8. **Disease Diagnosing** Each crop is prone to particular diseases that will affect the quantity and quality of the yield potential. Average yield loss for most of the important food crops is due to crop diseases, which contributes about 42% of the crop failure. In many cases, the whole crop production is destroyed due to crop diseases. Crop production is affected by number of diseases worldwide. Timely detection of diseases will allow to monitor and implement control measures with greater efficiency. The main aim of this project is to design an AI-Based disease detection system that detects the type of disease present in tomato leaf by clicking the images of various leaves through camera and spray the respective pesticide to the diseased part of the plant. Deep Convolutional neural networks (D-CNN) and transfer learning techniques are

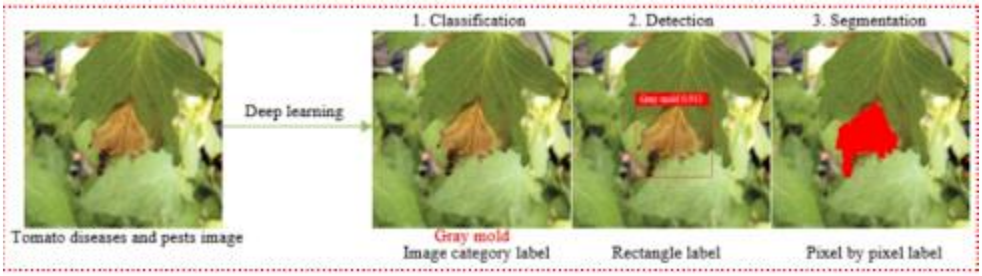

Figure 5 Disease Identification

used to detect and classify the disease. Using image recognition technology based on deep learning, we can now automate detection of plant diseases and pests. This works using image classification, detection, and image segmentation methods to build models that can "keep an eye" on plant health.

5.9. **Aerial Survey and Imaging** At this point it's probably unsurprising that computer vision also has some terrific applications for surveying land and keeping an eye on crops and live stock. But that doesn't make it any less significant for smart farming. AI can analyse imagery from drones and satellites to help farmers monitor crops and herds. That way they can be notified immediately if something looks amiss without having to constantly observe the fields themselves. Aerial imaging is also useful for boosting the precision and efficiency of pesticide spraying. As mentioned previously, ensuring that pesticides only go where they're intended saves money as well as the surrounding environment.

Figure 6 cattle detection from aerial imagery

5.10. **Produce grading and sorting** AI computer vision can continue to help farmers even once the crops have been harvested. Just as they are able to spot defects, disease, and pests as the plants are growing, imaging algorithms can also be used to sort "good" produce from the defective or just plain ugly. By inspecting fruit and vegetables for size, shape, color, and volume, computer vision can automate the sorting and grading process with accuracy rates and speed much higher than even a trained professional.

5.11. **Picture perfect produce:** Take carrot sorting, for example. It's laborious and usually done by hand. However, researchers have developed an automated sorting system that uses computer vision to pick out carrots that have surface defects or are not the correct shape and length. A "good" carrot, then, is one that's the right shape (a "convex polygon") and does not contain any fibrous roots or surface cracks. On these three criteria, the computer vision model was able to sort and grade carrots with accuracy rates of 95.5%, 98% and 88.3%, respectively. Further, bringing us back to the classic tomato, another study found that AI with machine learning was able to use image data with seven input features to grade tomato quality with 95.5% accuracy. In both cases, the amount of painstaking manual labor saved is enormous. And it's all thanks to a bit of AI training on what a "good" carrot or tomato looks like.

5.12. **Intelligent spraying** We've seen that computer vision is good at spotting disorders in agriculture, but it can also help with preventing them. UAVs equipped with computer vision AI make it possible to automate spraying of pesticides or fertilizer uniformly across a field. With real-time recognition of target spraying areas, UAV sprayers are able to operate with high precision both in terms of the area and amount to be sprayed. This significantly reduces the risk of contaminating crops, humans, animals, and water resources. While the potential here is great, currently some challenges still exist. For example, spraying a large field is much more efficient with multiple UAVs, but assigning specific task sequences and flight trajectories for individual crafts can be tricky. Researchers from Virginia Tech have devised a smart spray system based on servo motor controlled sprayers that use computer vision to detect weeds. A camera mounted on the sprayer records the geo-location of weeds and analyzes the size, shape, and color of each pesky plant in order to deliver precise amounts of herbicide with precision targeting. In other words, it's a kind of weed terminator. But unlike *the* Terminator, the accuracy of the computer vision system allows it to spray with such accuracy that it manages to avoid collateral damage to crops or the environment.

5.13. **Automatic weeding** Intelligent sprayers aren't the only AI getting into weed… er, weeding. There are other computer vision robots taking an even more direct approach to eliminating unwanted plants. Now, spotting a weed in the same way that computer vision can spot an insect or oddly-behaving chicken doesn't actually eliminate very much work for the farmer. To be of even greater help the AI needs to both find *and* remove the weed.

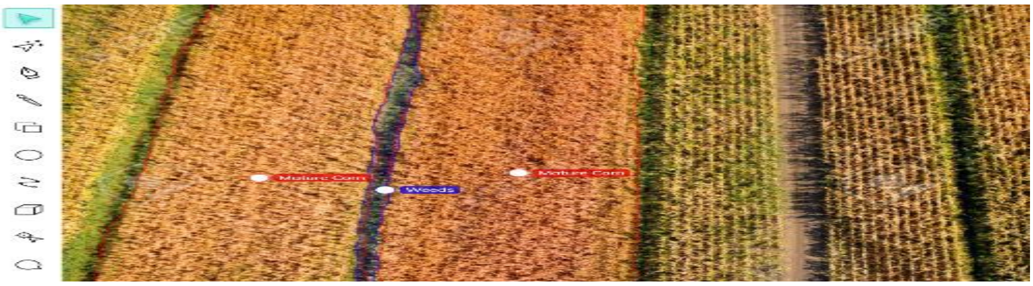

Figure 7 Automatic Weeding using AI

Weed and mature corn field annotation using V7 Being able to physically remove weeds not only saves the farmer quite a bit of work, but also reduces the need for herbicides and thus makes the whole farming operation much more environmentally friendly and sustainable. Luckily, object detection can do a great job of identifying weeds and distinguishing them from the crops. However, the real power comes when computer vision algorithms are combined with machine learning to build robots that perform automatic weeding.

5.14 **Picture perfect produce** Consider the example of carrot sorting. It's laborious and usually done by hand. However, researchers have developed an automated sorting system that uses computer vision to pick out carrots that have surface defects or are not the correct shape and length. A "good" carrot, then, is one that's the right shape (a "convex polygon") and does not contain any fibrous roots or surface cracks. On these three criteria, the computer vision model was able to sort and grade carrots with accuracy rates of 95.5%, 98% and 88.3%, respectively. Further, bringing us back to the classic tomato, another study found that AI with machine learning was able to use image data with seven input features to grade tomato quality with 95.5% accuracy. In both cases, the amount of painstaking manual labor saved is enormous. And it's all thanks to a bit of AI training on what a "good" carrot or tomato looks like.

5.15 **Crop and soil monitoring System:** Micro and macronutrients in the soil are critical factors for crop health and both the quantity and quality of yield. Then, once crops are in the soil, monitoring the stages of growth is also essential to optimizing production efficiency. It's vital to understand interactions between crop growth and the environment in order to make adjustments for improved crop health. Now, traditionally soil quality and crop health were determined by human observation and judgment. But this method is neither accurate nor timely. Instead, we can now use drones (UAVs) to capture aerial image data, and train computer vision models to use this for intelligent monitoring of crop and soil conditions. Visual sensing AI can analyse and interpret this data to:

- track crop health
- make accurate yield predictions.
- detect crop malnutrition much faster than humans

AI models can inform farmers of specific problem areas so that they can take immediate action. Manual observation of wheat head growth stages is just the kind of labor-intensive process that AI can help with in precision agriculture. Researchers achieved this by collecting images of wheat at different "heading" stages across three years and in different lightings, which enabled them to create a "two-step coarse-to-fine wheat ear detection mechanism". This computer vision model was then able to *outperform* human observation in accurately identifying wheat growth stages, meaning that the farmers no longer had to make daily treks into the fields to examine their crop. Or imagine having to check the ripeness of tomatoes by hand on an industrial level.

Figure 8 Ripe Vs Not ripe Tomatoes annotate with bounding boxes using V7

5.16 Detection of maturity of vegetables: Another study examined how well computer vision can detect maturity in tomatoes. Researchers created an algorithm that analyzed color from five different parts of the tomato, and then made maturity estimates based on this data. Shockingly well! The algorithm achieved a successful detection and classification rate of 99.31%. Overserving and estimating crop growth and maturity is hard, labor-intensive work for farmers. But AI is proving capable of handling much of that work with both ease and impressive accuracy.

5.17 **Hitting the Ground with Computer Vision** Getting back to the importance of soil, another study set out to see how well computer vision can characterize soil texture and soil organic matter (SOM). Ordinarily, evaluating soil requires farmers to dig up samples and bring them to a lab for time- and energy-intensive analysis. Instead, researchers decided to see if image data from an inexpensive handheld microscope could be used to train an algorithm to do the same thing. Sure enough, the computer vision model managed to make sand content and SOM estimates with accuracy comparable to costly lab processing. So, not only can computer vision eliminate a large amount of the difficult, manual labor involved in crop and soil monitoring, in many cases it does it more effectively than humans can.

5.18 **Insect and plant disease detection** We've seen how AI computer vision can detect and analyze crop maturity and soil quality, but what about agricultural conditions that are less predictable? Using image recognition technology based on deep learning, we can now automate detection of plant diseases and pests. This works using image classification, detection, and image segmentation methods to build models that can "keep an eye" on plant health.

5.18 Diagnosing disease severity: A good example of this in action comes from a study of apple black rot. Researchers trained a Deep Convolutional Neural Network using images of apple black rot which had been annotated by botanists according to four major stages of severity. As with our previous examples, the alternative to computer vision requires a lot of labor-intensive human searching and evaluation. Fortunately for farmers, the AI model in this study was able to identify and diagnose disease severity with an accuracy of 90.4%!

5.19 **Diagnosing multiple disease:** Researchers in another study went even further by using an improved YOLO v3 algorithm to detect multiple diseases *and* pests on tomato plants. Armed with a digital camera and a smartphone, the researchers took photos at local tomato greenhouses and identified 12 different cases of either disease or pests. Once the model was trained using the images, which varied in resolution and size of the object featured, it achieved a disease and pest detection accuracy of 92.39% with a detection time of just 20.39

ms..

Figure 9 Diagnosing multiple disease

5.20 Researchers first set up a sticky trap to capture six different species of flying insect and collect real-time images. They then based the detection and coarse counting method on YOLO object detection, and the classification and fine counting on Support Vector Machines (SVM) using global features. When all was said and done, their computer vision model was able to identify bees, flies, mosquitoes, moths, chafers, and fruit flies with an accuracy of 90.18%, and count them with 92.5% accuracy. These studies show that the future of AI computer vision for monitoring the health of our food systems is promising. Not only can it reduce labor inefficiencies, but it can do so without sacrificing reliability of the observations.

5.21 **Produce grading and sorting** Finally, AI computer vision can continue to help farmers even once the crops have been harvested. Just as they are able to spot defects, disease, and pests as the plants are growing, imaging algorithms can also be used to sort "good" produce from the defective or just plain ugly. By inspecting fruit and vegetables for size, shape, color, and volume, computer vision can automate the sorting and grading process with accuracy rates and speed much higher than even a trained professional.

6 ADVANTAGES OF AI IN AGRICUTLURE SECTOR

Along with above mentioned points we do have the other advantages of artificial Intelligence in Agriculture sector. Some of them are as follows:

6.1 **Brings in cost savings:** Precision farming using AI-enabled equipment helps the farmers to grow more crops with lesser resources and cost. AI provides the real-time insights to farmers that enables them to take proper decision at each stage of farming. With this correct decision, there is less loss of products and chemicals and efficient use of time and money. Moreover, it also allows the farmers to identify the particular areas that need irrigation, fertilization, and pesticide treatment, which saves excessive use of chemicals on the crop. All these things sum up and result in reduced use of herbicides, better crop quality and high profit with fewer resources.

6.2 **Tracking Labor Challenges** There has always been an issue of labour shortage in the agriculture industry. AI can solve this issue with automation in farming. With AI and automation, farmers can get work done without having more people, and some examples are Driverless tractors, smart irrigation and fertilizing systems, smart spraying, vertical farming software, and AI-based robots for harvesting. AI-driven machines and equipment are much faster and accurate compared to human farmhands

6.3 **Enabling Right Decision:** Predictive analytics is really a boon for the agriculture industry. It helps the farmers solving the key challenges of farming, such as analysing the market demands, price forecasting, and finding optimal times for sowing and harvesting the crop. Moreover, AI-powered machines can also determine soil and crop health, provides fertilizer recommendations, monitor the weather, and can also determine the quality of crop. All such benefits of AI in agriculture enable the farmers to make better decisions and do efficient farming.

6.4 **Predicting the best time to sow:** Depending on the weather conditions, what will be the right time to sow the seeds can be checked using AI.

6.5 **Crop yield predictions and price forecasts:** AI is very useful to identify the output yield of crops and forecast prices for the next few weeks will help the farmer to obtain maximum profit.

7 STARTUPS IN AGRICULTURE FIELDS

The following are the most common start-ups available in Agriculture sector :

Agribotix
Awhere
Cainthus
Connecterra
Deere and Company

Descartes Labs
Ec2ce
Farmbot
Gamaya
Granular

IBM
Mavrx
Microsoft
Precision Hawk
Prospera

Resson
Skysquirrel Technologies
The Climate Corporation (Subsidiary of Monsanto)
Tule Technologies
Vision Robotics

Details of some of them are as follows:

7.1 **Prospera:** It is an Israeli start-up founded in the year 2014. This company creates intelligent solutions for efficient farming. It develops cloud-based solutions that collect all the data from the fields such as soil/water, aerial images, etc. and combine this data with an in-field device. This device is known as the Prospera device, and it makes insights from this data. The device is powered by various sensors and technologies such as computer vision.

Figure 10 Detection of harvesting

Figure 11 Detection of automatic dying plants

7.2 **Blue River technology:** Blue-River technology is a California-based start-up that has started in the year 2011. It develops next-generation agriculture equipment using AI, computer vision, and robotics technology. This equipment identifies individual plants using computer

Figure 12 USing Lattuce Robot for agriculture

Figure 13 Using Saas for Agriculture

vision, ML decides action, and with robotics, the action is performed. This helps the farmers to save costs and chemicals in farming.

FarmBot: Farmbot is an open-source CNC precision farming machine and software package, which is developed to grow crops by anyone at their own place. The complete product "Farmbot" is available at a price of $4000, and it enables anyone to do complete farming ranging from seed plantation to weed detection on their own with the help of a physical bot and open-source software system. It also provides a webapp that can be downloaded on any smartphone or computer system and allows us to manage farming from any place at any time.

7.3  

Figure 14 CNC operated Gardening Robot

7.4 **Fasal:** The use of AI in the agriculture industry is increasing day by day in various places across the world. However, agriculture holdings per farmer in the poorer region is less compared to the rich region, which is advantageous for automated monitoring as it requires a lesser number of devices with low bandwidth and size to capture the complete agriculture data. In this field, the Indian start-up Fasal is working. It uses affordable sensors and AI to provide real-time data and insights to farmers. With this, farmers can be benefitted from real-time, actionable information relevant to day-to-day operations at the farm. The company's devices are easy to implement for small places. They are developing AI-enabled machines to make precision farming that can be accessible by every farmer.

7.5 OneSoil: Onesoil is an application that is designed to help farmers to take a better decision. This app uses a machine-learning algorithm and computer vision for precision farming. It monitors the crops remotely, identifies problems in the fields, check the weather forecast, and calculate nitrogen, phosphorus, and potassium fertilizer rate, etc.

7.6 BoniRob As an example BoniRob, an agricultural robot that uses camera and image recognition technology to find weeds and remove them by driving a bolt into the earth. It learns to distinguish between weeds and crops through image training on leaf size, shape, and color. This way BoniRob can roll through a field eliminating undesirable plants without the risk of destroying anything of value. A group of scientists is working on making this a reality with designs for agricultural robots that detect weeds as well as soil moisture content. This way, it can move through a field, removing weed and delivering appropriate amounts of water to the soil as it goes. Experimental results for this system show that its plant classification and weeding rates are both at or above 90%, all the while keeping deep soil moisture content at 80 ± 10%.

8 REALITY VS EXPECTATIONS OF ARTIFICIAL INTELLIGENCE FOR SUSTAINABLE FARMING

The benefits of AI in agriculture are undeniable. Smart farming tools and vertical farming systems can perform small, repeatable, and time-consuming tasks so farm workers can use their time for more strategic operations that require human intelligence. However, it's important to realize that unlike a tractor, one can't just buy AI and start it. AI is not something tangible. It's a set of technologies that are automated through programming.

Artificial intelligence is essentially a simulation of thinking; it's learning and problem-solving based on data. AI is just the next step in the development of smart farming, and it needs other technology to actually work. In other words, to reap all the benefits of AI, farmers first need a technology infrastructure. It will take some time, possibly even years, to develop that infrastructure. But by doing so, farmers will be able to build a robust technology ecosystem that will stand the test of time.

For now, technology providers need to think about a few things: how to improve their tools, how to help farmers address their challenges, and how to easily and understandably convey that machine learning helps solve real struggles, such as reducing manual work. The future of AI in agriculture is bound to be fruitful.

9 MAJOR ISSUES AND CHALLENGES OF USING AI IN AGRICULTURE SECTOR

By seeing the advantages of AI for sustainable farming, implementing this technology may seem like a logical step for every farmer. However, there are still some serious challenges that everyone knows, which are as follows:

9.1 **Lack of familiarity with AI machines** Although there are lots of benefits of using AI in agriculture, yet people are not familiar with the use of AI-enabled solutions and equipment across most of the world. To solve the issues, AI companies should provide the basic equipment to farmers, and once they get familiar with them, then provide them with advanced machines.

9.2 **Lack of experience with emerging technologies:** The adoption of AI and emerging technologies in agriculture for developing countries can be a challenging task. It will be very difficult to sell such technologies in the areas where there is no such agricultural technology is being taken into use. In such areas, to use these technologies, farmers need someone's help.

9.3 **Privacy and security issues:** As there are still no clear regulations and policies for using AI, it may raise various legal issues. Further, due to the use of software and the internet, there may also be some privacy and security issues such as cyberattacks and data leaks. All these issues can create a big problem for farm owners or farmers.

10 Key Companies playing an important role in Agriculture Sector

The following corporations are involved in working on AI in agriculture sector

- Spensa Technologies
- Granular
- Harvest Croo Robotics
- Prospera Technologies
- Microsoft
- Resson
- IBM
- The Climate Corporation
- Agribotix
- Mavrx
- Intel
- aWhere
- CropX
- John Deere
- SAP
- Precision Hawk
- Gamaya
- Vision Robotics
- Cainthus

11 CONCLUSION

The future of AI in farming largely depends on the adoption of AI solutions. Although some large-scale researches are in progress and some applications are already in the market, yet industry in agriculture is underserved. Moreover, creating predictive solutions to solve a real challenge faced by farmers in farming is still in progress at an early stage. In almost each sector, artificial intelligence is influencing how people will behave in the future. This already acts as the primary force behind developing technologies like big data, robotics, as well as the Internet of Things, and it's going to continuing to do so throughout the near future. The styrofoam container device uses machine learning and computer vision to detect and categorise different "safety occurrences." It cannot see everything, but somehow it sees a lot. Such as which direction his drivers is gazing while he drives, how quickly he's going, where he'll be going, where the people are around him and how other forklift drivers are controlling their trucks. IFM's technology instantly alerts warehousing supervisors to safety infractions, such as mobile telephone usage, so they may take appropriate action. The major objectives are to reduce fatalities and boost productivity. Gyongyosi asserts that perhaps the mere awareness that another one of IFM's surveillance systems is in place has had "a big influence." When considering a camera, he said, "It really is the richest sensor we have currently in an extremely attractive price bracket."

12 FUTURE DIRECTIONS

The fundamental building block of machine learning, AI is significant. In a fraction of a second it would take people, computers using artificial intelligence (AI) are capable of processing enormous volumes of data and utilise their acquired knowledge effectively achieve the best outcomes as well as conclusions. IFM is merely one of several AI pioneers in a sector that is constantly expanding. For instance, 2,300 of the 9,130 patents granted to IBM inventors in 2021 were there with artificial intelligence. Elon Musk, the founder of Tesla and a giant of the IT industry, contributed $10 million to support research being done at OpenAI, a non-profit research organisation. If his $1 billion co-pledge from 2015 is any indicator, this donation is indeed a blip in the ocean.

After such an evolutionary phase that started with "knowledge representation" and lasted over many generations characterized by periodic inactivity, technology advanced to model- and algorithm-based machine learning and increasingly centred on observation, thinking, including generalisation. Now, AI has reclaimed centre stage in a way that has never before been possible, and there are no plans to give it up anytime soon.

Throughout human history, technology has long been used in agriculture to improve efficiency and reduce the amount of intensive human labor involved in farming. From improved plows to irrigation, tractors to modern AI, it's an evolution that humans and agriculture have undergone since the invention of farming. With considerable changes occurring in our climate, environment, and global food needs, AI has the ability to transform 21st century agriculture by:

- Increasing efficiency of time, labor, and resources.
- Improving environmental sustainability.
- Making resource allocation "smarter".
- Providing real-time monitoring to promote greater health and quality of produce.

Of course, this will require some shifts in the agricultural industry. Farmers' knowledge of their "field" will need to be translated into AI training, and this will depend on greater technical and educational investments within the agricultural sector. But then again, innovation and adaptation are nothing new in agriculture. Computer vision and agricultural robotics are just the latest way farmers can adopt new technology to meet growing global food demands and increase food security.

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