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The Role of AI in Modern Farming: Precise Pest Management and Optimal Water Use

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Abstract

The economy is influenced by agriculture. Globally, the most important matter and growing subject is farm computerization. A higher demand for food and opportunities are directly proportional to the exponential growth in the population. The requirement had not been supplied by the conventional farming practices are utilized by the farmers. An agricultural revolution has been conducted by the use of artificial intelligence (AI). Due to this technology, yields from farming have been shielded from risks like warming temperatures, a rise in population, unemployment and food insecurity. The 24 classes' datasets are gathered from a variety of farming crops to identify pests by using AI technology which is implemented in drones. In this research, we examine the function of AI in farming, in the areas of precise pest management (PPM) and optimal use of water. By using these technologies, excessive amounts of water, pesticides and herbicides are reduced, soil fertility is preserved, labor is used more effectively, productivity is increased, and quality is improved. The paper's findings include the application of AI to pest identification employing drone sensors, irrigation and farming. Because of these technologies, new forms of automation were developed. Innovative techniques not only fulfilled the need for food but also created opportunities for billions of people.

Keywords: Farming, Crop, Pest, Irrigation, and Soil

Full-length article **Corresponding Author*, e-mail: sonam.ahuja82106@paruluniversity.ac.in

1. Introduction

Farmers sometimes have challenges in attaining abundant harvests during periods of unfavorable weather or crop diseases. In the same vein, the absence of digitization makes it more difficult to manage different activities during global pandemics [1]. Farmers are under tremendous pressure to produce enough food to satisfy the growing demand as a result of shifting consumer preferences and higher disposable incomes [2]. Due to the continued scarcity of rich soil, conventional agricultural methods are going to be abandoned to meet this challenge. However, there are techniques to increase production that can help to mitigate the issue. Investigating the worldwide use of artificial intelligence (AI) in agriculture shows enormous possibilities for reducing and managing problems [3]. Farming is a labor-intensive operation that requires a lot of physical labor. With the help of AI, current innovations can be enhanced and complicated as well as simple jobs can be made much easier. When coupled with other technologies, it can process massive volumes of information on an online platform, to identify the next stage and even set off activities [4].

The term Precise Pest Management (PPM) refers to the use of devices and methods to keep pests, illnesses, herbicides and other unwanted organisms from interfering with agricultural output in a particular manner [5]. Intense PPM allows farmers to include all parts of pest control into their farming system, which is referred as PPM shown in Fig.1. There are a lot of ways in which AI can enhance farming, but one of the most significant ways to help farmers to accomplish more with less effort [6]. Reflectance-based crop monitoring utilizing aerial or orbital remote sensing equipment can detect insect hotspots. Second, precise management methods, such as natural enemy distributors and pesticide spray rigs, can offer regional solutions. Any of these developments can be placed on machinery moving across fields, human or unmanned vehicles driving in fields, or aerial drones [7]. The focus of PPM, a relatively new ecological management method, is to achieve the necessary control with less usage of pesticides. Reduced pesticide usage

and more efficient pesticide application are two ways in which PPM can aid in water quality protection by reducing the likelihood of chemical runoff into surface and underground water sources [8]. The need for constant upgrades that adapt to changing agricultural circumstances, overreliance on technology, high starting costs and restricted accessibility for small farmers and ethical issues regarding the privacy of information are negative aspects. The purpose of this research is to examine automated irrigation, AI in farming and pest management techniques that could enhance the yield while reducing the amount of labor. The article [9] explored the case that creating and promoting effective crop monitoring practices were a significant scientific topic related to increased sustainability of pest management in contemporary agriculture. Plants react biologically to biotic stress such as herbivorous worm pests by altering the reflected energy of their leaves.

Modern technologies for imaging were capable of identifying these alterations, making them useful for non-intrusive agricultural observation methods. The goal of the study [10] was to provide chlorantraniliprole (CAP) for long-term pest management using a smart nanocarrier that serves nutrition for plants and site-specific delivery. The produced CAP@MIL-101 (Fe) @silica, which measured around 270 nm in size, exhibited a well-crystallized regular octahedron and a stable core–shell nanostructure, according to the data. Under UV light irradiation, the medication placed in the carrier has visibility 16.5 times greater than that specified by the CAP. The purpose of the research [11] was to suggest the inclusion of an environmental layer to traditional precision agriculture region procedures to address challenges that are associated with the description of site-specific management zones for pest management. In particular, they investigated the possibility of technologies for accurate collecting and species distribution modeling.

The article [12] proposed a mathematical approach to investigate agricultural pest management awareness utilizing plant biomass, pest and aware population. Infected and exposed pests make up pest populations. They suppose that awareness increase is related to healthy pest density in the agricultural field. Global media like radio and TV could raise awareness. Knowledgeable individuals could use biological control approaches like integrated pest management. The article [13] suggested a biological management of pests was the emphasis of earlier integrated pest management (IPM) methods. Recent advancements in agricultural technology, communication technologies, consumer trends, sustainable food awareness and globalization point to a need to update the IPM paradigm for current times. The proposed model expands on previous ecological and economic models by including management, business coupled with sustainability features and emphasizing research. The paper [14] proposed a dynamic optimization simulation model based on the input–output approach to explore synthetic optimal policies for water resources, water environment protection and economic growth. Six synthesized policy possibilities were selected. According to the simulation findings, the social economy could expand entirely provided water resources and water environment preservation are met in a complete situation.

1.1. Research Highlights

- Keeping the agro-based industry advanced requires AI.
- Automated robotic devices reduced the need for cleaning and irrigation.
- Crop monitoring issues were resolved.

2. AI in Modern Farming: Precise Pest Management and Optimal Water Use

Artificial intelligence (AI) is revolutionizing current farming by giving accuracy and efficiency regarding pest control and water usage. AI-driven systems analyze data on insect behavior and environmental factors to deploy tailored treatments, hence reducing the amount of pesticides that are used. Through the provision of real-time knowledge, AI optimizes water consumption, which in turn enables farmers to apply precise irrigation schemes for best crop development.

2.1. Dataset

In this section, the study provided the datasets for multiple farm crops. Insect images have a total of 785 samples that comprise the training set and 612 compose the testing set; there are about 60 images of each class from the fields through monitoring in the 24-class dataset [15].

2.2. AI's role in farming

AI has the power to revolutionize farming by offering insights into crop productivity variables. These models assess complicated aspects including weather, soil and crop management which are interconnected. Weather greatly impacts agricultural output. Crop growth and health depend on rainfall, climate, sunshine and moisture. AI algorithms can examine chronological and real-time meteorological data to identify trends that contribute to agricultural yields. These computer simulations can discover that a given crop flourishes under certain temperature and rainfall parameters, which can be used to forecast agricultural yields. Crop management strategies, together with weather and soil conditions, affect crop output. Practices including irrigation, weeding, fertilizer, insect control and planting density impact crop growth. Precision farming is one area where AI has improved agricultural practices significantly. By using cutting-edge sensors, drones and satellite images, AI empowers farmers to track and assess their farms. We can identify the problem with pests or diseases, optimize irrigation according to soil moisture levels that find the best times to sow and harvest. This allows for a more sustainable and eco-friendly method of farming by increasing crop yields with less water and fertilizer expenditure.

Robots driven by AI have made great strides in the cultivation process. There can be much less need for human labor when AI-enabled robotic harvesters and autonomous tractors have a complete position. As a bonus, this eliminates the issue of labor shortages while simultaneously decreasing production costs and increasing efficiency. Unlike humans, AI-powered robots can work around the clock, allowing them to cover more ground and increase productivity in farming. AI helps in optimizing genetics and agricultural breeding. To speed up the process of creating new, more robust crop varieties, AI algorithms clean massive databases for genetic markers linked to desired features. Because AI allows for the production of more resilient crops to pests, illnesses and bad environmental conditions, this has significant ramifications for food security around the world. Fig.2. demonstrates the technology of AI in farming.

2.3. Precise Pest Management and Optimal Water Use

Pest management equipment and techniques fall into many categories. While there cannot be a single solution for controlling pests, externally applied pesticides remain the primary choice in food production due to their wide range of functions. Additionally, technological advancements in pesticide composition, including chemical along with bio pesticides, can improve the effectiveness and minimize environmental impact. This seems promising for microencapsulation and nanoparticles formation. One intriguing prospect for the future of pest management is organic food production, which provides a way with synthetic pesticides.

Farmers can comprehend pest movements using AI models of image recognition and sensor-based technologies. This understanding allows accurate pest identification and categorization, enabling focused treatments and reducing broad-spectrum pesticide usage. It reduces the impact on the environment and preserves ecologically important creatures. AI optimizes water use as shown in Fig.3, a major agricultural issue. Farmers can accurately anticipate irrigation schedules using AI algorithms based on soil parameters, weather predictions and crop water needs. This method conserves water and improves crop yields and quality by customizing water distribution to crop demands. Implementing accurate pest management and appropriate water utilization with AI is complicated. Small-scale farmers cannot be able to afford such complex equipment, which needs initial investment and continuing maintenance. Data privacy and technological overuse ethics should be considered. Despite these obstacles, AI's revolutionary abilities to transform farming demonstrate its promise to handle future agricultural difficulties including environmental sustainability and food security.

2.4. Irrigation

An essential part of contemporary farming, irrigation guarantees a steady flow of water to plants, allowing them to flourish. Improving irrigation systems has been one of the most significant contributions to the agricultural revolution in recent years of AI. The use of AI tools like data analytics is revolutionizing water management for farmers. This is leading to more efficiency, less water waste and improved agricultural yields. One of the most important developments in AI for irrigation systems is the ability to sort through mountains of data collected from a wide range of sources, including variations in the weather, water in the soil levels and crop health. By combining this data, AI systems can determine the exact amount of water that various crops need at different points in their development cycles.

This allows for more precise watering schedules, which in turn increases agricultural yields while decreasing water waste, to tailor irrigation tactics. The use of smart irrigation systems and sensors driven by AI has become crucial for control and monitoring in real-time. Drones outfitted with AI technology make it possible to fly over vast agricultural areas, giving farmers crucial data on the condition of their crops and how much water they require. Improved water resource management is possible with the use of AI-enabled predictive modeling and more precise irrigation. AI systems can assist farmers in planning irrigation schedules and water supply forecasts by evaluating past data and predicting future climatic conditions. This preventative measure performs double duty: it reduces water use and makes farming more resistant to the effects of climate change.

2.5. Use of drones in farming

Drones have caused a sea change in precision agriculture by altering traditional farming methods. Drones and other unmanned aerial vehicles (UAVs) with high-tech cameras provide farmers with very useful information for keeping tabs on their crops. Farmers can evaluate crop health, diagnose illnesses and pinpoint nutrient deficits with unparalleled precision using drones. Drones' high-resolution photos let farmers make rapid choices on irrigation water, fertilizer and issue prevention. Drones provide an important function in crop scouting by scanning vast areas and offering real-time observations. By increasing output while decreasing loss, this technique encourages ecologically responsible and long-term agricultural methods. The use of drones is becoming more important for contemporary farmers as the agricultural sector embraces innovation, allowing for more efficient and accurate farming techniques.

3. Result

In this part, we analyzed the pest detection from the dataset, the AI role in farming and irrigation time in the field.

3.1. Pest Detection

AI has brought a revolutionary change in farm pest detection. AI models allow for accurate pest detection and categorization by using cutting-edge technology like image recognition and sensor data. By focusing on specific areas, we can intervene quickly, which means less use of toxic, long-term pesticides and more support for long-term, environmentally beneficial solutions. Fig.4. and Table 1 show the comparisons and numerical values of pests from the dataset. The dataset used to train the pest detection model has three separate classes, each with eight, twelve and twenty-four classes. Each class's training set included 36%, 42% and 76% samples, respectively, but the test set had 48%, 51% and 89% samples. The variety of the dataset used to train and test the pest identification model can be seen by examining these percentages, which show the distribution of situations across the different classes. It is crucial to have an equal share of classes in the training and test sets so that the model can generalize well and correctly detect pests across various categories.

3.2. AI in Farming

In the agriculture sector, for example, AI-based solutions aid irrigation, weeding, crop yield, crop establishment, crop monitoring along with soil content sensing, among other areas and in managing the issues encountered by many businesses. The use of AI in farming makes agriculture more efficient and sustainable. Smart technology such as drones, sensors and AI make crop monitoring, precision farming as well as resource allocation are more efficient.

Figure 1. Precise pest management (Source: Author)

Figure 2. AI technology in Farming (Source: https://www.aesanetwork.org/wpcontent/uploads/2021/01/Blog-140.jpg)Methodology

Figure 3. Water usage in AI farming (Source: https://www.europenowjournal.org/wp content/uploads/2018/12/shutterstock_142601641.jpg)

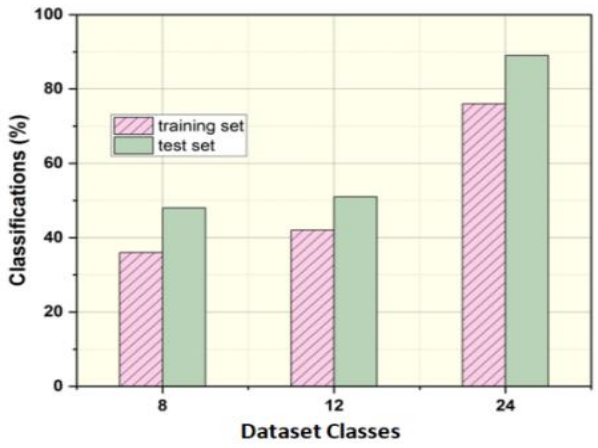

Figure 4. Comparisons of the dataset

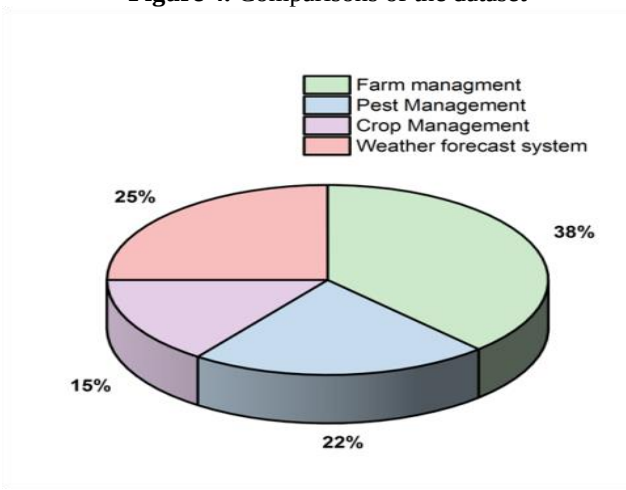

Figure 5. Pie chart of AI farming (Source: Author)

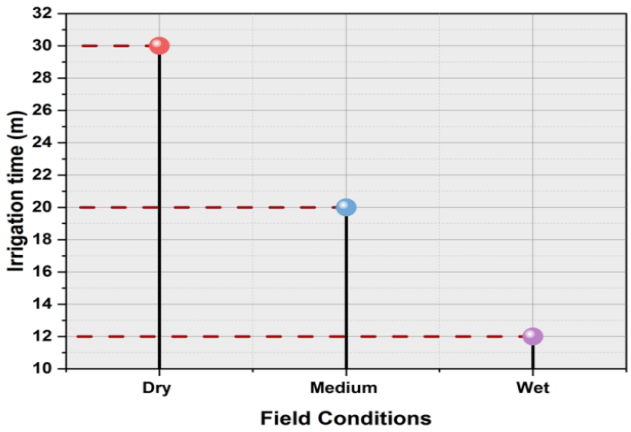

Figure 6. Comparisons of field Conditions (Source: Author)

Table 1. Numerical Outcomes of the Dataset

Dataset Classes	Classifications (%)	
	training set	test set
8	36	48
12	42	51
24	76	89

Table 2. Numerical outcomes of AI farming (Source: Author)

AI in farming (%)	
Farm Management	38
Pest Management	22
Crop Management	15
Weather forecast system	25

Table 3: Numerical outcomes of field Conditions (Source: Author)

Field Conditions	Irrigation time (m)
Dry	30
Medium	20
Wet	12

The sector that stands to gain the most from AI's ability to optimize resource allocation, boost productivity and streamline operations is farm management, which accounts for 38% of the total. Pest control is 22%, where AI-powered solutions detect and counteract crop dangers, reducing losses. AI in farming, the optimization of planting patterns and the assurance of optimum yields constitute 15% of crop management and Weather forecast system yields 25%. Fig.5 and Table 2 show the comparisons and numerical values of AI farming.

3.3. Irrigation in Farming

In terms of global freshwater use, agriculture accounts for eighty-five percent of the total. With a growing population and more food demands, this proportion is rising at a fast pace. This means we need to find better ways to utilize water for irrigation, which means we need to develop more efficient technology. Automatic irrigation scheduling methods supplanted the labor-intensive practice of hand-watering crops based on soil moisture measurements. AI in farming improves agricultural efficiency by optimizing irrigation according to field conditions. To make sure that there's enough water; AI suggests watering for 30 minutes when it's dry. The system recommends 20-minute duration in medium settings, striking a balance between too much water and less amount of water. The recommended irrigation period is 12 minutes to avoid overwatering in rainy weather when moisture is abundant. By adjusting irrigation methods to meet the unique demands of each field, this method reduces water waste, supports environmentally responsive farming and increases harvest yields. Precision farming has progressed in part to the incorporation of AI, which highlights a technologically sophisticated and resource-conscious strategy. Fig. 6 and Table 3 illustrate how long it takes to irrigate fewer than three conditions.

4. Conclusion

AI is revolutionizing farming by managing pests precisely and optimizing water use for more sustainable and efficient operations. The agricultural sector encounters various challenges, including inefficient irrigation systems, weed proliferation, challenges in monitoring plants due to varying crop heights and adverse weather conditions. The technology offers a viable solution to enhance performance and address these issues. Employing a range of AI-driven solutions, such as remote sensors for soil moisture assessment and GPS-enabled automatic watering, presents a promising avenue for improvement in agricultural practices. The utilization of AI technology in conjunction with drones for pest management as well as agricultural practices has demonstrated significant advancements and benefits in the realm of farming.

The varied crop dataset has helped identify pests with accuracy, improving pest control tactics. An imbalance should be noted during model evaluation and training since the training set comprises 24% of classes and the test set 76%. The integration of AI technologies in farming practices, particularly in PPM and optimal water usage in wet conditions (12 minutes), has yielded a range of positive outcomes. The detection and treatment of pests have become more precise and efficient than the use of drone sensors powered by AI. Among the many adSvantages are higher production, better product quality and more efficient use of labor. Innovations in agricultural automation have allowed the sector that adapt to the rising demand for food throughout the world and have opened the doors to new economic possibilities for billions of individuals.

4.1. Limitation and Future Scope

Changing temperatures, groundwater density, lack of irrigation, food shortages, waste and more are major agricultural concerns. Receiving different cognitive solutions determines the future of cultivating to a large degree. The sector is severely underserved, even though much research is ongoing and certain applications are on the market. In the next years, AI is going to change the market and agriculture. Farmers have found the technology helpful in understanding different kinds of hybrid cultivations that would increase their revenue in a shorter amount of time. Appropriate AI use in agriculture will facilitate farming and set the stage for a

market atmosphere. According to statistics from prestigious organizations, there is a significant amount of food waste around worldwide.

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