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An Analysis of Sustainable Future Farming - AI/ML based precision farming

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Abstract**—** *The main purpose of this study is to investigate the significance of technology, particularly AI/ML, in the development of sustainable farming practices for the future. Over the years, a wealth of knowledge and expertise in crop and soil management, as well as cutting-edge agricultural technology, has amassed. Indian farmers face a formidable obstacle in their pursuit of food and environmental security as the country's population rises and its agricultural resources dwindle [1]. Increasing the productivity and long-term sustainability of farming on a scientific foundation is urgently needed to combat these dual difficulties in the country [1]. Precision farming is a novel approach to agriculture that aims to better satisfy the needs of a growing population. This idea is a novel strategy for advancing farming practices that boost soil and crop output with little additional labor and financial outlay. Precision farming (PF) seems to be a win-win technique for boosting farmland's capacity for sustainable crop production. For the PF to work toward its goals of boosting agricultural productivity and decreasing environmental menaces, it relies on a method focused on identifying the geographical and temporal variability in crop output. It's cutting-edge tech that uses a slew of cutting-edge technologies, including GIS, VRT, RS, GPS, DSS, and Farmer [1,2]. Field conditions may be optimized for crop yield and input usage efficiency via the use of precision land leveling, precision planting, and precision nutrient management using tools like Green Seeker, leaf color chart (LCC), and site-specific nutrient management.*

Keywords— Sustainable Future Farming, Precision Farming, farming management, Machine Learning (ML) systems, Big Data Analytics, Future farming, Artificial Intelligence

I. INTRODUCTION

The study of soil in geotechnical engineering is a Precision agriculture is a type of farm management that considers and adapts to natural variation in plant growth and yield. A number of factors contribute to these variables, making computation challenging; nonetheless, technology has progressed to compensate for this. Precision agriculture often employs two categories of technology: those that guarantee precision and those that are designed to improve agricultural processes. These two technologies, when combined, provide farmers with a comprehensive decision-making framework that helps them increase yields while decreasing costs [2]. Producers may improve as land stewards by using precision agricultural technologies to implement optimal management practices for nutrients. Historically, manufacturing inputs have been applied in a consistent, across-the-board manner. Several studies have shown that uniformly applying production inputs across all agricultural fields is not always the most effective method since soil qualities vary between fields, resulting in spatial heterogeneity in crop yields. Low input usage efficiency, high production costs, and natural resource deterioration are the results of old input management approaches, in which agricultural inputs are applied to farms regardless of the resource characteristics[2]. Precision farming is a kind of farming that maximizes crop yields while minimizing negative impacts on the environment by emphasizing site-specific crop management strategies. Precision farming, also known as site-specific management, is the "art and science of utilizing advanced technologies for enhancing crop yield while minimizing environmental threat to the planet," with the goal of reducing environmental impact by maximizing crop yield through the management of soil spatial variability through the application of inputs tailored to the unique needs of each individual plot of land and crop. Such management strategies need for a quantitative understanding of the geographical heterogeneity of soil throughout the field. For farmers, precision means more than simply using cutting-edge equipment; it also means learning how to effectively collect and use data. Numerous industrialized nations are now researching and adopting precision farming technologies such as yield monitoring, variable rate input application, precision land leveling, the management zone method, and crop input decisions. Many methods for accurate input management are now being tested in many countries around the world.

II. RESEARCH PROBLEM

The main problem that this research will solve is to explore how technology like artificial intelligence and machine learning will solve sustainable future farming. Growing human populations on a world that has stayed about the same size have placed a severe strain on the available land area to meet rising demands for food. Focusing on precision agriculture to increase crop yields is crucial in this time of crisis so that we can ensure food security [3]. In order to assist farmers, maximize their profits from their agricultural yields, digital technologies are increasingly being used in agriculture. Here we get to the topic

of Artificial Intelligence (AI), which has recently been redefining the field of effective agriculture management. We should now investigate the potential gains for farmers who use this technology. Global warming, deforestation, soil erosion, and dwindling water supplies are just some of the other issues that threaten our ability to supply the world's insatiable food demands. Artificial intelligence (AI) and data analytics have the potential to help us solve this problem and lead us in the direction of a second green revolution, which might eventually ensure that people never go hungry again [4]. Despite the fact that Earth has become unpredictable, new technologies like artificial intelligence and big data analytics have given people reason to be optimistic by holding up the possibility of a radical improvement in human life via agricultural revolution.

III. LITERATURE REVIEW

A. Approaches for precision farming

Precision farming entails making use of the available variability to tailor the application of inputs. Soil and crop variability assessments are the foundation of precision agriculture. All factors (topography, soil conditions, etc.) that influence agricultural output should be identified, measured, and placed in their appropriate spatial contexts. A crucial part of precision farming is creating condition maps that account for unpredictability. Precision application maps were originally developed using grid sampling, in which fields were sampled in a grid pattern with a spacing of 60-150m, depending on the size of the field, and the samples were examined for the necessary properties [4]. These studies provide interpolated values for sites that were not sampled, which are then categorized using GIS methods into a small number of management zones. Bare soil imaging, geography, and farmer's experience are all used as GIS data layers in the zone demarcation process. Fields are often divided into productivity level management zones, which is a relatively new method for quantifying soil spatial variability for site-specific management. It is common practice to apply a single rate of a certain crop input throughout an entire field if the yield-limiting variables in a given zone are consistent with one another [5]. The productivity of a field may be used to split it into three zones: high, medium, and poor, so that the agricultural inputs are administered correctly.

B. A.I. and Agriculture Driven by A.I.

AI's primary roles are in algorithm learning, development, and implementation. All it needs to do is use all the data at its disposal, play games, and recognize patterns to achieve this goal. This applies to a broad range of applications, from decision making to computation to identification to labeling [5]. Agriculture that is powered by AI aims to build systems that are better at every step of the agricultural process, from harvesting to storing to processing. This may be accomplished in a number of ways, including the use of AI alone or in conjunction with human input, such as using trait or background recognition software that assists in the identification of pests or superior fruits and vegetables for human consumption. Additionally, it is beneficial to society as a whole since it lessens the need for human labor in the manufacturing of products and services [5].

C. Artificial Intelligence and AI-driven Farming Operations

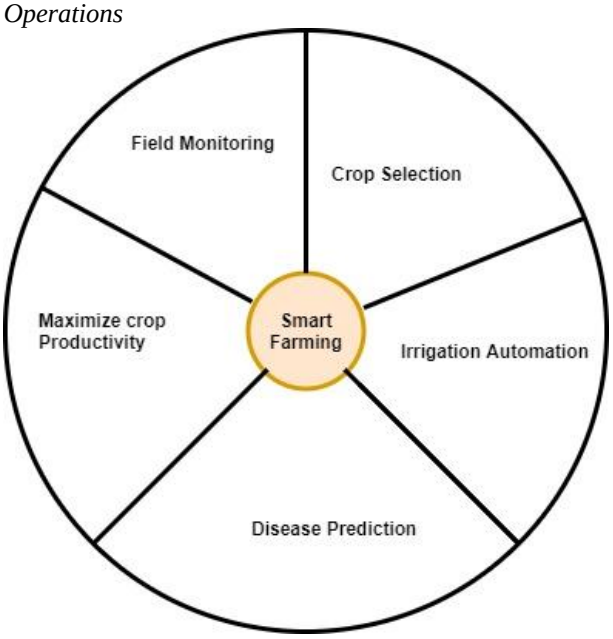

Fig i: An illustration of smart farming roles

Interest in automated agriculture has increased in recent years as a means to streamline the complicated and time-consuming processes involved in the manufacturing and distribution of food and drink. In order to improve the quantity and quality of food produced by smallholder farmers throughout the world, automation of agricultural operations has become a vital step. Smallholder farmers' social and environmental conditions will improve as a result of this practice, and corporations will save money in the process. The benefits of AI in agriculture go well beyond the food industry and might be seen across the economy. One research indicated that AI's ability to provide insights about food sources, taste profiles, cooking time, and other elements may assist to cut expenses and enhance quality. Our eating habits may be drastically altered as a result of this technology. For instance, in the food and drink industry, whereby the quality of products is directly tied to the health and well-being of consumers, it is essential to enhance the precision and efficiency of molecular design. Accurate molecular design is crucial to comprehending chemical interactions and creating novel agricultural practices [6], making it a critical part of the food science field.

Artificial intelligence (AI) has been gaining traction in the agricultural sector over the last several years as more and more scientists investigate its potential in the development of automated farming systems. Making robots as intelligent as possible is a top priority since it reduces the amount of time and effort required to perform jobs. Because of their growing sophistication, contemporary robots make it more challenging to simplify them as much as feasible. In order to simplify AI-driven robots, it is crucial that they have access to the necessary tools and the capacity to do jobs efficiently [6,7].

D. What AI Can Do for Precision Farming

Precision farming is increasingly reliant on artificial intelligence. This innovation may impact how crops are grown, foods are processed, and supplies are kept. There has been a sea change in the food industry during the last decade. AI and artificial intelligence have largely superseded conventional practices, such as farming with field cameras, aerial imaging, and satellite delivery. The worldwide epidemic has also contributed to this change. More and more people are turning to data to help them make better choices and create higher-quality goods [7]. Artificial intelligence's central promise for

precision agriculture is that it can streamline labor-intensive processes that previously required human intervention. Because of how taxing and intense the human body may be, we have a very small agricultural footprint. When compared to the human capacity, AI is designed to manage far more work. When applied to agriculture, AI has the potential to simplify the production process, which is a major advantage [7].

E. The Role of Artificial Intelligence in Precision Farming

Precision Agriculture, which utilizes a number of cutting-edge technologies like artificial intelligence, big data, the cloud, the internet of things, and machine learning, is predicted to revolutionize farming in rural areas. From the automated identification of drought patterns to the tracking of ripening trends for apples or tomatoes, to the development of "smart tractors" that can identify and remove infected or otherwise unhealthy plants, the technology's impact is far-reaching. Drones are now widely employed in agriculture for a variety of purposes including research analysis, safety, rescue, terrain scanning, spatial analysis, monitoring soil moisture, detecting production issues, etc.[7].

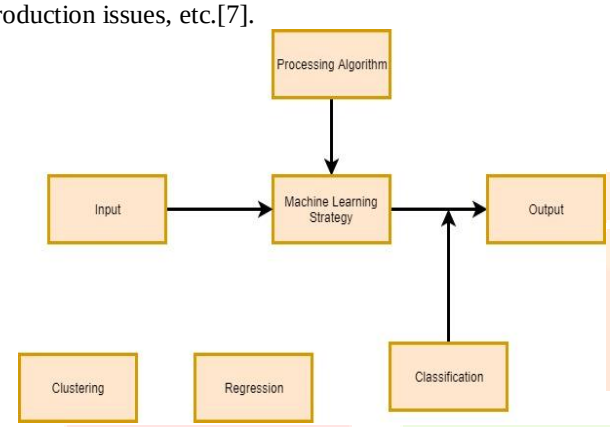

Fig ii: Machine learning process in farming operations

From the air, these sophisticated aircraft can pinpoint damaged plants and spray them with pesticides; they can also apply micro and macronutrients, monitor soil moisture and chemical composition, adjust soil pH using lime, and much more. With the use of an AI-driven application, precision agriculture can determine the match case: it can determine what illness has weakened the plant, match it against its database of disease images, and then initiate remedial actions. Thus, the potential of AI and data analytics in Precision Agriculture is boundless. The information farmers need will be delivered to them when it has been gathered and processed. Those pioneering farms that integrate AI techniques into their operations will have a leg up on the competition [8]. In order to increase a farmer's profit, sophisticated technology is required. The process involves setting up multiple data points in large agricultural farms and collecting precise and relevant data using edge devices such as drones, sensors, smart cameras, etc., powered by some intelligent monitoring and analytics systems in order to provide smart information to the farmers.

F. Technologies that Help Maximize Farm Yield

By adopting and integrating future smart technology into agricultural methods, farmers may maximize the potential of each and every plot of land and realize their ambitions of a five- to sixfold increase in farm production per acre. When compared to anything, it is an enormous sum. For the first time in history, modern technology is enabling farmers to make significant advancements, greatly enhancing their standard of living [8]. As far as farmers are concerned, this is nothing short of a miracle for their little property. We're transitioning from an emphasis on organic food to one that places a premium on artificial intelligence-enabled smart precision agriculture and smart connected farms, where the latter both dictates and empowers farmers. Farmers everywhere, but notably in Asia, have waged an uphill struggle against external and internal elements including climate change, insect infestations, lack of water, and drought for centuries. With the advent of AI and Big Data Analytics, a real discovery has surfaced that may help the farming community reverse this trend. To put it another way, it makes the most of every available square foot of farmland, so nothing is wasted as it was in the past when agricultural methods were less efficient. Technology advancements have made it feasible to scan crops for information on their health and development, as well as to identify and alert farmers to any persistent pest issues, which was not possible in the past [9,10].

G. Incorporating Precision Agriculture into an Existing System Producers

Precision farming being synonymous with variable-rate fertilizer application is gradually losing ground. Farmers who have been mapping their fields' yields for a while are starting to ask the fundamental questions that will help them understand the sources of yield fluctuation. Infertility is now understood to be a minor facet of the overall variability picture. On-farm field experiments of various management strategies are being conducted with the use of precision agricultural technologies. Acquiring and making sense of geographical and temporal data is at the heart of precision agriculture. Management does not include it, and it is not the sum of its parts [10]. Our hope is that farmers would invest as much time and energy as they can into implementing precision agricultural practices. What we're arguing for is that farmers open their minds to precision agriculture as a method to expand their knowledge and alter their approach to management. An agriculturist who relies only on short-term gains may be disillusioned by the potential of precision agriculture. Rather than demonstrating how a product or service can help a producer learn precision agriculture, it is far simpler to promote a particular component of management that can be immediately assessed for its improved profit potential. In order to give a comprehensive answer for farmers' problems, salespeople for agribusinesses will need the proper resources and education. To better comprehend the whole agricultural production system, we propose that many different agribusinesses, often in partnership with public research institutes, may work together to produce solutions that help draw information together [10]. To educate a system, you need to be able to talk about the elements that make it up. However, if we simply talk about the parts, and those talks don't work together to teach precision agriculture as a system, we'll fail. In its pursuit of a multimodal approach to education, precision agriculture may be foreign to certain teachers. Participation and coordination from teachers in other fields may need more work. Need: Precision agriculture educators, unlike their academic counterparts, must plan and promote educational and research initiatives in a collaborative and cross-disciplinary manner. The convergence of agricultural specializations is a potential outcome of precision agriculture. Unfortunately, in the realm of publicly financed education and research, multidisciplinary, team-oriented activities have not always received the same amount of appreciation as more narrowly focused investigations. Not discouraging transdisciplinary programs should be a part of the public and commercial sector's incentive and promotion system [10,11].

What must change?

- Countries to introduce more effective measures to prevent oligopolies/Agropoly
- Public subsidies to be transparent and encourage sustainable agriculture
- International regulation to punish human rights violations by corporations
- Food sovereignty to be supported
- The influence of corporations on politics and administration to be reduced
- Responsible companies as part of the solution

Target State:

IV. SIGNIFICANCE

The advancements in agriculture technology, has led to a new method known as "precision farming". The ultimate objective of every prosperous farmer is to maximize agricultural output and profitability, and this is where precision farming comes in. When farmers carefully manage their farms, they may save valuable inputs while still preserving the land's natural beauty [11]. Weather forecasting and the anticipation of climate disasters are two areas where AI and Machine Learning have shown to be useful. Because of this, the use of these technologies in precision farming may assist farmers in evaluating preventative measures to take in the event of crop loss. The predictions also help them select when and what sort of crops to sow. Unsurprisingly, improved crop management is the result of such precise forecasting [11,12].

Predictive analysis and crop and soil monitoring are the two main areas where AI is used in agriculture. Insect and disease forecasting, soil management parameters, weather forecasting, and scientific water management are all topics that farmers may now discuss in more depth. In addition, farmers' lives have become easier thanks to agricultural methods supported by the Internet of Things (IoT) through smartphone app. The improved crop production cycle and increased ROI on harvests are both direct results of these factors [12]. It's important to remember that AI is still relevant all the way through the agricultural process. There's no denying its importance in the expansion of plants. Artificial intelligence (AI) aids farmers in optimizing agricultural yields by providing guidance on seed selection, planting schedules, and harvest times. Ai sensors keep an eye on the soil and plants, and its complicated algorithms figure out how much water the plants require. Which implies AI is crucial for efficient water management as well. It's also worth noting that the IoT software has put cutting-edge farming techniques in the hands of farmers, resulting in increased profits [12,13].

Human efforts may not be sufficient to acquire exact soil data and samples. In addition, mistakes are more likely to occur with manual inputs. It is at this point that AI becomes useful. To a large degree, it has been able to compensate for the drawbacks caused by human error [13,14]. Artificial intelligence (AI) soil sensors, valves, and flow meters are being used by the agribusiness industry to gather both static and real-time information on the soil. In order to control the amount of water that reaches the crops on the farmlands, complicated algorithms evaluate the gathered data. This agricultural technology makes the whole system run more smoothly. The need for simplified adoption of this technology is rising outside of the United States, thus many businesses are working on creating integrated UASs for agriculture to serve the expanding US market. It will soon be feasible to analyze the data onboard the UAV as single-board computers continue to shrink in size and power, making it possible to offer real-time, actionable information for instant farm management actions [14,15]. The implementation of precision agriculture marked a technical milestone in the direction of farm management that is grounded on both experience and hard data. Since then, GPS-guided VRT trv vactors have been introduced, and the usage of UASs has been steadily increasing, both of which point to the trend toward more automation in agriculture. It is anticipated that both ground and air vehicles will be used to monitor the crop and coordinate their efforts so that all the essential duties are completed quickly and effectively on the farm of the future[15]. Humans may eventually no longer be necessary to do physical work but will instead become managers and controllers of technological systems in order to maintain a competitive edge.

V. FUTURE IN THE UNITED STATES

Farm managers are being pressured to embrace new technology and increase their competitiveness as precision agricultural methods become a more cost-effective way to boost crop output. The use of just the required amounts of inputs like water, fertilizers, herbicides, and pesticides is at the heart of precision agriculture, which not only helps lower costs but also lessens the ecological effect of chemicals on the soil, aquifers, and rivers [16]. Data gathering, prescription map creation, and custom input application delivery are the typical stages in the product cycle of a precision agricultural app. We now have tractor equipment that can pick out sick plants and satellite images that can provide photos of drought patterns, all thanks to advancements in artificial intelligence. The 'Plantix' plant software, backed by artificial intelligence, was a godsend for agriculturalists. It's a diagnostic and disease-checking instrument for plants that gives you all the data you could ever need. It aids in the detection of the affliction and provides guidance on how the farmer may treat the affected plants [16,17]. There is still some uncertainty about how much these technologies will cost, but one thing is certain: as more and more companies enter the market, the level of competition will increase, driving down prices and increasing the likelihood of widespread adoption. As a result, we will all benefit from increased agricultural output and food productivity. By going from "little" to "smart," farmers may not only solve their agricultural problems but also make substantial gains from the little acreage they have available.

But to make this a reality, industry leaders, IT firms, and agricultural specialists need wor together to continually enhance, develop, and tap into AI's potential. In addition, governments throughout the world should educate and encourage farmers to use cutting-edge technology like AI,

which is proven to be a game-changer with huge potential to increase agricultural crop productivity [17,18].

As a result of a dramatic uptick in research publications by universities throughout the globe, unmanned aerial vehicle (UAV) technologies are being adopted gradually by farm managers and agricultural consultants. Unmanned aerial vehicles (UAVs) provide a low-cost alternative to manned aircraft and satellite imaging by serving as a platform for specialized sensors to gather data from above. In addition, UAVs may be equipped with spraying devices to distribute input in precisely the amounts and at the precise areas the grower specifies, all while remaining out of sight of the crop. The development of UAVs for remote sensing has progressed to a very advanced stage. The farmer may learn quantitative information about the crop by obtaining aerial pictures using multispectral and hyperspectral sensors. Maps of crop vitality, nitrogen content, chlorophyll content, and other attributes may be generated because to these sensors' ability to capture spectral information in many bands. Thermal sensors also give useful data on crop and soil moisture that may be used to fine-tune irrigation schedules [18].

VI. CONTRIBUTIONS

This study's contributions are most evident in the emergence of precision farming, which represents one of the most significant technological innovations impacting the food chain in recent years. The combination of AI and ML is revolutionizing the farming industry, allowing farmers to do their jobs in more effective and creative ways. Some farmers in the area are receiving assistance from an artificial intelligence initiative that analyzes agricultural data to draw conclusions. Farmers' crop yields have increased from an average of six 90-kilogram bags of maize per year to nine thanks to this app, which transmits the relevant data directly to their mobile devices. Many millions of subsistence farmers might benefit greatly from his use of AI. This system can provide notifications about important planting factors like seed depth and placement. Connectivity to the IoT is also an important part of "smart farms"[18]. Nutrient levels, density, and other factors may all be gleaned via a network of sensors. With this knowledge at their disposal, farmers will be able to avoid many of the inevitable planting failures that would otherwise be unavoidable. The Maricopa Agricultural Center, which spans over 2,100 acres, now serves as the home base for university researchers. There, researchers use data and automation to diverse technologies. Achieving this aim involves advising farmers on how to maximize income while cutting costs. Participants at the facility are working to address well-documented issues in the agriculture sector.

Some parts of Arizona, for instance, have pollution difficulties, while others have irrigation water challenges. Many individuals at the University of Arizona and elsewhere credit precision farming for helping them overcome these difficulties. Growth in the precision agricultural industry may also be attributed to the increasing use of drone technology. Drones may spot issues that threaten the profitability of a business, such as insect infestations or improper planting. Data centers analyze the photos captured by manned or unmanned aircraft, satellites, and drones. For an in-depth look at how your crop photos evolve over time, several businesses provide user-friendly dashboards. In order to aid farmers in making decisions depending on what is being shown, Land O' Lakes has invested in speech recognition technology. These cases further highlight the importance of data centers [18,19].

Plants are moved about the facility by autonomous equipment, but people still plant each seed and prepare the food for delivery. Although there are numerous positive outcomes from combining AI with farming, it still cannot replace human labor. Automatic farms are constantly monitoring their crops and adjusting their care accordingly. If anything goes wrong, the staff is immediately notified. Farmers may have faith in robots to do their jobs because of the infrastructure and dependability provided by data centers. The USDA is also testing out a centralized platform where employees from throughout the agency may submit requests, outside of the scope of AI's intended usage. There has been mostly favorable response to the tool thus far [20,21]. One spokesperson said that the objective is to provide workers with technology that is superior to what they have at home [222]. Organizational officials estimated that the transformation would take many years. In order to meet expectations, this system must be comprehensive and trustworthy. Given the USDA's plans to merge its two data centers, availability must be guaranteed for both external customers and internal staff [22].

VII. CONCLUSION

This paper explored Sustainable Future Farming especially how AI/ML based precision farming is significant to the agricultural sector. These findings demonstrate that early adopters of AI and other developing technologies will have a competitive edge in the agricultural sector. As a result, farmers will be able to produce more food and earn more money, and more crucially, Precision Agriculture and sustainable farming will become a reality, which will have positive effects for all of humanity. The potential of AI in farming is really promising. There has been a lot of buzz about Google DeepMind, the company's newly formed artificial intelligence division. There are a number of obstacles that must be conquered before AI can be widely used in agriculture. A cheap AI platform, the success of automated agriculture, and the development of agriculture as a whole are all factors that contribute to these difficulties. As of the year 2019, artificial intelligence has been effectively used in a variety of agricultural contexts, particularly for jobs involving herbicides and feeds. However, the full extent of AI's effect on farming has yet to be determined. Others argue that there are potential issues with using artificial intelligence for large-scale operations due to its potential to lead to increased bias and efficiency that benefits those who amass benefits over society. Precision agriculture is where AI has really made its impact, with the increasing use of sophisticated algorithms, robots, sensors, and satellites. Increased profits from increased agricultural yields are incentivizing many businesses to use agriculture-friendly algorithms. It is anticipated that the greatest possible number of farmers would embrace and implement these innovations on their fields in the near future.

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