Journal of Advanced Zoology

ISSN: 0253-7214

*Volume **44** Issue **S-5 Year 2023** Page **255:263***

Precision Agriculture Technologies: Analysing the Use of Advanced Technologies, Such as Drones, Sensors, and GPS, In Precision Agriculture for Optimizing Resource Management, Crop Monitoring, and Yield Prediction

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Article History

Received: 06 June 2023
Revised: 05 Sept 2023
Accepted: 10 Sept 2023

Abstract

Precision agriculture, or precision farming, is a type of farming method that uses technology to improve the efficiency and yield of crops. It has become increasingly popular in recent years as a way for farmers to get the most out of their land and resources. By utilizing data-driven decision-making, precision agriculture can help farmers maximize crop yields while minimizing costs by reducing water usage, fertilizer application, chemical treatments, and labor needs. In this article, we will explore precision agriculture, why it's important, the different ways it is performed, and some key principles of this agricultural practice. Precision agriculture is a farming practice that uses advanced technology and data-driven decision-making to optimize crop yields while minimizing cost. This includes the use of sensors, aerial imagery, drones, global positioning systems (GPS), remote sensing technologies, geographic information systems (GIS), robotics, and even artificial intelligence (AI) to collect and analyze data. This data can be used to develop specific plans and strategies tailored to individual fields, farms, or even small areas within a farm. By accurately monitoring and analyzing data such as soil content, temperature, humidity, water levels, and more, farmers can better understand their land's needs and apply resources accordingly. Precision agriculture falls under the category of smart farming, where technologies are used to produce higher yields while reducing inputs, labor, and environmental impact. By utilizing technology, precision agriculture helps farmers make better decisions and ultimately increase crop production while reducing costs at the same time.

Keywords: *Precision agriculture, Remote Sensing (RS), UAV/drones, Machine learning (ML), artificial intelligence (AI), Internet of Things (IoT)*

1. Introduction

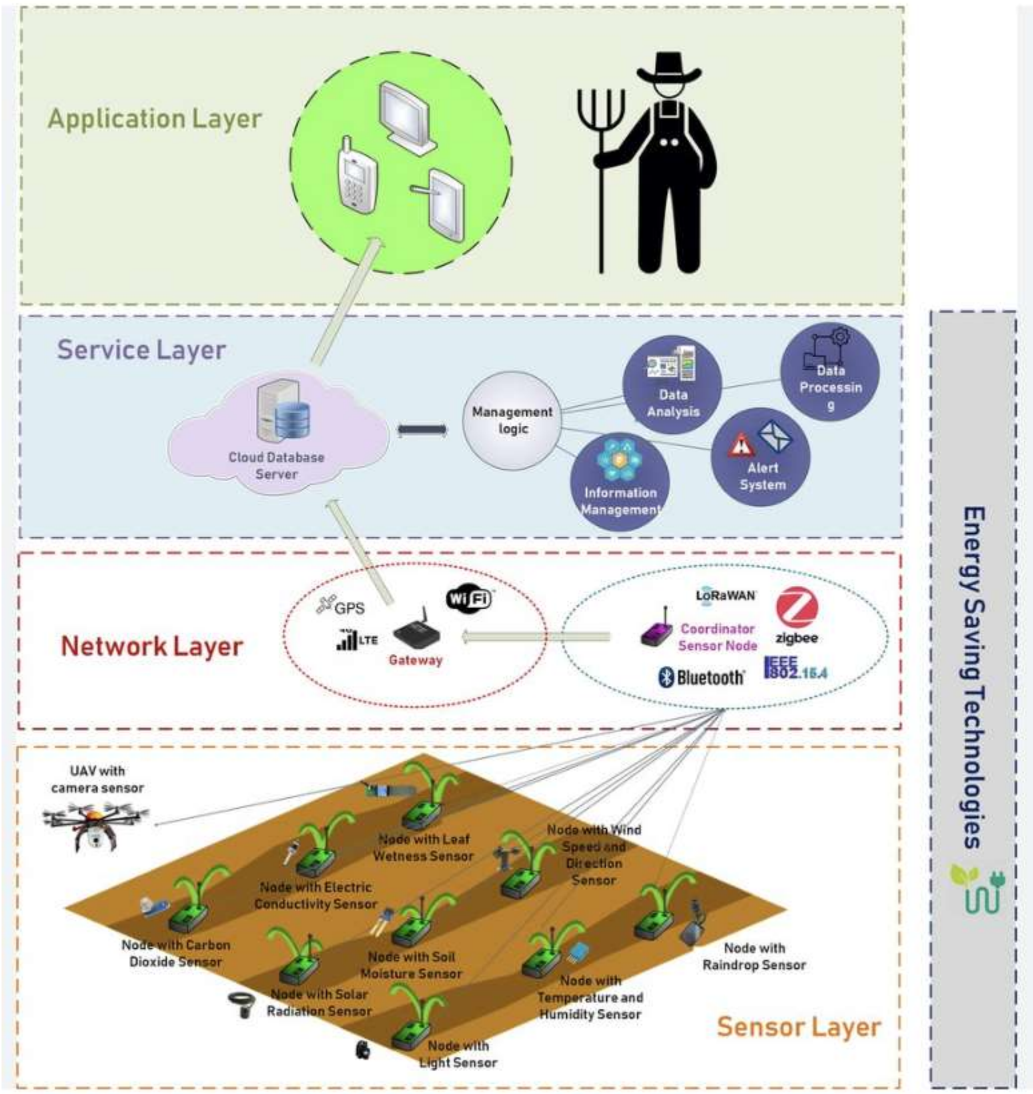
Precision agriculture utilizes modern technology to optimize agricultural practices, resulting in increased productivity while reducing costs and environmental impact. The use of remote sensing (RS), drones or unmanned aerial vehicles (UAVs), and machine learning (ML) has significantly transformed precision agriculture. These advanced technologies provide farmers with accurate, cost-effective, and timely tools to manage crops and resources effectively. This paper evaluates the use of these techniques in precision agriculture, including their benefits, and effective applications. Remote sensing involves using satellites, aircraft, or drones to collect data on crops and the environment, such as soil moisture, temperature, and vegetation indices. With high-resolution images and three-dimensional maps of crops, UAVs enable farmers to identify and address issues like pest infestations or nutrient deficiencies. Machine learning algorithms analyze large amounts of data to predict crop yields, optimize irrigation and fertilization, and identify areas of the field that need attention. Several case studies highlight the effectiveness of these techniques in different agricultural settings. However, the paper also acknowledges the challenges associated with adopting these technologies, such as cost, data management, and regulatory issues. While the initial investment in drones and sensors may be high, the long-term benefits in terms of increased yields, reduced costs, and environmental sustainability are substantial. Farmers need to be trained in the use of these technologies to make informed decisions, and effective data management and analysis are crucial. Additionally, regulatory frameworks are still evolving, and clear guidelines are required for data privacy, safety, and ethical use. Although challenges remain, the benefits of increased productivity, reduced costs, and environmental sustainability make these technologies an attractive investment for farmers worldwide.

Precision agriculture utilizes advanced technologies such as remote sensing (RS), unmanned aerial vehicles (UAVs), and machine learning (ML) to increase the efficiency and sustainability of agriculture. RS provides a non-invasive and cost-effective means of obtaining information about crops, soils, and water resources over large areas, while UAVs offer a flexible and efficient way to capture high-resolution images and collect data from specific locations. ML algorithms enable the analysis of large datasets and the development of predictive models to optimize crop management. Over the past decade, the application of RS, UAVs, and ML in precision agriculture has rapidly grown, and these techniques have become popular among farmers, researchers, and industry professionals. The integration of these technologies has enabled the development of innovative solutions to address critical challenges in agriculture, such as increasing yields, reducing inputs, improving resource efficiency, and mitigating environmental impacts. This paper reviews the current state of the art in precision agriculture and explores the effective applications of RS, UAVs, and ML in crop monitoring, yield prediction, disease detection, irrigation management, and nutrient management. The advantages and limitations of these techniques are highlighted, and successful implementations from different parts of the world are provided as examples.The basic principles and methods of RS, UAVs, and ML are introduced, and their applications in agriculture are discussed. The use of RS to monitor crop growth, detect stress, and assess water availability, the use of UAVs to collect high-resolution images for plant counting, plant height estimation, and disease identification, and the use of ML to develop predictive models for yield estimation, disease diagnosis, and irrigation scheduling are explored. The challenges associated with the implementation of these technologies in agriculture are examined, including data acquisition, processing, and

interpretation, as well as the need for specialized skills and knowledge. The importance of collaboration between researchers, farmers, and industry professionals to address these challenges and ensure the successful adoption of these technologies in the field is discussed. The integration of RS, UAVs, and ML has the potential to transform agriculture and contribute to a more sustainable and resilient food system. Future research should evaluate the economic and environmental benefits of these technologies, develop user-friendly tools for farmers, and address issues related to data privacy and security.

Benefits of Precision Farming Technology

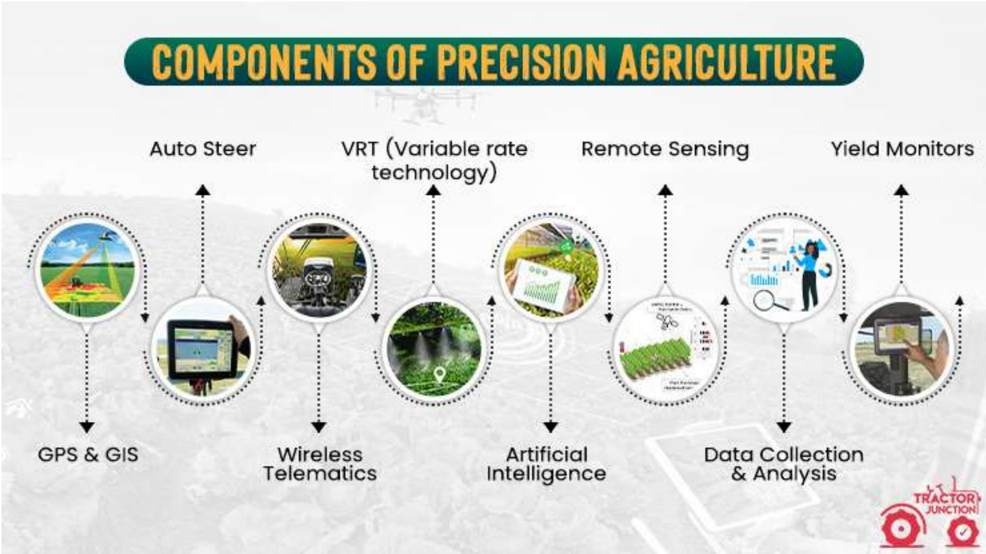
According to Folnovic, the goal of precision farming is to increase agricultural yield production and decrease the environmental risks. However, the benefits could include the following points: • detecting soil properties and plant physicochemical parameters including electromagnetic conductivity inductions, nitrates, temperature, evapotranspiration, radiation, leaf area index and soil moisture, • getting data in real time by installing the remote sensing instruments in the fields, allowing continuous monitoring of the selected attributes and will offer real-time data, ensuring an updated status soil and plant parameters at all-time as well as getting better information for management decisions and farming planning, • saving time and decreasing the costs through reducing fertilizer costs and other agrochemical applications by reducing the use of chemicals as well as reducing tillage operation, • supplying the farmers with good farm information and databases, which it is essential for sale and succession and • integrating farm management software, like Agrivi, to make all farm activities easier and to increase farm productivity. The increased efficiency of the management plan will come about through a good understanding of the interaction between environment, soil, crop and more detailed information using of new advanced and current information technologies such as short and long-term crop growth modeling, soil conservation, climate predictions and agro-economics modeling. Precision farming management is a cyclical process.



The farmer can start farming depending upon "site-specific land management" information and needs seasonal planning, the program of data collection, and analysis of data in order to complete the cycle of the precision farming management strategies plan. Soil analysis should be don before planting, and data analysis also should be finished for calculation and mapping of the variability in soil properties, which will be used at any time and by any method for variable rate application. Through crop growing season, the monitoring crop condition will do by starting the work by monitoring different values of seeds based on the data and use the variable rate application of fertilizer, which is determined based on soil, plant and water analysis. Crop growth is accomplished for research on many attributes such as variability of soil properties, water requirement, weeds, pests or diseases. At harvest time, the yield crop monitor system which is installed inside the combine provides the variation in soil and crop growth status based on the geographic location and map of crop growth status across the farm according to its geographical location. In order to collect and use information with high effectively and efficiently, it is significant for the farmers who used precision farming should have a good knowledge of the new tools of precision farming technology.

Effective Technologies Used in Precision Agriculture

Precision Agriculture (PA) is a farming management approach that leverages advanced technologies to boost crop yields, minimize waste, and optimize the use of resources such as water, fertilizers, and pesticides. Some of the effective technologies used in precision agriculture include:Geographic Information System (GIS) - This technology is used to map and monitor soil types, nutrient levels, and other key factors on a farm.



Farmers can use this information to make informed decisions on planting, fertilization, and other management practices. Global Positioning System (GPS) - GPS is used to accurately locate farm equipment and monitor their movement across the farm. This information can be used to optimize planting patterns, irrigation, and harvesting schedules.Remote Sensing - This technology involves the use of satellite images and aerial photographs to monitor crop health, detect pest infestations, and identify areas of water stress in a farm. The data collected can be used to develop precision application maps for fertilizers and pesticides.Variable Rate Technology (VRT) - This technology allows farmers to adjust the rate of application of inputs such as fertilizers, pesticides, and irrigation water based on the specific needs of different areas in a farm. VRT systems are controlled by GPS and GIS data and can be automated to apply inputs in real-time.Drones - Drones are used to capture high-resolution images of crops, providing farmers with valuable data on plant health, crop damage, and growth patterns. The images can be used to develop precision application maps for fertilizers and pesticides.Soil Sensors - Soil sensors are used to measure soil moisture levels, temperature, and nutrient levels. The data collected can be used to optimize irrigation and fertilization schedules.These technologies help farmers to reduce waste, increase yields, and improve the sustainability of their operations. By providing farmers with real-time information about their fields, precision agriculture helps them to make informed decisions that result in better crop performance and higher profits.

Sl. No.	Technology	Description	Application
1	Remote Sensing	Imaging technologies that capture data from a distance, such as satellite or aerial imagery.	Crop health monitoring and yield forecasting.
2	Geographic Information Systems (GIS)	Software tools used for the management, analysis, and visualization of spatial data.	Crop scouting, field mapping, and variable rate application.
3	Unmanned Aerial Vehicles (UAVs)	Drones equipped with cameras or sensors for aerial data collection.	Crop monitoring, field scouting, and yield mapping.
4	Global Positioning System (GPS)	A satellite-based navigation system used for precise mapping and guidance.	Field mapping, auto-steering, yield monitoring, and variable rate application.
5	Machine Learning	Artificial intelligence algorithms that analyze large datasets and make predictions.	Crop forecasting, disease detection, and yield optimization.
6	Internet of Things (IoT)	A network of connected devices that collect and transmit data.	Crop monitoring, irrigation management, and equipment tracking.
7	Robotics	Autonomous machines that perform tasks such as planting, harvesting, and spraying.	Precision planting, weed control, and crop harvesting.
8	Variable Rate Technology (VRT)	Technology that allows for the variable application of inputs, such as fertilizers or pesticides.	Precision fertilization and variable rate seeding.
9	Decision Support Systems	Software tools that assist with crop management decision making based on data analysis.	Irrigation scheduling and pest management planning.

Criteria for the Selection of Technologies in Precision Agriculture

Precision agriculture is a vital component of modern farming that utilizes advanced technology to enhance crop production and minimize waste. Choosing the appropriate technology for precision agriculture can be a daunting task due to the numerous factors to consider. Here are some of the key criteria to consider when selecting technologies for precision agriculture:

Accuracy: Accuracy is a crucial factor to consider when selecting technology for precision agriculture. The technology used must be precise in measuring essential parameters such as crop yield, soil moisture, and temperature. This precision enables farmers to make informed decisions regarding the use of water, fertilizer, and pesticides.

Compatibility: Compatibility is another critical factor to consider when selecting technology for precision agriculture. The technology should be compatible with existing farm machinery and equipment, as well as with other technology used on the farm. This ensures that the technology can be easily integrated into the existing farm operation.

Ease of use: The technology used in precision agriculture should be user-friendly and easy to use. It should have an interface that allows farmers to quickly and easily collect and analyze data. This simplicity ensures that farmers can make informed decisions about crop management without spending too much time on data collection and analysis.

Reliability: The technology used in precision agriculture must be reliable, with a low failure rate and minimal downtime. This reliability ensures that farmers can depend on the technology to collect and analyze data accurately and consistently.

Cost-effectiveness: The technology used in precision agriculture must be cost-effective and provide a positive return on investment. This cost-effectiveness ensures that farmers can afford to adopt the technology and optimize their operations for maximum efficiency and profitability.

Scalability: The technology used in precision agriculture should be scalable, meaning that it can easily expand to cover larger areas of farmland or more crops. This scalability ensures that farmers can continue to use the technology as their operations grow and expand.

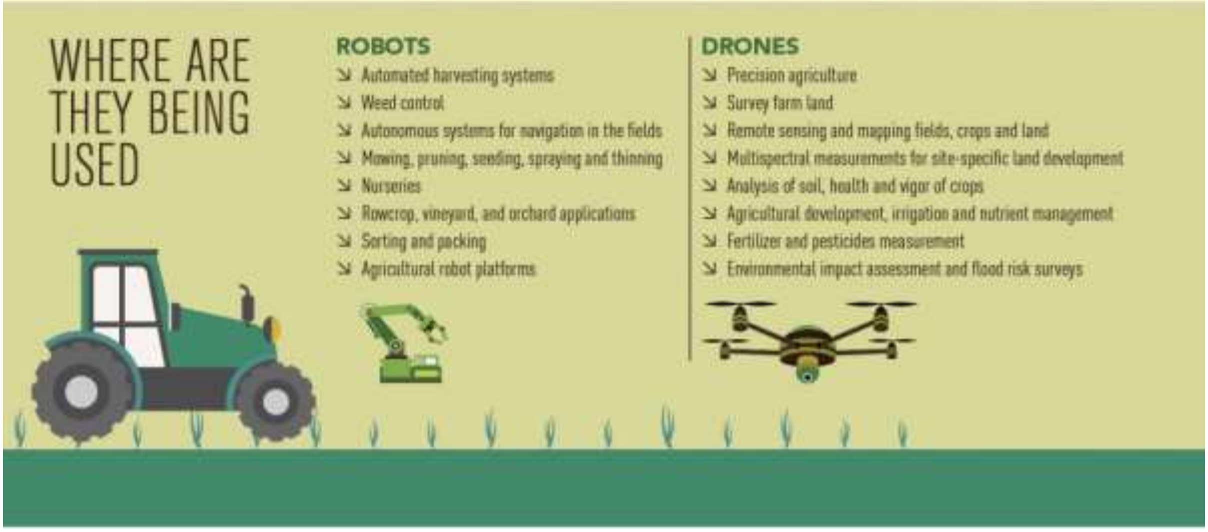
Sustainability: Finally, the technology used in precision agriculture should be sustainable, with minimal environmental impact. This sustainability ensures that farmers can reduce waste and conserve resources while still maximizing crop production. By considering these criteria, farmers can select the most appropriate technologies for precision agriculture and optimize their operations for maximum efficiency and profitability while minimizing environmental impact.

Impact of artificial intelligence (AI) and internet of things (IoT) in precision agriculture

Precision agriculture involves the utilization of technology and data to enhance farming operations and augment crop yields. In recent times, the emergence of artificial intelligence (AI) and the Internet of Things (IoT) has transformed precision agriculture, empowering farmers to collect and evaluate data more efficiently, precisely, and in real-time

As a result, farmers can make informed decisions, maximize resources, and increase productivity. The application of AI and IoT in precision agriculture has various specific applications, such as:Sensors and IoT Devices: IoT sensors and devices collect data on weather, soil moisture, nutrient levels, crop growth, and pest infestations.

This data provides real-time insights into crop conditions, allowing farmers to make informed decisions regarding irrigation, fertilization, and pest control.Data Analysis: AI algorithms analyze vast amounts of data from IoT devices to identify patterns and make predictions. For instance, machine learning algorithms use historical data to predict weather patterns and forecast crop yields.



This information helps farmers make better decisions regarding planting, irrigation, and harvesting.Autonomous Farming: AIpowered autonomous vehicles and drones monitor crops, evaluate soil conditions, and apply fertilizer or pesticides. These machines operate 24/7, providing continuous monitoring and enabling farmers to optimize resource utilization.Smart Irrigation: IoT sensors monitor soil moisture levels and automatically adjust irrigation systems to optimize water usage.

This helps farmers conserve water and reduce their environmental footprint.Crop Monitoring: AI-powered image recognition algorithms analyze images of crops to detect issues such as disease, nutrient deficiencies, or pest infestations. This enables farmers to identify and resolve issues early, preventing severe crop damage.AI and IoT technologies have revolutionized precision agriculture by providing farmers with more data, insights, and automation. This empowers farmers to optimize resources, reduce waste, and increase crop yields.

Sl. No.	Impact Areas	Artificial Intelligence (AI)	Internet of Things (IoT)
1	Crop Yield	AI algorithms can analyze data on weather patterns, soil conditions, and crop health to optimize farming practices for increased yield.	IoT sensors can provide real-time monitoring of soil moisture, temperature, humidity, and other conditions to help farmers adjust farming practices for optimal crop yield.
2	Resource Management	AI can optimize resource usage by determining the right amount of water, fertilizer, and pesticides to use based on specific crop needs.	IoT sensors can monitor resource usage, such as water and fertilizer, and provide data to help farmers reduce waste and optimize usage.
3	Maintenance	AI can predict equipment failure and schedule maintenance to prevent	IoT sensors can monitor equipment performance in real-time and provide

2. Conclusion

The integration of Remote Sensing (RS), UAV/drones, and Machine Learning (ML) has demonstrated its potency in the field of precision agriculture. By combining these technologies, farmers can access accurate and timely data, enabling them to make informed decisions that improve crop yields, reduce input costs, and increase sustainability. In terms of productivity, the use of RS, UAV/drones, and ML enables farmers to detect issues early on and take corrective actions promptly, resulting in higher yields and better-quality crops. Furthermore, farmers can reduce input costs by identifying areas of the field that require treatment, thereby minimizing the use of fertilizers and pesticides. In addition, precision irrigation systems can help conserve water and reduce energy costs associated with pumping and distribution. The application of precision agriculture techniques has contributed to the overall sustainability of farming practices. By reducing the use of fertilizers, pesticides, and water, farmers can minimize the impact on the environment, improve soil health, and protect biodiversity. Additionally, precision agriculture can reduce greenhouse gas emissions associated with farming practices, contributing to a more sustainable future. To achieve these benefits, farmers can use RS to monitor crop growth, detect diseases and pests, and assess soil quality from a distance. UAV/drones can collect higher resolution data, which improves the accuracy of crop monitoring and analysis. Machine learning algorithms applied to this data can develop predictive models, allowing farmers to anticipate potential problems and take corrective actions proactively. Although there are still challenges to address in data processing, technology integration, and cost-effectiveness, the potential benefits of precision agriculture are immense. As technology continues to advance and algorithms become more sophisticated, precision agriculture will become an even more powerful tool for improving the efficiency and sustainability of farming practices.

The precision farming or precision agriculture or site-specific land management is relatively a new farming technology for increase soil and crop production, however, precision farming technology includes remote sensing, GIS, DGPS, yield map, variable rate application, soil sampling, and site-specific management zones. The main aim of precision farming include, the good understanding of soil and crop variability within-field and follow up by farm management inputs depending on the main source of the variability Moreover, this precision farming technology is the purpose of assisting management of agriculture resources in farm return and environmentally effective methods in the spatial and temporal field variability. In the last two decades, precision farming technology has been more and more developed, including mechanization and automation. Site-specific management has been an important sector of the agricultural system of the developed countries, but implementation of this high technique of precision farming to farm through the farmers in developing countries is still very slow and needs a lot of extension efforts and farmer motivation.. Due to most farmers do not know new information technologies, e.g. remote sensing, GIS, and GPS. The government should be made to increase investments to educate farmers for the application of new methods and technologies in agriculture. The size of the agriculture land is another problem for adopted precision farming technology in the third country like Egypt. Egyptian farmers and experts should use the PF experiences that have been used by developed countries such as USA, Germany, Japan. In conclusion, integrating new technology for farmlands management and provided investment in agriculture are two essential issues that help to improve Egypt's agriculture production.

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