Vol. 3 Issue-11, July 2023 (e-ISSN: 2582-8223)

Precision Agriculture: The Digital Age of Agriculture

Anita Verma*, Bharat Garg, Shilpi and Shikha Yashveer
Department of Molecular Biology and Biotechnology, College of Biotechnology, CCS Haryana Agriculture University, Hisar-125004, India

ARTICLE ID: 47

Abstract:

Multiple information and communication technologies, such as the Internet of Things (IoT), are improving the agriculture business. IoT has a lot of potential for Smart Farming and Precision Agriculture applications as it enables farmers to get real-time data concerning the environment. Precision Agriculture (PA) and Wireless Sensor Networks (WSN) are the key elements driving agriculture automation. PA uses certain sensors and software to ensure that crops get exactly what they require in order to make optimal productivity and sustainability. PA consists of certain advanced devices in the fields that can be used to get real information about the soil, crops, and weather. The term "digitalization" has been applied to the process of incorporating cutting-edge digital technologies into the agricultural sector. Any system that is linked to the agricultural production system is included here, such as AI, big data analytics, robotics, unmanned aerial vehicles, sensors, communication networks, and so on. The "sense–analyze–act" cycle is the simplest way to explain how digitization is changing agriculture.

The Sensors give raw data such as weather data, GPS coordinates, digital pictures,

etc. Though humans are still very important for making decisions here. "Smart" devices, like robotic vehicles and drone-mounted cameras analyze the data collected by sensors in real time. And when we put all of this together, we end up with "smart systems" that can make decisions on their own and can reduce the amount of analysis and planning that needs to be done by people who can save farmers' time and money. The goal is to use such advanced technology in farming that can generate notifications on multiple platforms and can help in sustainable agriculture.

Introduction:

Agriculture is essential to economic expansion and development since it produces food grains and many other essential raw materials (such as wool and crop stalks). Food production must keep up with the world's ever-increasing population if humanity is to continue to thrive. It is difficult to meet the world's food needs with the planet's current resource allocation. To alleviate poverty and ensure sufficient food supply, it is essential to boost agricultural output and earnings. As a result of its potential to reduce resource use while raising yields, "smart agriculture" or "precision agriculture" has recently gained widespread interest. Modern, eco-friendly farming relies heavily on precision agriculture (PA). When it comes to resources (such as water, fertilizer, pesticide, seed, fuel, labor, etc.), PA comprises a management plan that makes use of a suite of cutting-edge information, communication, and data analysis techniques (Sishodia *et al*, 2020). It aids in increasing crop yields while decreasing the waste of water and nutrients and other unfavorable effects on the environment. Monitoring crop health at various stages of development is made possible by the Internet of Things (IoT) sensors used in precision agriculture (PA). The process of PA requires collecting and analyzing a huge amount of information on the condition of crops. Using PA, a farmer can determine exactly when, where, and how much of a variety of parameters are required for a healthy crop. In order to provide useful agronomic advice, it is necessary to examine all data obtained. The goal of precision agriculture (PA) is to maximize crop yields while decreasing wasteful practices through the coordinated use of many technologies. Several automated devices, such as harvesters, robot weeders, unmanned aerial vehicles (UAVs), and other machinery, are currently useful to farmers for keeping an eye on their crops. Several sensors placed for these systems quickly report data on the condition of the soil, crop, and related aspects. Robots, Internet of Things (IoT) sensors, and unmanned aerial vehicles (UAVs) are just a few of the equipment that various manufacturing organizations are offering to supply in order to collect data in real-time at much higher resolutions (Khanna and Kaur, 2019).

Advanced technologies for precision agriculture:

The agricultural sector needs precise and innovative tools for advancement. Further, for agriculture to be sustainable, the effects of climate and the environment should be kept to a minimum. Better outcomes are achieved by farmers because of remote "on-site monitoring" made possible by the Internet of Things (IoT). With the use of wireless sensors, farmers are able to keep an increased focus on their crops and catch problems early on, when they're still easy to fix.

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- **Smart Wireless Technologies:** Since the 1990s, there has been a proliferation of the Internet of Things devices and Wireless Sensor Network technologies, prompting the development of new communication protocols. These protocols have specific bandwidth, available channel numbers, data rate, battery life, cost, and other parameters (Shafi *et al*, 2019). In agriculture, IoT-based applications typically use the following wireless communication protocols with their specific physical range: 6LoWPAN (2-15 km), ZigBee (10-100 m), BLE (30 m), RFID (10-20cm), Wi-Fi (50 m), LoRaWAN (5-10 km).
- **Remote sensor Technologies**: Over the past two decades, Precision Agriculture has made extensive use of remote sensing to track the condition of crops. Through remote sensing, scientists are able to examine Earth's physical conditions from afar by calculating the radiation being emitted and reflected. Images can be captured with specialized cameras and then analyzed to determine the features of a given region. These cameras that take pictures of the things are mounted on a variety of structures. Airborne platforms, satellite platforms, and Unmanned Aerial Vehicle (UAV) platforms are all options for spectral image remote sensing.
    - **Satellite-Based Platforms**:

      When compared to other types of platforms, this platform is the most reliable for remote sensing. Satellites, rockets, and space shuttles are all examples of such technology. These are grouped on the bases of the orbits and schedules of spacecraft. Satellite-based remote sensing offers many benefits, including excellent spatial resolution, which bodes well for the extraction of substantial time-series data. Satellite platforms provide steady, wide-area photographs free of the noise that is usually introduced by interference. One of the broadly-used satellites Sentinel (Sentinel-1, Sentinel-2 and Sentinel-3).
    - **Airborne-Based Platforms:**

      As compared to satellite platforms, airborne platforms are more adaptable yet still a bit costly. The interval between visits is flexible and subject to vary at any time and can be controlled by humans. Its coverage area is significantly less than that of satellite-based platforms but more than that of UAV platforms. An

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example of an Airborne platform is a Fixed wing (LearJet 35A) having InSAR remote sensor with a maximum flying height of 45,000 ft.

- **UAV-Based Platforms:**

  Unmanned aerial vehicle platforms are a modern alternate to satellite and airborne systems because of their adaptability and low cost. An array of sensors is typically attached to an unmanned aerial vehicle's platform, which consists of a communication and navigation system. Most unmanned aerial vehicle (UAV) platforms are of the fixed-wing variety as well as multi-rotor variants. Using today's technology, a fixed-wing UAV can fly for about two hours with a payload of high-quality cameras weighing less than 300 grams (Zhong *etal*, 2018).

Applications of advanced technologies in Precision Agriculture:

The agricultural industry is making extensive use of the Internet of Things and wireless se nsor networks. Common uses include Soil and water analysis, smart irrigation, smart fertilization, plant health assessment, herbicides/pesticides spray, crop disease monitoring, and crop harvesting monitoring and forecasting.

- **Soil and Water Analysis:**

  By collecting precise information about soil and soil water conditions before planting crops using advanced technologies like UAVs can aid in the selection of optimal crop types for a given area. In addition, it may tell us what kinds of soil and environmental conditions are best for growing a certain seed.

- **Smart Irrigation:**

  The artificial irrigation application known as "smart irrigation" regulates watering amounts by determining precisely where watering is required. The health, cost, and production of crops are profoundly affected by this most important component in agriculture.A smart sprinkler system was presented by Kumar *et al* in 2017 which powered by an ATMEGA 328 that monitors environmental conditions like temperature and humidity in addition to soil moisture.

- **Smart fertilization:**

  Fertilizers and organic components are crucial to a plant's growth, development, and reproduction. In order to achieve fertilization with little effort and maximum efficiency, new technology is applied to estimate the spatial-temporal

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application of nutrients. In precision agriculture, technologies like the IoT help with precise estimates of fertilizer rates. The normalized vegetation index (NDVI) is commonly employed for this purpose of assessing plant vitality prior to nutrient delivery. Nutrient estimates in the field are calculated using a variety of modern technologies, including geographic information systems (GIS), variable rate technology, and global positioning systems (GPS).

- **Assessment of crops' health:**

UAVs equipped with infrared (IR) and visible (IR) light sensors can inspect fields for signs of fungicide or bacterial infestation. Early detection of such issues help in preventing the transmission of a disease from one crop or plant part to another.

- **Spraying Pesticides/Herbicides:**

Insecticides, pesticides, and herbicides can all be applied to crops with the help of remote sensor technologies. Spraying pesticides or herbicides with UAVs allows for pinpoint application to specific problem areas, such as directly on weeds. Direct application to weeds is possible. Furthermore, costs can be kept to a minimum by spraying only the areas, plants, or weeds that need it with an unmanned aerial vehicle (UAV).

- **Crop disease monitoring:**

Hyper-spectral images captured by a remote sensor system or unmanned vehicles equipped with spectral cameras are used to assess the state of crops and the extent of any damage caused by pests. Then Machine learning methods can be applied to the collected photos in order to correctly diagnose the plant disease. Due to their superior ability to understand complicated structures and patterns, advanced Neural Networks (ANNs) are increasingly being used to interpret visual data.

- **Crop Harvesting Monitoring and forecasting**:

Predicting harvest yields through the use of crop forecasting is a common practice. Predictions like these aid farmers in making short-term strategies and choices. Furthermore, analysis of crop maturity and quality allows for estimation of the precise harvesting time. Any harvesting machine can be linked to modern technology like a newly built yield monitor. Connecting the yield monitor to FarmRTX, a smartphone app that displays precise harvesting data, is also possible.

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This mobile software can be used to create very detailed mapping tools, which can then be shared with other experts and producers before being exported to the other agricultural tools needed for crop yield monitoring.

Current Challenges and Future Prospects:

Expecting that the use of AI and big data, integrated systems are projected to transform agriculture into a cutting-edge industry in the near future. A wide range of agricultural management tasks, from planting to crop yield prediction, will be possible with the help of these integrated systems. For future agriculture to be sustainable, it will be necessary to use the following tools and techniques:

Smartphones and the Internet of Things:

Smartphones and the Internet of Things, among other information and communication technology, have the potential to revolutionize farming in third-world countries by expanding farmers' access to markets and helping them find solutions to previously intractable issues. These technologies can help the next generation of farmers connect with urban centers.

Drones and Other Robots:

Robots and drones have proven their utility in terms of speed and precision when compared to traditional machinery serving the same purpose. Drones aren't the only robotic tool that's improved crop yields and boosted worker efficiency in today's farms. The use of fewer pesticides is one benefit of using robots to do the weeding and spraying.

Artificial Intelligence and Machine Learning:

Data mining for trend analysis is a common use of machine learning (ML) and AI. In agriculture, for instance, ML/AI is used to discover the most promising genes for generating high-yield crops. Farmers can now access more robust, climate- and location-specific seed types. Owing to recent advances in ML/AI, farmers will be able to more accurately categorize their crop products and discard less useful things before planting.

Vertical Farming and Hydroponics:

In order to overcome geographical and resource limitations, it is essential to use both advanced technologies and innovative agricultural techniques. It is estimated that 3 million individuals around the world have moved to metropolitan regions, further straining already scarce urban resources. These issues are resolved by VF since it is well suited for adoption in locations close to cities and can address related issues of water scarcity and land management.

Conclusion:

The rising global population has resulted in a greater need for food. As a result, once-forested and agricultural areas are becoming urbanized. To feed a growing global population while arable land decreases is a challenge that requires cutting-edge, efficient technology. Today, it's easy to see the progress being made toward more advanced methods of increasing agricultural output and enhancing other agriculture metrics. Those who aren't technologically savvy or creative often choose farming as a career. Suppliers, farmers, retailers, and purchasers all work together, but there isn't enough communication between them. In order to bridge this gap, cutting-edge innovations in technology are desperately needed. In order to satisfy future expectations, agriculture will need to adopt advanced technologies, and this assessment covers a wide range of those technologies. Sustainable farming also requires the use of other cutting-edge technology, such as unmanned aerial vehicles (UAVs), remote and ground sensors, communication technologies, and cloud computing. This analysis sheds new light on recent findings in the field. All of the foregoing data points to the absolute necessity of increased crop production and advancement. There is no choice but to adopt cutting-edge innovations like the Internet of Things. Farmers can enhance their agricultural operations and resources by adopting these cutting-edge technologies. Sustainable farming practices will be made possible by the development and implementation of such cutting-edge technologies.

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