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Precision Agriculture: Smart Farming Taken to The Next Level

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Abstract
According to the World Bank, 32 percent of food losses in developing countries can be traced back to conventional farming practices. This is largely due to the lack of attention to detail and the overuse of resources. Conventional farming techniques mainly involve the use of crops throughout an area. This method produces unpredictable and excessive waste production. Before the rise of tech in agriculture, it was highly probable that a farmer would produce bountiful harvests. Since there was no way of knowing what caused crop loss, farmers resorted to asking for help. This condition pushed them into debt. Advancements in satellite imagery and big data analytics have helped the agriculture sector overcome uncertainties. A precision agriculture system is an approach to farming that uses various technologies to improve the efficiency and profitability of the operation. This paper aims to introduce the concept of precision agriculture and its various aspects. It also reviews the various challenges that one has to face in order to successfully implement this field of agriculture.

Keywords: Precision Agriculture, GPS, GIS, VRT, Drone, Livestock

I. Introduction

Cultivation, plant life, soil fertility, crop types, the terrestrial environment, and so on are all things that come to mind when we think about agriculture. However, in today's world, phrases like climate change, irrigation facilities, technology innovations, synthetic seeds, advanced technology, and so on are associated with agriculture. In short, we're curious about how modern technology may assist us in the realm of agriculture. As a result, Precision Agriculture (PA) comes into play. [1]

The broad definition is an information and technology-based farm management system that identifies, analyses, and manages spatial and temporal variability within fields for maximum productivity, profitability, sustainability, and land resource protection while lowering production costs. Simply described, precision farming is a method of growing crops that uses precise amounts of inputs to produce higher average yields than traditional methods. As a result, it is a comprehensive system designed to optimise production while having the least possible negative influence on our terrestrial system. [5]

Precision agriculture is made up of three primary components: information, technology, and management. Precision farming necessitates a lot of data. Precision agriculture is a management method that employs information technology to gather valuable data from a variety of sources and incorporate it into decision-making. For use with variable rate, it relies on technology such as GPS (Global Positioning Systems), GIS (Geographic Information Systems), yield monitors, remote mapping sensors, and guidance systems, which provide in-depth monitoring of field fluctuations.

It can be defined in the Indian agricultural context as the precise use of agricultural inputs based on crop, soil, and weather requirements to optimise the use of fertilisers, pesticides, and irrigation requirements for maximum productivity. Precision agriculture has the advantage of being eco sustainable and cost-effective because it uses less water, herbicides, insecticides, and fertilisers, in addition to farm implements. Instead of making farming decisions based on theoretical principles, precision farming strategies identify site-specific differences in the fields and, as a result, coordinate management operations. [2]

II. Need

Agriculture is the backbone of India's economy, accounting for 18% of the country's GDP and employing almost half of the country's workers. Agriculture is the primary source of income for more than 70% of rural families. India, which is home to over 17% of the world's population, confronts the problem of meeting the ever-increasing demand for agricultural products. It's critical to modernise old agricultural methods and prepare for a technological revolution in order to establish eco-friendly crop-production systems. Smart farming concepts like precision agriculture can be aptly deployed to achieve this goal. [7][10]

To meet the increasing demands of the world's population, global food production must increase by 70 percent, which is a requirement to feed the entire population. The answer to this daunting challenge lies in the continuous pursuit of improvement, which is rooted in the gathering of real-time data and analysis of agricultural processes.

Through the advancements in technology, precision farming has become a widespread practice in the agriculture industry. This trend is expected to continue happening in the coming decade. However, while searching for new techniques and methodologies, one should not forget to analyze the existing ones and their environmental impacts. [8]

III. Objectives

The major objectives of using precision agriculture are as follows:

- Collect farming data, such as historical, predictive modelling, and environmental insights, in order to select suitable crops with higher yields.
- Measure the site's performance by capturing data in real time.
- Utilize digital farming data (soil, crop health, weather, and so on) to provide the precise amount of water, nutrition, and pest control.
- Improve the farm's economic and environmental viability.
- Predict weather changes and respond to them ahead of time.

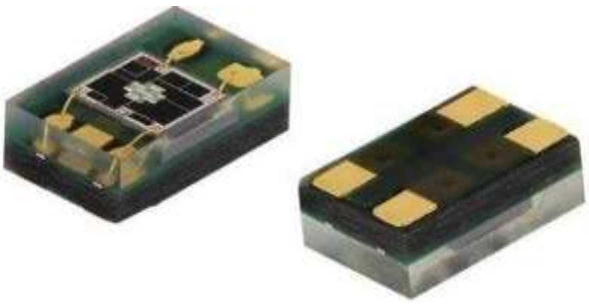
IV. Cutting-edge Technologies Used in Precision Agriculture

The concept of precision agriculture refers to the use of technologies that are heavily connected to the Internet of Things as shown in figure 1.

Figure 1. IoT in Precision Agriculture

A. Sensors. They can detect a variety of biomolecular, chemical, optical, thermal, electrical, radiation, and biological metrics to provide a 360-degree perspective of a crop's health. Farmers may track the health of their cattle in real time by attaching health monitoring devices to them. Location sensors are used to determine the latitude, longitude and altitude of the given location. Light is used by optical sensors to measure soil qualities. Electrochemical sensors provide vital information such as pH and nutrient levels in the soil. Soil compaction is measured using mechanical

sensors. [17] They employ a probe that enters the soil and uses load cells or strain gauges to record the resistive forces. To determine moisture levels, dielectric soil moisture sensors measure the dielectric constant in the soil. The permeability of the soil-air interface is measured by airflow sensors. The various sensors widely used in precision agriculture are depicted in figure 2.

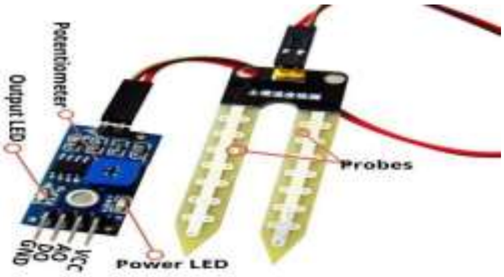


Location Sensor

Optical Sensor

Electrochemical Sensor

Mechanical Sensor



Dielectric Soil Moisture Sensor

Air Flow Sensor

Figure 2. Various Sensors used in Precision Agriculture

B. **Global Positioning System (GPS).** GPS is a network of satellites that provide precise location and time information to users. It works by sending signals from space to receivers on earth. The signals are generated by GPS receivers and are used to determine the exact position and time of a field. It has an accuracy of between 100 and 0.01 m. It provides farmers with valuable information on various farm fields. [6]

C. **Geographic Information System (GIS).** Geographic Information System is a tool that enables users to collect, store, and manage spatial or geographic data. It provides tools to create maps and reports based on geographic data. A computer-controlled GIS map contains layers of data that can be used to inform decisions about crops, weather conditions, and pests. A farm GIS database can provide a variety of useful information about a farm's operation, such as crop production, soil types, surface drainage, and irrigation rates. After being processed, the data is utilised to deduce the correlations between the numerous factors affecting a crop at a certain location. [11]

D. **Grid Soil Sampling and Variable Rate Fertiliser Application.** Site-specific grid sampling is a simple and quick method for managing soil conditions. It can be utilized for farm operations with variable rate technologies (VRT). GIS sends information about farm inputs based on soil type, such as crop determination and the timing of application of fertilizer and herbicide. It can then control these processes at a variable rate. Grid sampling is a technique used for soil sampling. It increases the intensity of sampling by taking advantage of the geographic location thereby giving us an application map. A grid soil sample is analysed to determine the nutrients needed for a crop. Then, a fertilizer application map is generated. Both maps are loaded into a computer, which develops a thorough and systematic planting and fertiliser schedule. [16]

E. **Rate Controllers.** A rate controller is a device that controls the delivery rate of a chemical input. It uses a variety of sensors to monitor the material's flow and pressure.

F. Precision Livestock Farming. Precision livestock farming is a process utilized for the management of livestock. This procedure involves the use of various technologies to improve the efficiency of livestock production as shown in figure 3. This includes growth of animals, production of milk and egg, illness diagnosis and other related aspects of animal behavior. Systems used for monitoring milk and microbial levels help to identify potential infections, and they can also help improve the efficiency of feeding and weighing systems. Pigs coughing due to respiratory illness can be detected using acoustic sensors. Other sensors are now being employed to deliver childbirth and fertility alarms and notifications. [18]

G. Mobile Apps. With the increasing use of electronic devices, it is very easy to obtain information from anywhere. Android apps make it possible for developers to create interactive and useful apps that can be used in the field of PA. These apps can help improve the efficiency and profitability of farming operations. Apps for farm monitoring include data such as weather, market rate, and availability, among other things. Weather apps are useful for monitoring agriculture. They can provide real-time data on various factors such as weather conditions, market rate, availability of seeds, and chemicals available. [12]

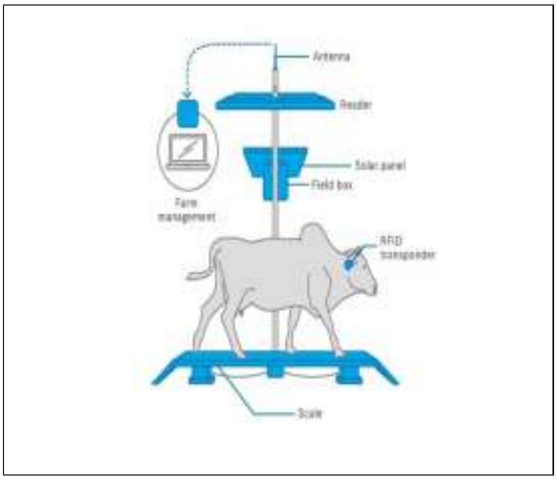


Figure 3. Precision Livestock Farming

V. Approach

There are two main types of precision agriculture, namely soft and hard. The former refers to the process of observing and managing crops and soil conditions, while the latter uses modern technologies like GPS and VRT. Understanding the various factors that affect the cultivation of crops is very important for successful farming. This includes choosing the right seeds and ensuring that they use the most effective irrigation techniques. Before planting a crop, it’s important that the seed is suitable for the area and its environment. This includes factors such as the weather and the number of plants needed to grow.

The decisions regarding the use of fertilizers and the maintenance of crops are often influenced by the weather. For instance, if the heavy rains are expected, the farmers may not use the fertilizer since it would get washed away. Predictive weather analytics can help in optimizing the use of freshwater. It can also predict when it will rain and how much it will rain. Because agriculture uses 70% of the world's fresh water, its efficient use will have a significant impact on the world's freshwater supply.

Weather conditions play a vital role in the harvesting and transportation of crops. For instance, when it comes to sugar cane harvesting, the soil must be dry enough to allow the harvesting equipment to operate. Weather forecasts can help determine the timing of the harvest and the logistics of transporting food. These forecasts can also inform the decisions about the deployment of workers. In addition, poor transportation and the wrong market can affect the profitability of a farm. Having the right temperature and route selection can help avoid food waste and prevent it from spoiling. [13]

VI. Challenges

Almost 90% of the studies conducted on precision agriculture revealed that these techniques were only used on a single field or at experimental stages. This suggests that the concept of precision agriculture is still very early in its development. As a result, farmers are hesitant to use new agricultural techniques that they are unfamiliar with.

Lack of information is also a primary reason for slow implementation of PA. To ensure efficient PA adoption, farmers require appropriate information and timely guidance. This discipline requires the presence of an authority or organization that can provide the necessary equipment and training. Unfortunately, this is not always possible due to the lack of funds or resources. Farmers must be trained in the usage of these equipment and should be kept up to date on them on a regular basis. [3]

Although there has been a significant improvement in the quality of internet connectivity in rural areas, many regions in the world are still not able to enjoy the same connectivity as urban areas. This is, in turn, a setback for the efforts to implement smart farming techniques in rural areas. As a result, the bandwidth speeds in these areas are not ideal for carrying out effective and efficient operations. Since many agro-sensors rely on cloud services for storage and transmission of data, cloud-based computing needs to become stronger. GPS signal reception becomes a major challenge in farmlands with tall, dense trees and/or mountainous terrains. [4]

Lack of financial resources is one of the main factors that can slow down the implementation of PA. Due to the limitations of their fields and the lack of resources, many small-scale farmers are forced to continue using traditional farming techniques. [9]

VII. Possible Solutions and Current Applications

It is not feasible for small-scale farmers to implement precision agriculture due to various reasons. There are, however, possible solutions. Small-scale farmers can also benefit from the presence of large multinational corporations in their area by providing financial aid and other technical equipment needed for conducting PA. This method helps the farmers share in the profits of their farm. It also elevates their burden as they are not only aware of the technical knowhow but also receive guidance on how to implement it. Companies like TechMahindra are exploring this subject. [14]

Although the government can provide assistance to all farmers in need, it may be limited to those who are already suffering from drought. The government can also help in providing technical assistance to farmers. For instance, in the Marathwada region, the state government has deployed drones to monitor crop losses due to unfavorable weather conditions and provide timely compensations. The state has also started cloud seeding on a pilot basis in the Marathwada region to create artificial rains.

Some of the current applications include:

Precision Fruit Picking. Instead of manual labor, robots have been developed to perform tasks such as picking crops using a computer vision system as in figure 4. These robots can also detect the position of vegetables and fruits. [19]

Figure 4. Robots for picking fruits

Figure 5. Precision Crop Management

Precision Crop Management. Using crop sensors, optimised boundary spreading and GPS technology, risk of over and under-fertilisation is eliminated and spraying is also reduced by avoiding overlapping areas as in figure 5.

Next Generation VRT. The OSU Next Generation VRT applicator is designed to be used in the fields of wheat, soybeans, and corn as shown in figure 6. It features a self-inflating unit and can spray foliar nutrients.

Farm Making. In Thailand, the government and telecommunications companies are working together to help local farmers face the challenges of climate change, plant disease and soil moisture. Through a new farming system, farmers will be able to gain a better understanding of their crop's production and improve their efficiency. This will help them reduce their costs and improve their quality. [20] Farm making is depicted in figure 7.

Figure 6. Next Generation VRT

Figure 7. Farm Making for PA

VIII. Future Prospects

Improvement of the availability and performance of PA technologies is expected to be among the key factors that will drive the industry's growth in the future. These include improvements in internet connectivity, sensor technology, better and more accurate mobile applications, machinery equipment, etc.

In the future, drones will be used for the management of PA crops as in figure 8. With drones, we can quickly identify pests and diseases in crops, perform weather damage assessments, and find issues with irrigation systems. Drones eliminate the need for GPS and strong internet connectivity it requires. [11] [15]

Figure 8. Future Advancements in Drone Applications towards PA

IX. Conclusion

Various technologies such as GPS, sensors, and mobile apps can be used to implement precise farming techniques in developing countries. Although the concept of Precision Agriculture is still in its early stages, many of its applications are already being used. Lack of information, connectivity and financial support are some of the factors that could prevent the adoption of precision agriculture. The adoption of precision agriculture involves three phases: exploration, analysis, and execution. While the process is usually done in advance, it is not always done efficiently. Despite the various efforts made by the various agencies and organizations, the need for PA to become the sole choice in terms of agriculture still remains. Coordination between the private and public sectors is gaining momentum, but concerns about the cost-effectiveness of implementing new technologies remain a work-in-progress.

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