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Precision Agriculture – A Vital Approach Towards Modernizing the Smart Farming in India

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***Abstract:* Precision agriculture, also known as precision farming, is generally understood to be a farm management system based on information and technology that identifies, analyzes, and manages spatial and temporal variability within fields for maximum productivity and profitability, sustainability, and protection of the land resource by minimizing the production costs. The general public's growing environmental awareness makes it necessary for us to change agricultural management practices in order to sustainably conserve natural resources like water, air, and soil quality while being commercially successful.**

In the presented paper, we explore the idea of precision agriculture. This paper discusses the necessity for precision agriculture, related technology, the strategy for achieving it, the challenges encountered along the way, and potential solutions that can help the discipline advance. This work summarizes a thorough knowledge of the concept and the future path necessitating additional research, taking into account various research publications produced in the previous decade. Anyone interested in learning more about or conducting research on precision agriculture can use it as a starting point.

***Keywords:* Precision Agriculture, Smart Farming, IOT, Sensors, GIS, GPS, VRT.**

I. INTRODUCTION

Agriculture conjures up images of cultivation, plant life, fertile soil, different kinds of crops, the terrestrial environment, etc. However, in the modern world, we link phrases like climate change, irrigation systems, technical development, synthetic seeds, advanced technology, etc. with agriculture. In a nutshell, we are curious about how modern science may benefit us in the agricultural sector. Precision Agriculture then enters the picture. The application of inputs (such as chemical fertilizers and pesticides) in the proper amount, at the proper time, and at the proper location. Site-Specific Management is the term used to describe this style of management. More than a third of the world's food is currently produced by irrigation, which has been increasingly important to productivity gains in the food supply during the past few decades. The economic viability of the existing agricultural systems is being challenged by market-based worldwide competition in agricultural products, necessitating the creation of fresh and innovative production methods. To discover, analyze, and manage spatial and temporal variability within fields for maximum productivity and profitability, sustainability, and conservation of the land resource by reducing the production costs, is the broad description of an information and technology-based farm management system. Simply described, precision farming is a method that uses precise input levels to produce higher average yields than traditional agricultural methods. As a result, it is a thorough system created to maximize production with little harm to our terrestrial system.

Oxygen and water is what every individual on the planet will always need. In order to keep the levels of oxygen and carbon dioxide in the air stable, plants are essential. Numerous flora are obliterated daily as a result of urbanization. Additionally, fewer plants are done. In addition to these, other plants perish from neglect. The major goal of this project is to preserve the natural state of the plants by regularly tracking the variables that promote both plant and human longevity. A manual system is preferred to an automatic system. The precision agriculture not only provides precise approach to agriculture but also save a lot of resources used in agriculture. Information, technology, and management make up the three main elements of precision agriculture. Information is abundant in precision farming. Using information technologies, the management method known as "precision agriculture" gathers important information from various sources and incorporates it into decision-making. It is dependent on technology like GPS (Global Positioning Systems), GIS (Geographic Information Systems), yield monitors, remote mapping sensors, and guidance systems for use with variable rate that allows for in-depth field variation monitoring. The technology for tomorrow's environmentally friendly agriculture may be provided by the precision agricultural advancements of today. Precision farming promises the possibility of significant yield improvement with minimum external input use, particularly for small farmers in developing nations **[1]**.

II. NEED OF PRECISION AGRICULTURE

The food system around the world is currently facing significant difficulties that will only get worse over the next 40 years. With today's knowledge and technologies, a lot can be done right away with enough effort and money. The food system will need to undergo more significant changes in order to meet future challenges, and funding for research to develop fresh answers for brand-new issues will be necessary. Major issues in agricultural growth and development now include the decline in total productivity, diminishing and depleting natural resources, stagnating farm incomes, lack of an eco-regional approach, dwindling and fragmented land holdings, trade liberalization on agriculture, limited employment opportunities in non-farm sectors, and global climatic variation.

Therefore, one way to boost farm productivity in the future is through the implementation of recently developed technology. A precision farming technique takes into account site-specific differences within fields and modifies management measures accordingly, as opposed to managing an entire field based on some hypothetical average condition that may not exist anywhere in the field. Most farmers are aware of the uneven yields that exist throughout their crops.

These variances can be linked to management methods, the qualities of the soil, and/or environmental factors. Due to the enormous sizes and yearly changes in lease agreements in the farm region, it is challenging to maintain the degree of understanding of field conditions. So the entire farm must be divided into little farm units, each of which must be worth no more than fifty cents. The gathering and analysis of data could be automated and made simpler with precision agriculture. It enables the quick and effective implementation of management choices on smaller fields within bigger fields.

According to the UN World Population Report, 9.7 billion people will inhabit the planet by 2100, an increase of 34% from the current level. The developing nations that have the most agriculturally productive land in the globe, such as China, India, Brazil, and others, are predicted to contribute significantly to this expansion. To be able to feed everyone on the planet, global food production must expand by 70% in order to keep up with population growth and income increases **[2]**.

The collection of real-time data, analysis of the agricultural process, and the pursuit of improvement are the solutions to this enormous task. Therefore, it is necessary today more than ever to explore how current "precision agriculture" techniques and approaches, while looking for new ones, may increase food production, limit environmental effect, and cut costs. Ulisses Mello, an IBM researcher and Distinguished Engineer, said, "We have the potential to make a difference utilizing science and technology innovation to address significant issues that will have profound effect on the lives of billions of people**[3].**

III. TOOLS, TECHNOLOGIES AND EQUIPMENTS USED

There are various technologies, tools, equipments, sensors and information systems are used to achieve goals of precision agriculture. Most prominent tools and technologies involved in the precision farming are briefly discussed here:

A. Global Positioning System (GPS System)

With an accuracy range of between 100 and 0.01 m, GPS is a satellite-based navigation system that enables users to record positional data (latitude, longitude, and elevation) [4]. The precise location of field data, such as soil type, insect occurrence, weed invasion, water holes, boundaries, and impediments, can be found by farmers using GPS. There is an automatic controlling system with a DGPS, antenna, and receiver for light or sound. GPS receivers may determine their position by using the signals that are transmitted by GPS satellites. According to performance standards and prior input applications, the system enables farmers to accurately locate fields so that inputs (seeds, fertilizers, pesticides, herbicides, and irrigation water) can be applied to a specific field [5].

B. Geographic Information System (GIS System)

The components of this system include hardware, software, and protocols for compiling, storing, retrieving, and analyzing feature characteristics and position information to create maps. Information is linked in one location via GIS so that it can be extrapolated as necessary. Computerized GIS maps differ from traditional maps and have multiple informational layers, for example, yield, soil nutrient levels, rainfall, soil survey maps, crops, and pests. GIS is a type of computerized map, but its true purpose is to analyze people and places using statistics and spatial approaches. An agricultural GIS database can offer details on crop production, field topography, soil types, surface drainage, subsurface drainage, soil testing, and irrigation. After being analyzed, this data is used to comprehend the connections between the many factors affecting a crop at a certain location. By merging and modifying different data layers, the GIS may be utilized to analyze different management scenarios in addition to storing and displaying data.

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C. Sensors

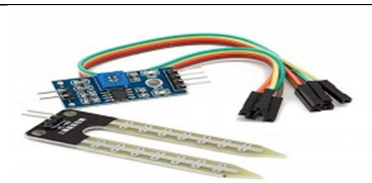
The use of sensors in precision agriculture has been widely documented to provide crucial data on soil characteristics, plant fertility, and water status. Sensor technology is a key component of this technology.

Measurements of humidity, texture, vegetation, temperature, physical character, structure, , conductivity, photo electricity, and ultra sound are made using a variety of methods, including electromagnetic, conductivity, photo electricity, and ultra sound. Crop species can be distinguished, stress points can be found, pests and weeds can be identified, and drought, soil, and plant conditions can all be tracked using remote sensing data. Sensors allow for the capture of enormous amounts of data without the need for laboratory examination **[6]**.

The use of sensors in precision agriculture has been widely documented to provide crucial data on soil characteristics, plant fertility, and water status. Sensor technology is a key component of this technology. Some of the widely used sensors are listed below:

1) *Electrochemical Sensors:* Important data like pH and soil nutrient levels are provided by these sensors.
2) *Mechanical Sensors:* Soil compaction is measured via mechanical sensors. They employ a probe that enters the ground and measures resistance using load cells or strain gauges**[7]**.
3) *Dielectric Soil Sensors:* To determine soil moisture levels, these sensors analyze the dielectric constant in the soil.
4) *Airflow Sensors:* These sensors assess the permeability of soil to air.
5) *Location Sensors:* Latitude, longitude, and altitude may all be determined to within a few feet with the aid of location sensors.
6) *Optical Sensors:* Optical sensors measure the characteristics of soil using light.

Table 1: Various Sensors Used in Precision Agriculture

Sl. No.	Sensor Type	Image
1	GPS Sensor	
2	Soil Moisture Sensor	
3	Ultrasonic Sensor	
4	Electrochemical Sensor	
5	Optical Snesor (IR)	

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6	Air-flow Sensor	

D. Yield Monitor

Yield monitors are made up of a number of parts. The task computer, which is often housed in the combine cab and manages the integration and interaction of the many sensors and other components, as well as a data storage device, user interface (display and keypad), and other components, usually include a variety of sensors. The sensors measure the speed of the separator, the ground speed, the mass or volume of the grain flow, and the grain itself. Grain yield is continuously monitored in a combine's clean grain elevator by measuring the force of the grain flow as it strikes a sensible plate.

A mass flow sensor that has recently been developed operates on the idea of delivering microwave energy beams and measuring the amount of that energy that bounces back after striking the stream of seeds moving through the chutes. GPS receivers are employed in all yield monitors to map yield data and record its location. Devices used in forage crops to measure weight, moisture, and other data per-bale are another type of yield monitoring system **[8].**

E. Software

In order to perform a variety of tasks, including display-controller interface, information layer mapping, pre and post processing data analysis and interpretation, farm accounting of inputs per field, and many other duties, precision agricultural technologies are frequently applied. Software to filter acquired data, software to make variable rate applications maps, such as for fertilizer, lime, chemicals, etc, software to generate maps for yield and soil, software to overlay multiple maps, and software to provide advanced geo-statistical characteristics are the most prevalent.

All are great alternatives for managing and keeping track of farms using precision agriculture to meet the demands of contemporary, information-intensive farming systems. A small number of businesses operate globally and offer integrated software packages that include tools for creating various sorts of maps, statistical analysis, and record keeping. Software to produce yield maps is also made available by machinery manufacturers that sell yield meters, and software to produce variable rate application maps is made available by fertilizer manufacturers.

Some of the packages are quite expensive and difficult for farmers to use, while others are far less expensive and have fewer possibilities. The farmer has a lot of alternatives and the packages are more user-friendly. Data transfer issues still exist between farmers as well as between farmers, co-ops, and consultants. Another challenging challenge to date is to overlay maps, particularly soil and yield maps.

F. Grid Point Sampling & Variable-Rate Fertilizer (VRT) Applications

An objective, straightforward, and rather quick method for site-specific soil management is grid sampling. The use of variable-rate technologies (VRT) is possible in a variety of farming operations. They base the rate of distribution of agricultural inputs on the kind of soil. GIS extrapolation data can regulate activities like crop selection, planting rate, and rate of fertilizer, pesticide, and herbicide application at the proper location and time. The use of it is widespread in developed nations. The same concepts are used to increase sampling intensity with grid soil sampling. We can create an application map by mapping samples collected in a methodical grid to certain locations. To ascertain the nutritional requirements of crops, grid soil samples are studied and interpreted [9]. Depending on the soil, VRT systems determine the pace of delivery of agricultural inputs. Based on the soil type identified on a soil map, VRT System determined the rate of delivery of agricultural inputs. Extrapolating data from the GIS can be used to control activities like seeding, fertilizer and pesticide application, herbicide selection, and application at the proper time and place with a variable rate.

The same concepts of soil sampling are applied in grid soil sampling, however sampling intensity is increased. The geographic location of soil samples gathered in a systematic grid also provides the ability to plot the data. A map of nutrient requirements known as an application map is the end result of grid soil sampling.

Samples may be taken from multiple fields within a single zone that fall within the same yield range, soil color range, etc. Grid soil samples are analyzed in the lab, and for each soil sample, crop nutrient requirements are interpreted. The whole collection of soil samples are then used to plot the map for applying fertilizer. A computer that is mounted on a variable-rate fertilizer spreader has the application map loaded into it.

G. Rate Controllers

Pace controllers are tools used to regulate the rate at which chemical inputs, such as liquid or granular fertilizers and insecticides, are delivered. These rate controllers keep an eye on the tractor/speed sprayer's as it crosses the field, as well as the flow rate and pressure (if the material is liquid), and they modify the delivery in real time to achieve the goal rate. Rate controllers are widely utilized as standalone devices and have been around for a while.

H. Mobile Applications

It is quite simple to share or acquire any information from anywhere thanks to the rising use of electronic gadgets like smart-phones, tablets, and other devices, as well as the accessibility of internet connectivity. Apps for Android offer rapid and effective functionality that can develop with technology. The apps created for agriculture monitoring and information exchange can aid farmers in areas like PA more. Applications intended to monitor agriculture provide information such as meteorological data, market rates and availability, etc. Similar apps can offer forecasting of the weather, a selection of seedlings, fertilizers, insecticides, and herbicides, etc **[10]**.

IV. METHOD OF ADOPTION

There are two methods of Precision Agriculture adoption and this can be categorized as:

1) *Soft PA:* Soft PA generally relies on visual crop and soil inspection, as well as management choices based on knowledge and perception.
2) *Hard PA:* Hard PA relies on statistical analysis of scientific data and makes use of all current technologies, including GIS, GPS, remote sensors, VRT, and others.

Farmers need to learn how to produce crops in a specific location while taking into account a seed's resistance to the weather, local pathogens, and the environmental impact of planting that seed. For instance, it is advisable to use a seed that needs less fertilizer when planting in an area next to a river to help decrease pollution, while picking a crop that demands a lot of irrigation.

Following the plantation, choices about fertilizing and caring for the crops must be taken quickly and are greatly impacted by the weather. Farmers may decide not to use the fertilizer if they expect strong rains the following day since it would be swept away. Making decisions also involves taking into account whether it will rain or not. This is possible with the use of predictive weather analytics. Since agriculture uses 70% of the world's fresh water, efficient use will have a significant impact on the fresh water supply. Weather has an impact on transportation and harvesting logistics in addition to crop growth. For example, in order to harvest sugar cane, the soil must be sufficiently dry to withstand the weight of the harvesting machinery. Otherwise, it can ruin the crop. Better decisions about labor deployment can be made in advance by looking at what the weather will be like over a few days. Following harvest, the logistics of getting food to distribution facilities take precedence.

Because poor delivery or choosing the incorrect market can also have a negative impact on the farmers' success. Food must be transported at the proper temperature and shouldn't be kept for an extended period of time because this reduces the amount of food that is damaged, discarded, or spoiled during distribution. Farmers can choose better transportation routes just by knowing where it will rain and which routes may be impacted **[11]**.

V. BARRIERS

1) Nearly 90% or more of the research on precision agriculture claimed that the techniques have primarily been used on a single field, as an experiment, or solely on commercial farms due to the lack of a whole-farm emphasis. This is due to the fact that precision agriculture has not yet been integrated into the everyday farming operation. Because they are unfamiliar with current agricultural techniques, farmers are hesitant to choose them.
2) One of the main causes of PA's limited deployment is a lack of information. To successfully implement PA, farmers require enough knowledge and prompt guidance. In the absence of a recognized authority or group that promotes knowledge of PA procedures and provides the required tools, this is challenging to do. Farmers should be periodically updated and should be conversant with how to use these tools.

3) Strong, dependable internet access is still not available in rural and other isolated places of the world, particularly in developing nations. In turn, this thwarts attempts to use smart agriculture methods in such places. Precision farming won't be fully implemented unless network performance and bandwidth speeds greatly increase. Due to the fact that many agro-sensors/gateways rely on cloud services for data transmission/storage, cloud-based computing must also develop, which calls for strong interconnectivity. Reception of GPS signals becomes a major problem in farmlands with tall, dense trees and/or mountainous terrains.
4) One of the main reasons for the implementation of PA's slow progress is a lack of financial resources. The small size of their fields and lack of financial resources to spend in the acquisition of PA devices are obstacles for small-scale farmers. These factors require them to continue farming using their old methods. Even with the availability of financial aid, PA is an unwise career option due to the scale of the sector **[12]**.

VI. CONCLUSION

Several cutting-edge Precision Agriculture techniques can make use of technologies like GPS, GIS, mobile apps, and sensors. However, most developing nations are still just beginning to embrace precision agriculture. The public and commercial sectors' strategic support is still in the planning stages. Precision agriculture faces obstacles such as a lack of information, connectivity issues in rural areas, and a lack of funding.

In many developing nations, precision farming is still merely an idea, therefore it requires thoughtful assistance from both the public and business sectors to encourage its quick adoption. Exploration, analysis, and execution are the first three phases of a successful adoption, though. Environmental and economic concerns that now surround production agriculture can be addressed with precision agriculture. The idea of "doing the right thing in the right place at the right time" has a strong intuitive appeal, but questions concerning cost-effectiveness and the best uses of the technological tools we now have persist. An all-out attempt should be made to leverage new technical inputs to transform the "Green Revolution" into a "Evergreen Revolution" in light of the pressing need of the day. Finally, the ability and speed with which the information required to direct the new technologies can be discovered will greatly influence the success of precision agriculture.

Using a systems perspective, precision farming offers a fresh approach to current agricultural problems like the need to strike a balance between productivity and environmental considerations. Advanced information technology serves as its foundation. It entails documenting and simulating soil and plant species variety, as well as combining agricultural operations to satisfy site-specific needs. It tries to maximize economic returns while decreasing agricultural energy use and environmental impact.

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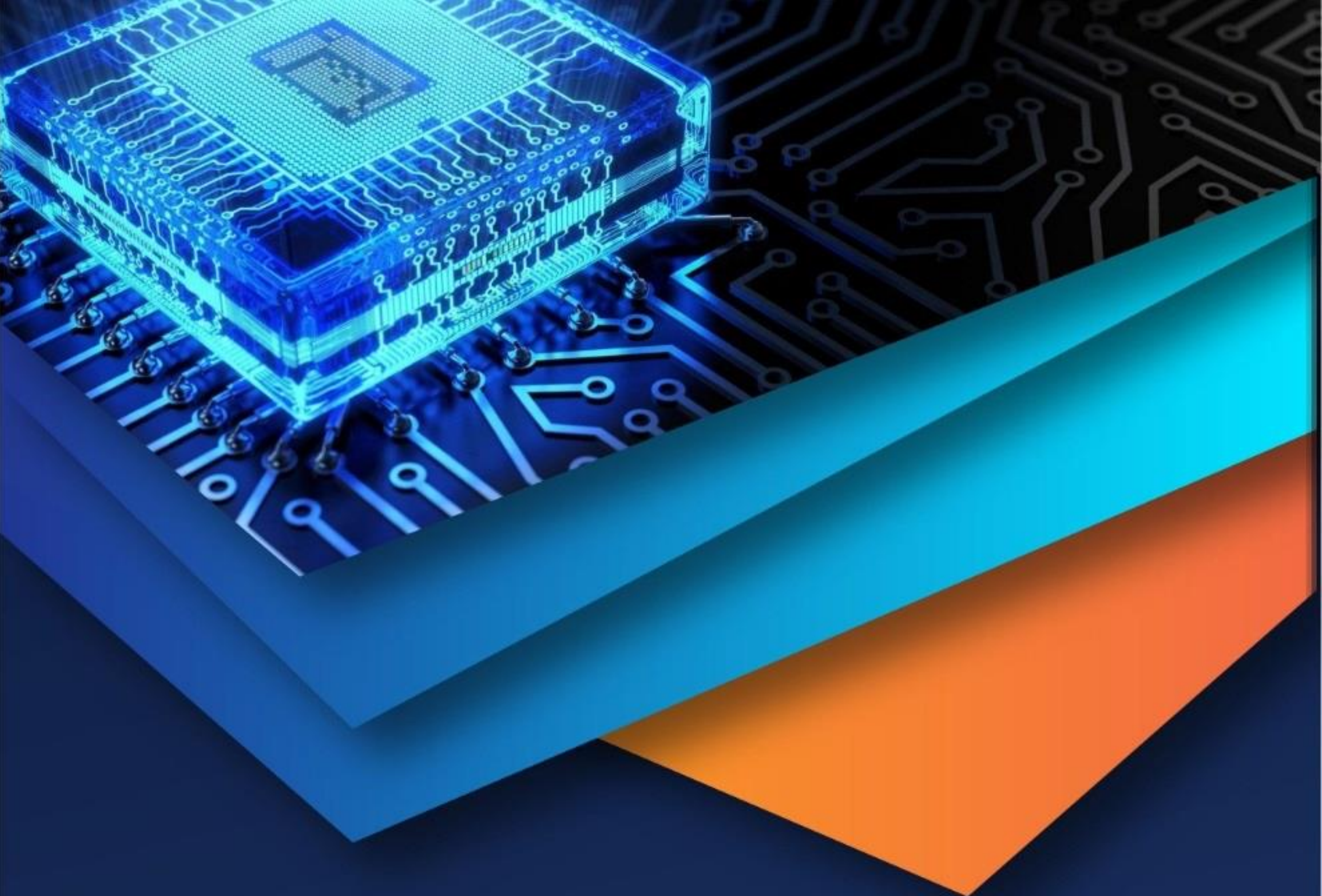

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