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Precision Farming and Its Future

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Precision farming is a farm management system based on information and technology. Its goal is to identify, analyze, and manage the spatial and temporal variability within fields to achieve the highest levels of productivity and profitability, sustainability, and protection of the land resource by minimizing production. Precision farming involves using precise inputs to get higher average yields than traditional cultivation approaches. This method optimizes production by utilizing information, technology, and management to improve efficiency, product quality, crop chemical use, energy conservation, and environmental sustainability. Precision farming employs information and decision-making tools such as Remote Sensing (RS), Geographic Information Systems (GIS), Global Positioning Systems (GPS), soil testing, yield monitors, and variable rate technology. It requires collecting, managing, analyzing, and disseminating massive amounts of spatial and temporal data.

Need of Precision Farming

- Increases agricultural productivity.
- Prevents soil deterioration.
- Reduces chemical use in crop production.
- Efficient use of water resources.
- Dissemination of modern farming methods to increase product quality, quantity, and cost.
- Promoting positive attitudes.
- Precision farming is altering farmer's socioeconomic situation.

Components

Precision agriculture contains three essential components: technology, information, and management Precision farming is information-intensive, and treatment maps require a large amount of data, and numerous strategies are under development or have been established in the recent decade. Earlier, precision agriculture comprised on three "R's": the right time, amount, and place.

Goal of the Precision Farming

- You can improve agricultural performance and protecting the environment by creating precise strategies that are compatible with farming techniques.
- Create a system for detecting the factors that influence crop performance variation within a field.
- To create acceptable guidelines for achieving precision agricultural technologies and optimal management.
- We study the findings and make crop growth management recommendations based on GIS and remote sensing techniques.

Present Scenario of Precision Farming in India

Underdeveloped nations like India struggle to implement these systems due to farmers' low economic status, small land holdings, and depend on farming for livelihood. Despite challenges in developing countries, this technique has achieved substantial progress. Consider the following scenario: a farmer approaches his field with a GPS-guided tractor. The GPS detects the tractor's precise position in the field. The device transmits signals to the tractor's computer, which includes a GIS with a soil nutrient need map. The GIS, in interaction with a Decision Support System, determines an appropriate fertilizer amount for each region. The system directs a variable rate fertilizer applicator, coupled to the tractor, to apply the appropriate amount at the farm's particular place. Precision farming is primarily used by farmers who operate in developed countries. While precision farming is often discussed in developed countries, it is still in its early stages in emerging nations like India. The Space Application Center (ISRO) in Ahmedabad is conducting a remote sensing experiment at the Central Potato Research Station farm in Jalandhar, Punjab, to evaluate its capabilities for mapping and analyzing spatial and temporal variability. Chennai MS Swaminathan Research Foundation coordinated with NABARD to evaluate the effectiveness of variable rate contributions in a village cluster in Tamil Nadu's Dindigul district. The Indian Agricultural Research Institute in New Delhi aims to assist farmers achieve the potential of frontier technologies while maintaining land quality. Additionally, the Project Directorate for Cropping Systems Research (PDCSR) in Modipuram and Meerut (UP) collaborated with the Central Institute of Agricultural Engineering (CIAE) in Bhopal to implement variable rate inputs in diverse crop systems. Precision farming can provide Indian farmers with cutting-edge technologies without compromising land quality in the future.

Information

Detailed information about the crop characteristics, soil properties, pests and disease incidence, climatic conditions, stress (biotic and abiotic) etc., can be used to create various kinds of maps which can help the farmers to use the available information while making decisions.

Management

By combining the available technology with the information acquired, efficient management will produce an integrated system. Producing crops will not be possible without precise and effective management. Farmers need to be capable of evaluating the data at their disposal, utilizing technology effectively, and making effective choices on productivity.

Tools of Precision Farming

1. Global positioning system (GPS)
2. Remote sensing
3. Geographic information system (GIS)
4. Yield monitoring:
5. Variable rate technologies (VRT)
6. Sensor Technologies

1. Global positioning system (GPS): Precision agriculture depends significantly on global positioning systems (GPS). GPS receivers with high accuracy are accessible and appropriate for precision activities such as yield mapping, grid sampling, and variable rate application. Farmers can utilize GPS to precisely locate field data, such as soil type, pest incidence, and weed invasion. Differential GPS (DGPS) is the most used approach for correcting GPS errors. The differential global positioning system (DGPS) integrates space-based and ground-based components to create a radio navigation facility. Agriculture involves a diversity of activities, including precision sowing, irrigation, and pest and disease management, which varies each field plot. Although GPS is not widely used in agriculture, it has potential for future applications. A GPS-enabled aircraft can be used for precision crop dusting in areas as small as 4 m^2. Farmers have been utilizing GPS to record observations. In a few years, Indian farmers will benefit from advanced technology that improves land quality without compromising profitability.

2. Remote Sensing: Remote sensing technology allows for easy collection of field-related data while sitting in one location. Precision farming uses remote sensing to collect field information, including crop growth habits, plant status, and spatial variability information. Over three decades of research, precision farming has reached near-perfect levels. Remote sensing is used for soil moisture monitoring, crop nutrition analysis, management of agricultural disease and pest control, crop growth analysis, and yield estimation, and many other such tasks. Remote sensing is the primary source of information for precision farming. The recorded information is processed and analyzed to provide a prescription map for variable rate applications. It enables the identification of the landscape without the sensor coming into direct contact with the soil. It senses crop vegetation and detects crop stressors and insect infestations via aerial or satellite imagery.

3. Geographical Information System (GIS): A Geographic Information System (GIS) is a set of computer tools for working with data related to a particular location or mapped area on Earth. A GIS database is designed to work with map data. GIS allows multiple detailed data to be drawn graphically, which can be used for decision-making. A farming GIS database provides information on field topography, soil types, surface drainage and subsurface drainage, soil testing, irrigation, chemical application rates, and yields of crops. This data is evaluated to understand the impact of various factors on a crop at a certain location. GIS is a computer hardware and software to create maps by combining feature attributes and location data. Agricultural GIS involves storing layers of information, including yield, soil survey maps, and remote sensing data. This platform facilitates information sharing with other systems and users. Information services often include information management, message exchange and update, decision analysis, and information release.

4. Yield Monitoring: Precision farming depends significantly on yield monitoring and mapping, which were previously the most constantly used methods Yield monitoring is the most comprehensive measure of regional yield variability in agricultural fields, allowing farmers to analyze how management skills and environmental variables influence crop output "Yield monitoring enables the farmer with quick and important feedback which in turn helps to make better management choices, his evaluation supplies the farmer with rapid and essential input, helping us to make better management decisions". Feedback can include yield and moisture maps, digital pest records, immediate yield and moisture recording, and data classifications by year, farm, field, load, and crop. Long-term yield monitoring creates a single GIS database, allowing farmers to examine field variances, make better variable-rate decisions, and establish a spatial data history. This approach is being used to study and market crops like potatoes, onions, sugar beets, and tomatoes.

5. Variable-rate technology (VRT): Variable-rate technology (VRT) is used to modify agricultural inputs based on site-specific needs of each portion of the field. If machines are used, variable-rate equipment is necessary. For small farms, inputs can be applied manually. Variable-rate applications require precise field positioning, accurate location information, and farm machinery equipped with VRT controllers. This technique involves modifying input rates in certain zones over a field. VRT aims to maximize profit, improve input efficiency, ensure long-term sustainability, and emphasize environmental safety. "These are automatic and applicable to many farming operations. It determines the rate of farm input delivery based on the soil type identified on a map. GIS data can be used to control activities like seeding, fertilizer and pesticide application, herbicide selection, and application at variable rate in the optimal time and location. These controllers typically use DGPS receivers to identify spatial variability in the field and automatically control the rate of application based on pre-derived input maps.VRT technology can effectively control site-specific cropping systems. The following are some of the most popular VRT applications. Variable-rate application equipment is the most often used precision agriculture technology.

6. Sensor Technologies: Sensor technology plays a vital part in precision agriculture, providing valuable information into soil quality, plant fertility, and water status. Various technologies, including electromagnetic, conductivity, photo electricity, and ultrasound, can monitor humidity, vegetation, temperature, texture, structure, physical characteristics, nutrients levels, humidity, vapour, and air etc. Remote sensing data helps identify crop species, locate stress conditions, identify pests and weeds, and monitor drought, soil, and plant conditions.

Advantages of Precision Farming

Modern precision farming can help farmers improve yields and resources while reducing environmental implications like over-fertilization and pesticide use. This method is beneficial for assessing crop stress, soil quality, vegetative cover, and yield estimation precision farming technologies allow farmers to adjust the distribution and timing of fertilizer and other agrochemical in their fields based on spatial and temporal variability. To acquire an accurate risk estimate, farmers can conduct economic analyses based on crop output variability. "Nitrate leaching is a major issue in potato cropping systems, particularly in coarse-textured soils. A study in two adjacent fields, one treated with URT for nitrogen fertilizer and the other with VRT, demonstrated that VRT effectively reduces groundwater contamination. "Topographic data for fields using Precision farming technologies allows for analysis of the interaction between tillage and soil/water erosion." This can help reduce erosion.

Constraints of Precision Farming

Mapping soil, crop, and environmental characteristics in a field generates a significant amount of data for crop managers to handle. Managers can tackle data overload by developing tools for integrating data, expert systems, and decision assistance."Although data required on soil, crop and environmental factors can be obtained, most methods are labour-intensive and costly (such as soil sampling followed by laboratory analysis". Precision farming requires the implementation of new-age technologies. For small farmers, setting up IoT and sensor networks will become a challenge. Training farmers on different Precision farming tools are of significant importance and the success of Precision farming will rely on the training. In many villages, strong, reliable internet connectivity is not available. Unless there is a significant improvement in network performances and bandwidth speeds, and will remain problematic. Cloud-based computing also needs to become stronger.

Future scope of Precision Farming

Precision application technology enables fewer treatment units based on site-specific demands. Future automated systems will use sensors and computer technology to categorize plants in fields as weeds or crops, and then identify the weed species. Artificial Intelligence (A.I.) is increasingly being used for prediction, control, and recognition in sensing contexts. However, the integration with embedded systems remains limited. Shradin *et al*. (2019) used Artificial Intelligence to detect seed germination in a low-power embedded system. They compared the system's performance to that of a desktop computer and found that seed recognition was 97% accurate. Precision farming is a rapidly rising sector. Roland Berger Strategy Consultants GmbH reported a CAGR of approximately 12%. Connectivity is crucial to this development process. The precision farming has substantial challenges in data handling, storage, and processing, as well as connecting devices.

Conclusion

Precision farming is still in its early stages in many developing countries, demanding strategic support from both public and corporate sectors for rapid adoption. Successful adoption involves three phases: exploration, analysis, and execution. Precision farming can address economic and environmental challenges in producing agriculture today. Although there are concerns about cost-effectiveness and optimal use of technology, the idea of "doing the right thing in the right place at the right time" has a strong intuitive appeal. To meet current needs, it's essential to take advantage of modern technology to transform the 'Green Revolution' into an 'Evergreen Revolution'. Precision farming provides an innovative solution based on a systems approach is necessary to balance productivity and environmental concerns in modern agriculture. This is based on advanced information technology. The process involves characterizing and modeling soil and plant variations, as well as combining agricultural methods to fulfill site-specific requirements. The goal is to enhance economic returns while both minimizing energy input and impact on the environment in agriculture.

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