PRECISION AGRICULTURE: A SMART FARMING TECHNIQUE

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Traditional and precision agriculture represent two distinct approaches, each characterized by unique farm management practices and outcomes. Traditional agriculture has been passed down through generations and relies mostly on labor-intensive farming practices. Resource utilization in these systems tends to be inefficient, with inputs such as water and fertilizers applied uniformly across fields, regardless of site-specific needs. This one-size-fits-all approach can lead to resource wastage and environmental degradation. Moreover, traditional farming often fails to consider within-field variability in soil quality, sunlight exposure, and pest pressure, which can limit crop performance. In contrast, precision agriculture (PA) leverages advanced technologies, data analytics, and spatial information to optimize input use, enhance productivity, and support sustainable practices. It represents a transformative shift in modern agriculture, enabling farmers to make informed, site-specific decisions.

International Society of Precision Agriculture (ISPA) defines PA as: “a management strategy that gathers, processes, and analyses temporal, spatial, and individual plant and animal data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability, and sustainability of agricultural production.” In other words, PA is a data-driven approach that accounts for spatial and temporal variability to improve the sustainability and efficiency of agricultural production. The PA principle is often summarized as *doing the Right Operation at the Right Time, in the Right Place, and in the Right Quantity*. (Figure 1).

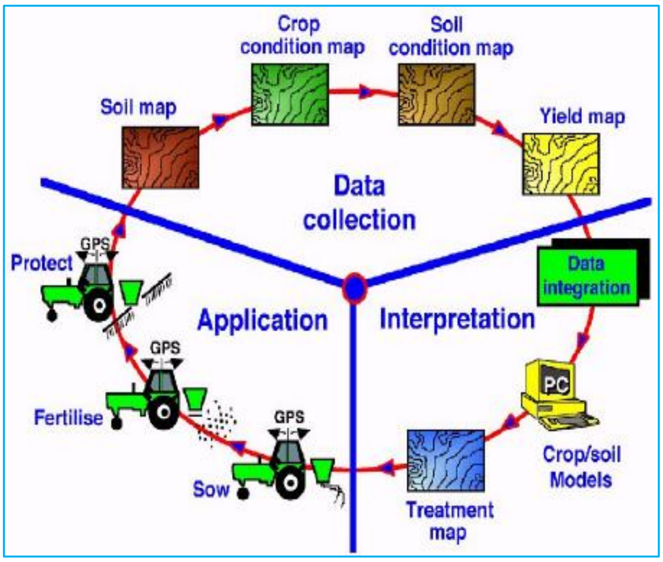

Figure 1. Process involved in Precision Agriculture (Source: https://semantictech.in/blogs/components-of-precision-farming-a-breakdown-of-the-essential-elements/)

COMPONENTS OF PRECISION AGRICULTURE

Global Positioning System (GPS): A satellite-based navigation system that provides geolocation and time information to receivers anywhere on or near the Earth with an unobstructed line of sight to satellites.

Geographical Information System (GIS): A tool for collecting, storing, analysing, and managing geographically referenced data to support informed decision-making in agriculture.

Sensors: Drones, satellites, and in-field sensors provide real-time data on crop health, soil moisture, temperature, and nutrient levels.

Variable Rate Technology (VRT): Allows for the site-specific application of inputs (e.g., fertilizers, pesticides), thereby improving efficiency and reducing environmental waste.

Yield Monitoring and Mapping: This involves measurement of yield variations across the field to understand spatial variability. Further, this data helps identify the underlying reasons of differences in yield and informs more targeted interventions.

NEED OF PRECISION AGRICULTURE IN INDIA

Resource Scarcity: With limited scope for horizontal land expansion, India faces constraints in arable land and freshwater availability. PA enables precise input use, reducing fertilizer loss and promoting efficient irrigation.

Input Inefficiency and Waste: Precision tools allow inputs to be applied exactly where needed, minimizing waste and maximizing effectiveness.

Field Variability: Variations in soil quality, sunlight, and pest pressure within a field can now be managed through targeted applications.

Labour Intensity: Traditional farming's dependence on manual labor is unsustainable. Automation through PA can reduce physical burden and attract younger generations to farming.

Climate Change: Unpredictable changes in weather parameters pose risks to crop production. PA enables real-time monitoring and adaptive decision-making to enhance climate resilience.

Yield Enhancement: By tailoring inputs to site-specific needs, PA can significantly improve average yields over conventional methods.

Environmental Protection: Reduced input overuse prevents the contamination of soil and water bodies, contributing to ecological sustainability.

Adopting of PA offers an opportunity to transform the agriculture sector in India towards higher productivity, sustainability, and resilience. Many Indian states have initiated efforts in this direction. Some successful cases are highlighted below:

1) **Tamil Nadu Precision Farming Project (TNPFP)**

   Focus: Horticultural crops (fruits and vegetables)

   Intervention: Micro-irrigation and fertigation

   Results: Yields increase of 30–200% over the conventional practices

   Benefits: Improved water use efficiency, reduced fertilizer wastage, and superior produce quality

2) **Sugarcane Farming in Bihar**

   Focus: Enhancing sugarcane yield and profitability

   Intervention: Drip irrigation and application of site-specific fertilizers based on soil test values

   Results: Farmers observed a 45% rise in profits along with reduced water and input costs

3) **Precision Farming in in Northern India**

   Focus: Enhancing productivity of cotton and wheat

   Intervention: Sensor-based nutrient management (N-sensor) and laser land levelling

   Results: Wheat yield increased by 3% (0.24 t/ha); laser land levelling expanded arable area by 3–6% by reducing bunds and channels

CHALLENGES IN THE ADOPTION OF PRECISION AGRICULTURE IN INDIA

High Initial Costs: Technologies such as drones, sensors, and software require significant investment, posing a barrier for small and marginal farmers.

Lack of Technical Knowledge: Implementation of PA practices require skills in technology operation and data interpretation. Many farmers require capacity-building support and training.

Digital Divide: Poor internet connectivity in rural areas limits access to real-time data, software updates, and online resources crucial for PA.

Fragmented Landholdings: Small and dispersed plots make it difficult to scale up PA solutions efficiently.

Data Privacy Concerns: Farmers may be reluctant to share personal and farm-related data due to trust and security concerns.

Lack of Standardization: Incompatible proprietary systems hinder integration and scalability of agricultural technologies across different farms and regions.

Infrastructure Gaps: Lack of reliable power supply and weather monitoring infrastructure in remote areas limits the effectiveness of PA.

Market Access: Without well-integrated markets that reward quality and sustainability, the benefits of PA may not be fully realized.

CONCLUSION AND FUTURE DIRECTIONS

Precision agriculture is an emerging paradigm that integrates recent advancements in cloud computing, artificial intelligence (AI), machine learning (ML), and the Internet of Things (IoT) to enhance agricultural productivity. Research suggests that PA-based practices significantly improve both productivity and sustainability. These systems provide decision-support tools that consider various crop parameters—such as soil nutrients, moisture, wind speed, solar radiation, temperature, humidity, and chlorophyll content. However, the development and widespread implementation of precision agriculture systems face multiple challenges, including technical, financial, and infrastructural barriers. Overcoming these hurdles will require coordinated efforts from governments, research institutions, agri-tech companies, and farmers.

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