

2. Concept of Precision Farming

So, precision farming, also known as precision agriculture or site-specific crop management, is a sophisticated conception of farming that depends on information and communicative technology to enhance refine how we grow our crops. The basic objective is simple: to deliver plants and soil exactly what they require nutrients, water, and protective chemical agents at exactly the right moment and exactly in the right place. The outcome is more prolific growth, increased yields, and higher profits, in contrast to old-fashioned farming techniques where all areas are treated equally, precision farming acknowledges and adjusts to differences among and within areas.

The methodology involves observations, measurement, and analysis of the natural variation in soil, crop growth, moisture, nutrient content, and the way pests and diseases act. By responding to these natural variations, precision farming optimizes the efficiency of inputs, minimizes waste, and reduces the footprint on the environment. Precision farming combines the art and science of agronomy, equipping the farmer with the information needed to make timely and informed decisions about the crop throughout its growth.

Key Principles of Precision Farming

1. **Site-Specific Crop Management:** Crop treatments and practices are tailored to specific areas of a field rather than a generalized approach being adopted across the entire field.
2. **Efficient Use of Inputs:** It emphasizes the efficient use of inputs like fertilizers, irrigation water, pesticides, and energy to minimize costs.
3. **Data-Driven Decision Making:** Decisions are based on current as well as past data received from sources like sensors, satellite images, or even yield monitors.
4. **Environmental Sustainability:** Precision farming contributes to the reduction of pollution by conserving agrochemicals and, in this manner, enhances environmental sustainability.

3. Technologies Powering Precision Farming

Putting precision farming into action means weaving together a suite of digital and mechanical tools to gather data, analyze it, and apply inputs precisely where they're needed.

3.1 Global Positioning System (GPS)

Precision farming uses GPS at its very core to establish precise field and machinery geospatial locations. It enables field mapping, geo-referencing of soil samples, yield monitoring, and tractor/equipment guidance. It underpins automated steering and delivers variable-rate input applications by keeping spatial alignment precise, minimizing overlap, misses, and general inefficiency in operations.

3.2 Geographic Information System (GIS)

Geographical Information System is a powerful platform for storing, managing, analyzing, and visualization of spatial field data; it integrates information collected from soil tests, notes from crop scouting, yield maps, and remote sensing images. Spatial analysis through GIS will reveal variability in soil fertility, crop health and moisture, and yield characteristics, thus allowing the establishment of management zones for specific interventions.

3.3 Remote Sensing and Drones

RS—from satellites and unmanned aerial vehicles—provides timely, nondestructive assessments of field and crop conditions. Multispectral and hyperspectral images help track crop vigor, spot nutrient gaps, detect pests and diseases, and gauge water stress. The NDVI index is one of the most commonly used indices to assess plant health and biomass for early action and precision management.

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INTRODUCTION

The twenty-first century faces the agriculture sector with a wide array of challenges, including rising climate variability, degradation of soil and water resources, declining factor productivity, rising costs of agricultural inputs, and the pressing need to ensure food and nutritional security for the ever-growing global population. These issues are more pronounced in developing nations like India, where the agricultural sector is still largely dependent on natural resources and is extremely sensitive to climatic uncertainties. Conventional or blanket-based farming systems, where uniform inputs are uniformly applied to the entire field, often overlook the natural spatial and temporal variability of soil characteristics, crop growth, pest infestations, and micro-climatic conditions. Consequently, such farming systems often result in inefficient use of inputs like fertilizers, water, and pesticides, leading to rising production costs, low input use efficiency, environmental degradation, and natural resource deterioration.

Precision farming has come up as a promising and sustainable solution to overcome the limitations by providing site-specific management of crops and resources. It is founded on the concept of "doing the right thing, at the right place, at the right time, and in the right amount." Precision farming uses the latest technologies like Global Positioning System (GPS), Geographic Information System (GIS), remote sensing, variable rate technology (VRT), soil and crop sensors, and data analysis to track, analyze, and manage variability in the field. Precision farming practices the concept of tailoring agricultural inputs according to the needs of the crops and the field, thus increasing productivity, optimizing resource use, minimizing environmental hazards, and maximizing farm profits.

Recently, the idea of smart advisory systems has further reinforced precision agriculture by filling the gap between technological advancements and decision-making. Smart advisory systems use information and communication technology (ICT), artificial intelligence (AI), machine learning, big data analysis, Internet of Things (IoT), and mobile-based platforms to provide location-specific, real-time, and personalized advisories to farmers. Smart advisory systems offer decision-support services to farmers on crop choice, planting dates, nutrient application, irrigation scheduling, pest and disease management, and weather-based risk management. By integrating field data with weather forecasts, market data, and expert opinions, smart advisory systems enable farmers to make informed decisions, thus minimizing uncertainties and maximizing climate change resilience.



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Precision Farming and Smart Advisory Systems

संकलन

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3.4 Internet of Things (IoT) and Smart Sensors

IoT integrates smart sensors and implements connecting networks that stream live real-time field data. Soil and crop sensors for moisture, temperature, electrical conductivity, humidity, and nutrient-level monitoring provide a constant feed of data on which one can make accurate irrigation timing, nutrient management by type and quantity, and microclimate-based decisions to improve crop yield while minimizing waste.

3.5 Variable Rate Technology VRT

VRT enables varied applications of inputs like fertilizers, seeds, irrigation water, and pesticides across the field based on crop and soil requirements. VRT systems depend on prescription maps created from the Geographic Information Systems (GIS) and sensor data or operate in real-time with on-the-go sensing. The alignment of input rates with the actual requirements of the field increases consistency in yield, reduces costs, and minimizes environmental impact.

4. Smart Advisory Systems

Smart advisory systems are high-tech digital decision technologies designed to assist farmers in the provision of timely, tailored, and location-specific agriculture advice. These systems utilize the benefits of cutting-edge technologies like AI, ML, data, cloud computing, and the Internet of Things to help transform the vast amounts of data into executable information. In contrast to traditional extension systems that provide generic advice, smart advisory systems incorporate real-time information collected from the fields and scientific data to assist in precision farming practices.

What makes up a Smart Advisory System

Data gathering: The data is collected from various sources, including weather stations, soil testing laboratories, remote sensors, IoT devices, crop scouting data, and farmer reports.

Data processing and analysis: The collected data is used to analyze patterns, trends, and risk factors in relation to crop growth, pests, and resource utilization through big data processing and machine learning techniques.

Decision Support Algorithms: These rules provide crop and location-specific decision support by applying predictive models, historical information, and expert guidelines.

Communication Channels: The advisories reach the farmers through user-friendly platforms like mobile applications, SMS, IVR technology, and websites developed in native languages.

Kind of advisories offered

1. Crop and variety guidance in tune with agro-climatic conditions
2. Nutrient and irrigation schedules for effective use of resources
3. Pest and disease forecasts with associated integrated management advice
4. Weather alerts for extreme events like heat waves, frost, or heavy rain - Market intelligence such as price trends, forecasted demand, and post-harvest tips

5. Applications in Indian Agriculture

In India, the use of precision agriculture and smart advisory systems has picked up pace in various agricultural sectors, especially in areas where resource scarcity and climate change are prominent. These systems are increasingly being used in:

Horticultural Crops: Precision agriculture is being used extensively in vegetables, fruits, and floricultural crops to improve their productivity, quality, and use efficiency due to their high value and susceptibility to management practices.

Protected Cultivation: Polyhouse and greenhouse cultivation practices are heavily dependent on sensors, automated irrigation, fertigation, and climate control systems using smart advisories.

Irrigation and Fertigation Management: Precision irrigation systems such as drip and sprinkler irrigation systems are being integrated with smart sensors to ensure efficient water and nutrient application.

Climate-Smart Agriculture: Smart advisory systems are being used for climate-resilient agriculture practices by providing weather-based advisories, early warning systems, and risk management strategies.

Various government schemes have played an important role in developing digital agriculture in India. Schemes such as the Digital Agriculture Mission, Soil Health Card Scheme, Pradhan Mantri Fasal Bima Yojana (PMFBY), and Agronet Advisory Services (AAS) have increased data availability, awareness, and institutional support for the use of smart advisory systems.

6. Benefits of Precision Farming and Smart Advisory Systems

The convergence of precision farming technologies and smart advisory systems provides a wide range of agronomic, economic, and environmental advantages:

1. Increased crop productivity and quality
2. Decreased input costs through optimized fertilizer, water, and pesticide use
3. Improved water and nutrient use efficiency
4. Effective and timely pest and disease management
5. Improved decision-making and risk management under climatic uncertainties
6. Improved farmer income and profitability of farming operations
7. Reduced environmental pollution and conservation of natural resources

7. Constraints and Challenges

Despite the potential benefits, the large-scale adoption of precision farming and smart advisory systems is currently being challenged by the following factors, especially in developing countries:

1. High capital investment requirements for sensors, equipment, and technology infrastructure
2. Low digital literacy and technological capabilities among small and marginal farmers
3. Poor internet connectivity and power availability in rural areas
4. Data compatibility and accuracy issues across different platforms
5. Unavailability of trained human resources for technology dissemination

To overcome these constraints, there is a need for collective action by policymakers, research institutions, private sector entities, and extension organizations.

8. Role of Extension and Capacity Building

The role of agricultural extension in facilitating the adoption and effective use of precision farming and smart advisory systems cannot be overstated. Extension organizations act as a bridge between technology developers and farmers by:

1. Providing training on the use of digital technology, mobile applications, and smart devices
 2. Demonstrating precision technologies in the field through pilot projects
 3. Creating linkages between farmers, agri-tech startups, research institutions, and input suppliers
 4. Encouraging public-private partnerships for the large-scale dissemination of technologies
- Capacity development through farmer field schools, digital literacy initiatives, and participatory learning strategies is necessary to ensure long-term acceptance.

9. Future Prospects

The future of precision agriculture is based on the effective integration of AI-based advisory systems with other technologies such as blockchain for supply chain tracing, agricultural robotics, autonomous farm equipment, and real-time decision support systems. As the price of sensors and digital technologies continues to fall and mobile connectivity improves, smart advisory systems are likely to become more and more accessible to small and marginal farmers. These technologies will have a crucial role to play in promoting sustainable intensification and climate-resilient food system transformation in the years to come.

CONCLUSION

Precision agriculture and smart advisory systems are the backbone of next-generation agriculture, enabling data-driven, timely, and site-specific farm management practices.

Their integration improves productivity, profitability, and sustainability while reducing environmental degradation. To achieve their full potential, particularly in developing countries such as India, there is a need for supportive policies, adequate digital infrastructure, affordable technologies, and capacity-building programs. With collective efforts, precision agriculture and smart advisory systems can make a substantial contribution to sustainable and climate-resilient agricultural development.