



Precision Agriculture: Transforming Modern Agronomy Through Smart Farming Technologies

Shrinivas C S

Department of Agronomy, University of Agricultural Sciences, Raichur

✉ *Corresponding author: shrinivascs@gmail.com



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ABSTRACT

Agriculture is entering a new era where technology plays a central role in improving productivity, sustainability, and resource-use efficiency. Among the most significant advancements in modern agronomy is Precision Agriculture, also known as Precision Farming or Smart Farming. This innovative farming approach utilizes advanced technologies such as Global Positioning System (GPS), Geographic Information Systems (GIS), remote sensing, drones, Internet of Things (IoT), artificial intelligence (AI), satellite imagery, and variable rate technology (VRT) to manage agricultural fields with greater accuracy. Unlike conventional farming practices that treat an entire field uniformly, precision agriculture recognizes that variations exist within fields in terms of soil fertility, moisture, nutrient availability, crop health, and pest incidence. By identifying and managing these variations, farmers can optimize input use, increase crop productivity, reduce

production costs, and minimize environmental impacts. Precision agriculture is increasingly becoming an essential component of climate-smart agriculture and sustainable farming systems worldwide. This article discusses the principles, technologies, applications, benefits, challenges, and future prospects of precision agriculture, highlighting its transformative role in modern agronomy.

INTRODUCTION

Agriculture has continuously evolved through technological innovations, from the invention of the plough to mechanization and the Green Revolution. Today, agriculture faces unprecedented challenges including climate change, declining soil fertility, increasing input costs, labor shortages, shrinking agricultural land, and the growing demand for food from an expanding global population. These challenges require farming systems that are more productive, efficient, and environmentally sustainable.

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Traditional farming practices generally apply fertilizers, irrigation water, pesticides, and other inputs uniformly across an entire field. However, agricultural fields are naturally heterogeneous, with considerable variability in soil texture, nutrient content, organic matter, moisture availability, and crop performance. Uniform application often results in overuse of inputs in some areas and insufficient application in others, leading to economic losses, environmental pollution, and reduced crop productivity.

Precision agriculture has emerged as a revolutionary solution to overcome these limitations. It is a site-specific crop management system that enables farmers to apply the right input, at the right place, at the right time, and in the right quantity. This approach improves input-use efficiency while maintaining or enhancing crop yield and quality. The integration of digital technologies, sensors, automation, and data analytics has transformed farming into a knowledge-intensive and data-driven enterprise. Precision agriculture is now regarded as one of the most important innovations supporting sustainable agricultural development in the twenty-first century.

CONCEPT OF PRECISION AGRICULTURE

Precision agriculture is a farm management strategy that collects, processes, and analyzes spatial and temporal data to support informed decision-making. Instead of treating an agricultural field as a single homogeneous unit, precision agriculture divides the field into smaller management zones based on variations in soil characteristics, crop growth, topography, and environmental conditions. Each zone receives customized management according to its specific requirements.

The fundamental philosophy of precision agriculture is based on maximizing productivity while minimizing unnecessary input use. This is commonly referred to as the "4R" principle of precision farming: applying the right input, in the right amount, at the right place, and at the right time. By implementing this principle, farmers can improve crop performance, conserve natural resources, and reduce environmental impacts.

EVOLUTION OF PRECISION AGRICULTURE

The concept of precision agriculture originated during the 1980s with the introduction of yield monitors and GPS technology. During the 1990s, Geographic Information Systems (GIS), remote sensing, and computerized farm management software enabled detailed spatial analysis of agricultural fields. The 2000s witnessed rapid adoption of automated guidance systems, variable-rate fertilizer application, and advanced sensors.

In recent years, precision agriculture has expanded dramatically with the integration of artificial intelligence, cloud computing, drones, robotics, machine learning, Internet of Things (IoT), and satellite-based monitoring systems. Modern precision farming now enables continuous real-time monitoring of crops and automated decision-making, significantly improving farm efficiency.

KEY TECHNOLOGIES USED IN PRECISION AGRICULTURE

The success of precision agriculture depends on the integration of several advanced technologies. Global Positioning System (GPS) provides accurate field positioning and allows farm machinery to navigate fields with remarkable

precision. GPS-guided tractors minimize overlaps during planting, spraying, and harvesting, reducing fuel consumption and input wastage.

Geographic Information Systems (GIS) play a vital role in collecting, storing, analyzing, and visualizing spatial information. GIS combines data from soil samples, satellite imagery, weather records, and yield maps to identify variability across agricultural fields and assist in site-specific management decisions.

Remote sensing technologies utilize satellites, aircraft, and drones equipped with multispectral and hyperspectral cameras to monitor crop growth, nutrient deficiencies, pest infestations, water stress, and disease symptoms. These technologies enable early detection of crop problems before visible symptoms appear, allowing timely intervention.

Unmanned Aerial Vehicles (UAVs), commonly known as drones, have become indispensable tools in precision agriculture. Drones capture high-resolution aerial images, monitor crop health, estimate plant populations, assess weed infestations, and evaluate irrigation efficiency. They are also increasingly used for precision spraying of pesticides and fertilizers.

The Internet of Things (IoT) connects various field sensors, weather stations, irrigation systems, and farm equipment through wireless networks. Soil moisture sensors continuously monitor water availability, enabling automated irrigation scheduling that conserves water while maintaining optimum crop growth.

Artificial Intelligence (AI) and machine learning analyze massive datasets generated from sensors, satellites, drones, and weather stations. AI algorithms identify disease outbreaks, predict crop yields, optimize fertilizer

recommendations, forecast pest populations, and support informed farm management decisions.

Variable Rate Technology (VRT) allows machinery to apply fertilizers, pesticides, seeds, and irrigation water according to the specific needs of different field locations. Instead of applying uniform rates, VRT adjusts application rates automatically based on prescription maps generated from field data.

Yield monitoring systems installed on harvesting machines continuously record crop yields across different field locations. These yield maps help farmers identify high-performing and low-performing zones and evaluate the effectiveness of management practices.

APPLICATIONS IN AGRONOMY

CRISPR gene-editing technology has emerged as one of the most transformative innovations in modern agricultural science, offering unprecedented opportunities for precise and efficient crop improvement. Unlike conventional breeding methods, which often require many years to develop improved varieties, CRISPR enables targeted modification of specific genes within a relatively short period while preserving the desirable genetic background of elite cultivars.

This technology has already demonstrated remarkable success in developing crops with enhanced resistance to pests and diseases, improved tolerance to drought, heat, salinity, and flooding, increased nutritional quality, better yield potential, and extended shelf life. Such advancements have the potential to reduce dependence on chemical pesticides and fertilizers, minimize environmental impacts, improve resource-use efficiency, and support sustainable agricultural production systems.

BENEFITS OF PRECISION AGRICULTURE

Precision agriculture offers numerous agronomic, economic, and environmental benefits. One of its greatest advantages is improved input-use efficiency. By applying fertilizers, pesticides, and irrigation water only where required, farmers reduce unnecessary expenditure while maintaining optimum crop performance.

Crop productivity often increases because each portion of the field receives management tailored to its specific requirements. Improved nutrient availability, better irrigation scheduling, and timely pest management contribute to higher yields and improved product quality.

Environmental sustainability is significantly enhanced through reduced chemical applications and efficient resource utilization. Lower fertilizer losses decrease nutrient runoff into rivers and groundwater, while optimized pesticide applications reduce ecological risks and protect beneficial organisms.

Water conservation has become increasingly important under changing climatic conditions. Precision irrigation minimizes water wastage, improves irrigation efficiency, and supports sustainable groundwater management.

Farm profitability improves through reduced input costs, increased productivity, lower labor requirements, and better management decisions. Precision technologies also generate valuable historical data that help farmers continuously improve farm performance over time.

REFERENCE

- Jaganathan Gebbers, R., & Adamchuk, V. I. (2010). Precision agriculture and food security. *Science*, 327(5967), 828–831.
- Pierce, F. J., & Nowak, P. (1999). Aspects of precision agriculture. *Advances in Agronomy*, 67, 1–85.
- Zhang, N., Wang, M., & Wang, N. (2002). Precision agriculture—a worldwide overview. *Computers and Electronics in Agriculture*, 36(2–3), 113–132.
- Mulla, D. J. (2013). Twenty-five years of remote sensing in precision agriculture: Key advances and remaining knowledge gaps. *Biosystems Engineering*, 114(4), 358–371.
- Shamshiri, R. R., Kalantari, F., Ting, K. C., Thorp, K. R., Hameed, I. A., Weltzien, C., Ahmad, D., & Shad, Z. M. (2018). Advances in greenhouse automation and controlled environment agriculture. *Information Processing in Agriculture*, 5(1), 1–30.
- FAO. (2022). The State of Food and Agriculture 2022: Leveraging Automation in Agriculture for Transforming Agrifood Systems. Food and Agriculture Organization of the United Nations.
- Lowenberg-DeBoer, J., & Erickson, B. (2019). Setting the record straight on precision agriculture adoption. *Agronomy Journal*, 111(4), 1552–1569.