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Precision Agronomy: Transforming Traditional Farming into Smart Agriculture

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INTRODUCTION

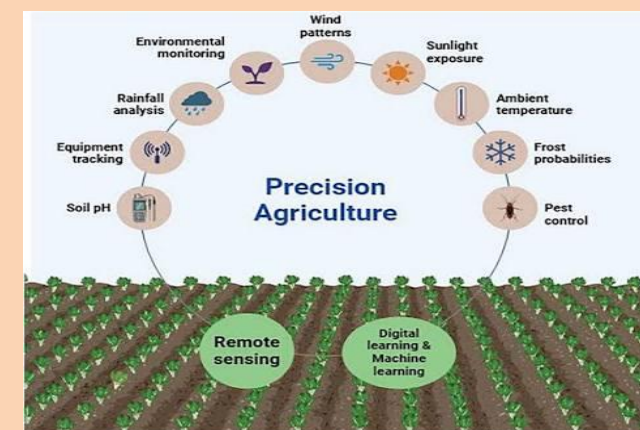
Why Precision Agronomy Matters

Agriculture is poised to enter a new digital era in which the use of scientific and engineering principles will extend to the optimization of every seed, every drop of water, every gram of fertilizer, and every farming decision. Traditional agriculture will often apply uniform inputs and treatments across a field, ignoring the fact that soil fertility, moisture, nutrient availability, pest pressure and crop growth vary within a field. This often results in overuse of inputs, rising production expenses, decreasing resource use efficiency, and environmental sustainability. Precision Agronomy is based on contemporary mechanism to monitor and control the variability by means of decision support systems. It is an integration of recent advances in technologies including Global Positioning System (GPS), Geographic Information System (GIS), remote sensing, Unmanned Aerial Vehicle (UAV) or drones, Internet of Things (IoT), artificial intelligence (AI), machine learning, sensors, robotics and digital decision-support systems that facilitate the application of the right input to the right place at the right time during the right rate and in right manner.

What is Precision Agronomy

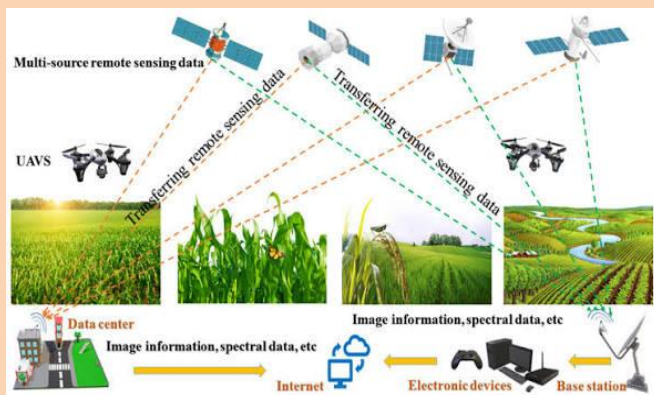
Precision agronomy is a scientific and technical approach that monitors, measures, and controls in-field variability to maximize crop production efficiency with least risk to environment. Instead of treating the whole field as uniform, it accepts the fact that there are different zones within the field that

differ in properties such as soil nutrient levels, moisture content, or crop vigour and an individual piece of land can do 'patchwork farming'. Based on the Five Rights of Precision Agronomy-the right input, right dose, right place, right time, and right application method-, it contributes to the improvement of the input use efficiency of agriculture, reduction of production cost, environmental load, and increase of productivity, profit, and sustainability.



Building Blocks of Precision Agriculture Satellite-Based Remote Sensing

Satellite remote sensing offers uninterrupted and extensive observation of crop development, plant health, soil wetness, nutrient shortages, disease proliferation, and field heterogeneity. Vegetation indices including the Normalized Difference Vegetation Index (NDVI) can identify crop stress at an early stage, before the onset of visible symptoms, thus allowing for timely and location-specific intervention.



Drone Technology

In agriculture, drones provide high-resolution images to monitor crops in real-time, for surveillance of pests and diseases, for mapping of weeds, for estimating plant population as well as for assessing nutrient deficiency. Drones also enable precision spraying of pesticides and fertilizers, increasing application accuracy, reducing chemical wastage and environmental pollution.

GPS and GIS

The Global Positioning System (GPS) offers accurate navigator in the field, and the Geographic Information System (GIS) allows the spatial information provided by soil maps and other sources to be integrated into digital maps that can be viewed, analysed, and printed in the field. Combined, these technologies enable soil and yield mapping, nutrient management zoning, monitoring of field variability, and site-specific cultivation that can increase productivity and resource use efficiency.

Internet of Things (IoT)

The Internet of Things utilizes a network of wireless sensors to monitor soil moisture, temperature,

salinity, nutrient status, weather conditions, and leaf wetness in real-time. Real-time information is sent to smartphones or web-based platforms, allowing farmers to take decisions on irrigation, nutrient management and crop protection in a timely manner.

Artificial Intelligence (AI)

AI analyzes the enormous data collected from satellites, drones, sensors, weather stations, and farm records, to offer an intelligent decision support. It foresees crop yields, suggests the best fertilizer doses, predicts pest and disease outbreaks, advises on irrigation scheduling and enables data-driven farm management with precision for increased productivity and sustainability.

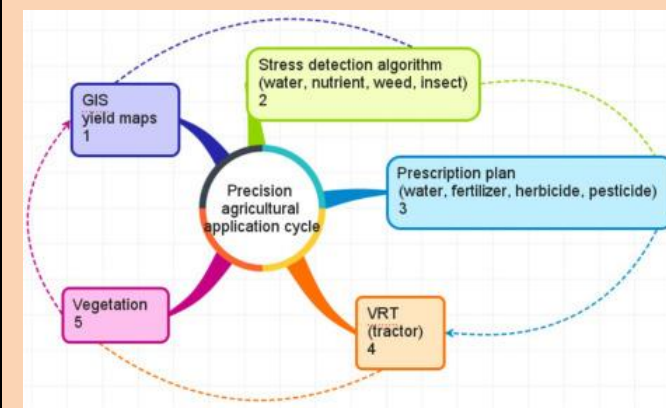
Variable Rate Technology (VRT)

VRT enables farmers to vary the rates of seeds, fertilizers, irrigation water, and pesticides in real-time according to site-specific soil fertility and crop needs. By applying the appropriate input at the right place and rate, VRT increases input-use efficiency, decreases production cost and environmental loss, and improves crop yield and quality.

How Precision Agronomy Works

Agriculture precision is a systematic process that starts with the data collection by using satellites, drones, soil sampling, weather stations, IoT sensors, mobile applications, and smart farming equipment. The data are then processed with AI and GIS to delineate field variability and management zones. Decision support systems produce site-specific recommendations for irrigation, nutrient, pest, and crop management, based on these results. Inputs are then applied with GPS-enabled precision equipment

at the right time and place and rate, and the crops are continuously monitored and their performance evaluated to allow timely interventions and further improvements to management.



Digital Technologies Powering Precision Agriculture

Technology	Major Applications
GPS	Field navigation, mapping
GIS	Spatial analysis, management zones
Remote Sensing	Crop monitoring
Drones	Imaging, spraying
IoT Sensors	Soil and weather monitoring
AI	Decision support
Machine Learning	Yield prediction
Robotics	Autonomous field operations
Cloud Computing	Data storage and analytics
Mobile Apps	Farm advisory services

Benefits of Precision Agronomy

Precision agronomy is the use of precision farming techniques and principles to improve crop production

and quality. It also reduces the cost of production by avoiding wastage of fertilizers, irrigation water, pesticides and fuel and protects the environment by avoiding unnecessary applications of inputs. Site-specific nutrient and water management enhance soil quality and water use efficiency for sustainable agriculture. Precision agronomy also contributes to building climate resilience through timely application of weather-informed management practices, which allows farmers to better protect their crops from drought, heat, floods and other climatic stresses. Decreased chemical use accounts for reductions in greenhouse gases, nutrients lost to the environment, and environmental pollution, while increased productivity and lower input costs increase farm profitability and farmer income.

Challenges in Adoption

Precision agronomy application has a great potential for the improvement of crop production systems, but its adoption is limited due to various reasons including, high initial investment, weak digital infrastructure, poor internet connectivity, fragmented farm holdings, limited technical know-how, cost of equipment, shortage of skilled manpower, data privacy issues, and lack of interoperability among digital platforms. Extension services need to be strengthened, rural connectivity improved, affordable technologies developed, and custom hiring centers and farmer producer organizations (FPOs) promoted to facilitate its widespread adoption.

CONCLUSION

Precision Agronomy is driving a change from the uniform management of fields to that of smart, field-specific crop production. Through the combination of

state-of-the-art digital technology and the know-how of agronomists, it can lead to farmers better utilizing their resources, boosting crop productivity, increasing profitability, and lessening their environmental impact. While barriers such as high investment costs, inadequate digital infrastructure and technical skills still exist, emerging technologies, supportive government policies and developing digital agriculture ecosystems are driving up the accessibility of precision farming. With agriculture challenged to feed a burgeoning population while warming climate threatens agricultural production, Precision Agronomy provides a sustainable approach to building resilient, efficient, and future-ready farming systems.