

AGRICULTURE FORUM FOR TECHNICAL EDUCATION OF FARMING SOCIETY

Kota, Rajasthan



Precision Agriculture Technologies

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INTRODUCTION

Precision agriculture is a highly evolved form of farming technique that involves the integration of digital technologies for maximizing the productivity of agriculture in terms of minimizing the consumption of resources and the impact on the environment. With the help of the application of technologies like GPS, GIS, remote sensing, drones, IoT, AI, ML, robotics, and big data analysis, precision agriculture makes it possible to conduct site-specific management of crops and soils. It provides information about the condition of crops, soil fertility, weather, and field variability. This allows farmers to make well-informed decisions about irrigation, fertilization, pest management, and harvesting. It increases the productivity, cuts the costs, improves efficiency of input usage, and contributes to climate resilient and sustainable agriculture. The purpose of this article is to analyze the concept, principles, main technologies, application areas, advantages, challenges, governmental measures, future perspectives, recommendations, and significance of precision agriculture technologies in modern agriculture.



There is a revolution in agriculture as far as the adoption of the latest digital technology that makes farming more efficient, productive, and sustainable is concerned. Traditional methods of farming do not

take into account the fact that soils, crop growth, water availability, nutrient content, and pest occurrence can vary greatly from one part of the field to another, thus leading to generalized management of these variables.

Precision farming compensates for the shortcomings through the acquisition, analysis, and application of site-specific data for the optimization of agricultural processes. With the help of modern technologies like GPS, GIS, drones, remote sensing, IoT sensors, Artificial Intelligence, robotics, cloud computing, and big data analytics, farmers will be able to monitor their fields constantly and apply resources in the places they are needed most.

2. Precision Agriculture Concept

Precision agriculture is a technology-based farming technique that uses spatial and temporal data in order to optimize agricultural inputs and improve the performance of crops. It uses information technology in conjunction with agricultural methods to manage the variability of a field and offer precise advice for growing crops. By applying inputs depending on specific needs of various parts of the field, precision agriculture allows maximizing productivity while minimizing waste.

Objectives

The key objectives of precision agriculture are improving productivity of agriculture, enhancing efficiency of input utilization, reducing costs of production, avoiding environmental pollution, increasing farm profitability, promoting sustainability of resource management and climate-smart agricultural practices.

- Increase agricultural productivity.
- Improve input-use efficiency.
- Reduce production costs.
- Minimize environmental pollution.
- Enhance farm profitability.
- Promote sustainable resource management.

- Support climate-smart agriculture.

3. Principles of Precision Agriculture

The foundation of successful precision agriculture is an internationally accepted "4R" principle which focuses on the right input use in right quantity, right place and at the right time. The application of 4R principles enables efficient usage of fertilizers, pesticides, irrigation water, seeds, machinery and labor. The use of 4R principles leads to improving nutrient use efficiency, reducing costs of production, preventing environmental pollution and increasing farm productivity.

4. Major Precision Agriculture Technologies

Precision agriculture involves the integration of several sophisticated technologies to help improve farm management and agricultural production.

4.1 Global Positioning System (GPS)

The Global Positioning System (GPS) provides geographic coordinates that assist in precise navigation and field work. GPS helps farmers in mapping fields, guiding tractors, taking soil samples, precision planting, and variable rate input application. It increases accuracy in field work, minimizes overlap of field operations, saves on fuel and labor, and increases field efficiency.

4.2 Geographic Information System (GIS)

The Geographic Information System (GIS) is a computer system for collecting, storing, analysing, and visualizing geographic data concerning agricultural fields. GIS helps in mapping soil fertility, analysing land use, monitoring crops, yield mapping, irrigation, and farm management.

4.3 Remote Sensing

Remote sensing can be defined as the process of acquiring information about crops and soils by the use of satellites, aircraft, and drones. Information obtained from remote sensing includes the status of crop health, vegetation growth, moisture level, nutrient deficiency,

pest infection, disease occurrence, and potential crop yield. Remote sensing helps in intervening on time and enhances the efficiency of agricultural management.

4.4 Drone Technology

Drone technology is unmanned aerial vehicles which are fitted with cameras, sensors and precise spray mechanism. High resolution aerial pictures taken with the use of drone's aid in monitoring crops, fertilizer spraying, pest control, damage assessments, weed detection, and crop population analysis. Drone technology helps in rapid surveillance of fields and effective data driven farm management.

4.5 Internet of Things (IoT)

Internet of Things (IoT) involves linking sensors, machines, and electronic devices of farms via communication networks based on the internet. Sensors involved in IoT include moisture sensors, weather station, temperature sensors, humidity sensors, water level sensors, and automatic irrigation controllers. The above-mentioned sensors collect data from the farm and help in irrigation scheduling and resource management.

4.6 Artificial Intelligence (AI)

Artificial Intelligence (AI) analyses huge amounts of agricultural data and gives intelligent advice on crop management. AI helps in disease detection, insect prediction, crop suggestion, yield prediction, image analysis, and farm automation. AI-based decision-making systems enhance the effectiveness of precision agriculture.

4.7 Machine Learning (ML)

Machine Learning (ML) is a subset of Artificial Intelligence that creates predictive models through historical and live agricultural data. ML algorithms enhance weather predictions, yield estimation, crop identification, deficiency prediction, and pest outbreak predictions. Predictive models created

through ML algorithms help farmers take proactive decisions.

4.8 Variable Rate Technology (VRT)

Variable Rate Technology (VRT) helps apply different amounts of agricultural inputs in the same field based on crop and soil conditions. Variable Rate Technology helps in variable rate fertilization, precision irrigation, site-specific application of pesticides, and variable seeding rates.

4.9 Robotics and Automation

Robotics and automation in agriculture enhance efficiency and precision in repetitive farming practices. Robotic technology is currently being utilized in precision planting, automation in harvesting, mechanical weed removal, fruit harvesting, greenhouse operations and crop monitoring. The use of automation in agriculture makes work less labor intensive, enhances accuracy and increases efficiency on farms.

4.10 Big Data Analytics

Big data analytics involves the processing of large amounts of data related to agriculture, including that gathered from sensors, satellites, drones, weather stations and farm equipment. This analysis leads to the production of useful recommendations on farm planning, crop prediction, resource allocation, market analysis and agricultural risk assessment.

4.11 Cloud Computing

Cloud computing involves centralized storage, processing and sharing of agricultural information using internet-based computing infrastructure. Farmers, researchers, extension services and policy makers can access farm information via cloud computing technology.

5. Applications of Precision Agriculture

Techniques of precision agriculture are extensively used during crop production to enhance productivity and efficiency in resource use.

Crop Production

Precision agriculture facilitates precision planting, site-specific seeding rates, crop growth surveillance, canopy analysis, and yield mapping to ensure better growth and increase yield.

Nutrient Management

The methods include site-specific nutrient fertilization, soil nutrient mapping, and balanced nutrient management to reduce nutrient losses and cost, as well as to optimize fertilizer use.

Irrigation Management

The methods involve smart irrigation scheduling with the use of soil moisture measurement, weather data, and crop water needs to reduce water use, save water resources, and promote crop production.

Pest and Disease Management

Early detection of pests and diseases is ensured by the use of precision agriculture with drones, remote sensing, artificial intelligence, and imaging systems. Site-specific pesticide application helps reduce chemical use.

Harvest Management

The methods facilitate yield prediction, harvest planning, crop maturity evaluation, and quality evaluation.

6. Advantages of Precision Agriculture Technology

The advantages of precision agriculture technology are economic, environmental, and social.

Economic Advantages

Precision agriculture enhances crop yield, cuts down production cost, raises farm profit, optimizes resource allocation, improves efficiency, and raises farmers' income by managing input efficiently.

Environmental Advantages

Application of site-specific inputs ensures less loss of fertilizers, reduced use of pesticides, improved water efficiency, lower emission of greenhouse gases,

resource conservation, better soil quality, and sustainable agricultural production.

Social Advantages

Precision agriculture improves farmers' decision-making skills, raises food security, builds rural livelihood, creates employment in the area of agri-technology, and helps raise digital awareness among farmers.

7. Government Initiatives for Precision Agriculture

Government of India has implemented various initiatives that help in promoting technologies and practices related to precision agriculture and digital farming. The Digital Agriculture Mission helps in the accelerated digitalization of Indian agriculture by using technologies based on data. Promotion of Kisan Drones helps in precise spraying of pesticides and crop monitoring. The Scheme of Soil Health Card helps in the management of nutrients in a scientific manner through regular testing of soil. The PM-KUSUM Scheme is helping in promoting solar-powered irrigation system for farming. The National Mission on Sustainable Agriculture (NMSA) is aimed at implementing the practices of agriculture that are resilient to the climate. The "Per Drop More Crop" initiative under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) is improving irrigation practices. National Agriculture Market (e-NAM) is helping in digital agricultural marketing, whereas the AgriStack is providing a digital platform for farm-based services.

8. Future prospects

In the coming years, the future of precision agriculture will be shaped by the fast evolution of digital technologies. Intelligent autonomous farms based on Artificial Intelligence will perform complicated agricultural tasks without much human involvement.

Drone swarms that can operate in concert to perform field work will optimize the process of crops monitoring and applying inputs to fields. Automated robotic harvesting will increase labor productivity and decrease harvesting losses. Blockchain technology will facilitate agricultural traceability and transparency in supply chain management. Digital twin technology will allow for farm modeling and prediction. The use of smart agriculture via 5G will provide opportunities for intercommunication between sensors, machines, and decision-making systems. Tractors and other smart farm equipment will become even more automated. Attention will be paid to the development of climate-smart precision farming, carbon farming, and sustainable monitoring.

9. Recommendations

For the widespread adoption of precision agriculture technologies, increased funding needs to be provided for digital agriculture infrastructure such as broadband connectivity, smart sensors, and data management tools. Programs for training and development of farmers should be strengthened to increase their technical and digital literacy skills. The use of precision farming technologies should be subsidized, and CHCs, FPOs, and cooperative farming techniques should be supported. There should be robust coordination among research organizations, universities, extension services, private industries, and technology firms. Enhanced rural connectivity to the internet is necessary for enabling real-time agricultural services. Government policy needs to support startups that develop precision agriculture technologies and promote public-private partnerships. Lastly, data-sharing mechanisms need to be put in place to provide privacy and security of agricultural data.