Precision Agriculture: Revolutionizing Farming Practices

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Introduction

According to the World Bank's Climate Smart Agriculture 2021 study, 8.9 percent of the world's population, or almost 60 million people, would suffer from undernourished. The issue of food security would further worsen, to feed an anticipated 9 billion people by 2050, the world will need to produce roughly 70 percent more food (FAO, 2005). Thus, Precision Agriculture (PA) is necessary to meet this demand. Precision agriculture, also known as satellite farming or site-specific crop management, a modern farming concept that integrates various technologies to enhance crop yields, reduce costs, and mitigate environmental impacts. Traditional farming methods often rely on generalized approaches to planting, irrigation, fertilization, and pest control, leading to inefficiencies and environmental degradation. Precision agriculture aims to address these challenges by applying data-driven insights and technology solutions tailored to specific field conditions.It is the application ofinputs atthe right time, in the right amount, and at the right place (Robert et al., 1994).

Key Components of PA:

- Global Positioning System (GPS) technology for accurate field mapping and navigation.
- Geographic Information System (GIS) for spatial analysis, temporal analysis and data visualization.
- Remote sensing technologies, including drones and satellites, for monitoring crop health, soil conditions, and pest infestations.
- Variable rate technology (VRT) forapplication of inputs.
- Automated machinery and robotics for practices such as planting, harvesting, and weeding.

Technologies in PA:

- GPS and GIS technologies enable farmers to create detailed maps of their fields, facilitating accurate planting, fertilizing, and irrigation.
- Remote sensing technologies provide real-time monitoring of crop health, allowing for early detection of diseases, nutrient deficiencies, and pest infestations.
- VRT systems adjust input application rates based on spatial variability within fields, optimizing resource utilization and reducing waste.
- Unmanned aerial vehicles (UAVs) or drones offer high-resolution imagery and multispectral data for monitoring crop growth and identifying areas of concern.

GPS

A network of satellites in orbit called the Global Positioning System (GPS) communicates precise position data to the ground. It obtains a bird's-eye view, albeit from orbit. The signals are used by GPS receivers to determine the exact position and time. With a 95 percent likelihood, the specified location on Earth will most likely be within 10 to 15 meters of the real site. Farmers may ascertain field data including soil type, insect occurrence, weed invasion, and water holes based on a particular location. Ex: NavIC, GLONASS, NAVSTAR (24).Ex. – NAVSTAR (24), NavIC, GLONASS.

GIS

Geographic information system (GIS) is a computerised mapping system used to collect, store, analyse, and present data that is specifically referenced to the earth. It is software that handles globally scattered data that is physically and temporally distributed.Spatial data is any information that relates to a certain geographic region or location. It offers the details necessary to locate the feature or the Earth's boundaries. Spatial data is additionally processed using GIS or image processing software.Data that depicts a state in time is referred to as temporal data. In essence, it is transitory data that is only valid for the period specified. To analyse weather patterns, track traffic, study demography, etc., data is gathered at a specific time.Temporal data helps analyse changes that take place across time. Following this investigation, plausible causes of the alterations are found to develop solutions. A GIS system offers a mechanism to combine various data layers, including those used to manage irrigation systems and analyse crops, soil, and the environment among other things.

Grid soil sampling

Same concept as traditional soil sampling with a difference of a greater number of samples at the grid level. It is a method of breaking a field into grids of about 0.5-5ha. sampling the soil within the grid is useful to determine the appropriate rate of application of fertilizers. The soil samples collected in a grid have location information that allows the data to be mapped.The goal of grid soil sampling is to generate a map of nutrient/ waterrequirements called an application map.Grid sampling reveals how the nutrients are distributed across a field. By collecting more soil samples on a field, we better understand the nutrients available.

VRT

Applying different amounts of fertilizer, herbicides, lime, gypsum, irrigation water, and other farm inputs throughout a field is feasible with the use of variable rate technology (VRT). VRT may be used to handle spatial variety between management zones. The variable rate applicator (VRA) is made up of the electronic control unit, computer, locator, and actuator. The application map is kept on a computer connected to a variable-rate applicator. Maps of input rate prescriptions for specific zones, GNSS,a controller that uses application maps to change the input rate, ray booms, the spraying disc applicator, and patch spraying VRT may be used to handle spatial variety between management zones.

Remote sensing

The practice of remote sensing science entails obtaining information about far-off places or things via satellites. They have a broad category for airborne or satellite sensors. By changing the colour of the field, they may convey variations in the kinds of soil, crop development, field boundaries, roads, water, etc. Aerial and satellite picture processing may be used to create yield mapping, soil mapping, topography analysis, and vegetative indices.

NDVI

Green Seeker's Normalized Difference Vegetation Index (NDVI) value. It offers a rough assessment of the health of the vegetation as well as a way to track changes in the vegetation over time.The NDVI value range is +1 to -1.The percentage of absorbed light that is used for photosynthetic activity is the biophysical interpretation of NDVI.NDVI measures the difference between red light and near-infrared (NIR) light.NIR and green light are reflected by healthy plants (chlorophyll) at a higher rate than other wavelengths. However, it reflects more red and blue light. Because of this, vegetation appears green to human sight. Example: Landsat and Sentinel-2.

Nutrient expert system

An individual farmer can use a nutrient expert system's balanced nutrition recommendations for rice, wheat, and maize in both the presence and absence of data from soil tests. Based on growing circumstances, this application also calculates the yield that farmers might expect. The International Plant Nutrition Institute (IPNI) South Asia program's personnel developed the Nutrient Expert and other computer-based decision-making tools like the Nutrient Manager (NM) delivery system and fertility maps based on geographic information systems.

Photometry

Photometry is the scientific term for determining how bright a light source is and how intense it is relative to human vision.It is a science of measuring light intensity and brightness to the extent that it can be seen by the human eye.Due to its value as a non-invasive diagnostic tool, the usage of spectrum imaging in the field of plant phenotyping and breeding has been growing.The morphology of the plants was also captured using photometric stereo, allowing for reconstruction of the leaf angle and surface texture, albeit additional work is required to increase the quality due to uneven lighting distributions, to allow for reflectance adjustment.

Challenges

In India, the main barrier to extensive agricultural mechanisation is thought to be land fragmentation. Market flaws and the heterogeneity of cropping systems, tools and techniquecomplexity demanding acquisition of new skills, lack of technological awareness and competence,infrastructure and organisational limitations, and agronomic factors area few major challenges.Inability to comprehend geo-statistics, which is necessary to comprehend crop and soil spatial variability, when using mapping software. Limited capacity to integrate data from various sources with varied resolutions and intensity and exorbitant capital expenses can deter farmers fromimplementing PA. High initial investment costs for technology acquisition and implementation. Technical complexities associated with data integration, interoperability, and cybersecurity. Ethical and privacy concerns related to data collection, ownership, and sharing.Regulatory barriers and policy constraints hindering widespread adoption and implementation are other challenges.

Benefits

PA aims to lower environmental risks while increasing agricultural output production.Monitoring soil characteristics, and plant physicochemical parameters such as electromagnetic conductivity inductions, nitrates, temperature, evapotranspiration, radiation, leaf area index, and soil moisture.Real-time information obtained from the installation of remote sensing equipment allows for ongoing mapping and monitoring of the chosen qualities, real-time data will be provided, guaranteeing that soil and plant parameters are always updated, and it will be possible to make better management decisions and plan agricultural operations with the use of this data.Farmers can assess how new varieties perform in site-specific locations and assess the effectiveness of various planting depths and rates. It is a technique for automatically gathering, storing, and analysing field records. Decreased use of fertiliser, agrochemical applications, and tillage operations result in time and cost savings.It includes farm management software to streamline all farm tasks and boost output.Subplots can be created from irregular fields.Over a longer time frame, trends and evaluations can be estimated.

Strategies for the adoption of PA

Virtual land consolidation that preserves the ownership structure can be the answer to India's land fragmentation issue. Savings of 15–25 percent are shown by the transborder farming method.The "dead reckoning system" can address the issue of expensive positioning systems for tiny fields. Another potential for the implementation of PA in small farms is the treatment of individual farms as management zones within a field and the cooperative information-sharing among the individual farmers by certain centralised entities.Identification of the target markets for the promotion of a certain crop for PA. Establishment of multidisciplinary teams composed of scientists from a variety of fields, engineers, economists, etc.,aiding farmers in developing pilot models that can be expanded on a big scale by providing them with full technical support.Evaluating the correct training requirements, exposure visits, and farmer demonstrations of the results. Tailoring precision agriculture solutions to meet the diverse needs and contexts of farmers worldwide, including those in developing countries. Policy incentives and support mechanisms to foster the adoption of precision agriculture and address socio-economic disparities in access to technology and resources. Adoption of a PA may be indirectly aided by an accurate assessment of environmental benefits, effective campaigning, and pollution levies.

Conclusion

Though widely used in developed nations, PA has not yet gained significant traction in India due to the country's unique land-holding structure, lack of infrastructure, socio-economic conditions, and demographic makeup. Urbanization, energy consumption, poverty alleviation, and economic growth in some emerging countries may all be significantly impacted by these changes. Thus, there is a need for a holistic system created to maximise production by utilising essential information, technology, and management components to boost production, improve quality, maximise chemical efficiency, save energy, and safeguard the environment.

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