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Precision Agriculture: A Tool for Sustainable Agriculture



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Synonyms

Precision – distinctness; Resource – assets; Variability – commutability

Definition

Precision Agriculture

Precision farming (PF), also known as precision agriculture, is around doing the right thing in the right place, at the right time. Handling agricultural production inputs such as water, seed, fertilizer, and so on in order to increase yield, quality, and profit, eliminate waste, and make it environmentally

friendly (Mahlein 2016). Satellite farming is another term for precision agriculture. Advanced technology agriculture includes farm management information systems and mechanization in agriculture including robotic machine that increases the precise information in agriculture (Balafoutis et al. 2020; Rose and Chilvers 2018).

Precision agriculture (PA), sometimes known as “prescription farming” or “variable rate technology,” is a collection of techniques that may be used to a variety of fields in agriculture. PA may be regarded as a novel management technique for agricultural systems’ control based on georeferenced data. It is based on the fine-tuning of georeferenced data through the use of monitoring procedures and the integration of soil, plant, and climatic variables (Stewart and McBratney 2000; Plant 2001). Prior to precision agriculture becoming extensively adopted, Stafford (2000) underlines the necessity to create new techniques, notably in the field of remote sensing and mapping of spatial variability.

Introduction

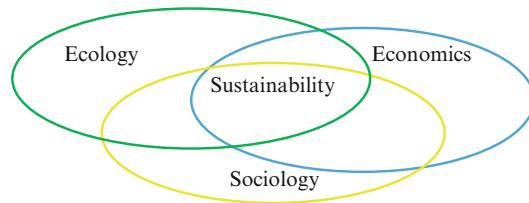
Food security, rising population, monsoon vagaries, and the backward nature of the farmers are among issues that India faces as an agriculture-based economy. Despite the revolution, there is still an increasing need for food. India faces a tremendous issue in terms of food grain yield per acre, which is abysmally low. In developing countries and in some developed countries, the productivity of crop is

becoming a serious issue in higher crop production. The per capita availability of grain in India is nearly two-thirds of the global average. These all issues can only be tackled by increasing the resource use efficiency. The resource use efficiency can be increased by increasing the actual information and demand of essential inputs at different growth stages (e.g., soil tillage, seed sowing at optimum moisture level for higher germination percentage, nutrient and water requirement at optimum growth stage for maximum utilization, and most important postharvest processes) through GIS data on ground information and its adaptation strategically. Slowly but very effectively, precision agriculture is occupying its space in world agriculture from the United States (two-thirds of farmers are already adopted) to Europe and Australia and Asian nations which are also adopting these technologies for better food security and also earning as a nation (Fountas et al. 2014). Small countries like Argentina, Brazil, etc. are also adopting precision agriculture. The yield mapping on the basis of previous year and upcoming year resources, nutrient management through customized fertilizers, laser leveling, and various navigation system in different technologies are the important examples of precision farming technologies (Griffin et al. 2017).

Sustainable Agriculture

The definition of “sustainability” has been contested for a long time. Agricultural and industrial innovations that decreased or eliminated environmental deterioration commonly connected with economic activity were initially referred to as green technologies. It was described economically as the ability to sustain constant consumption or output by replacing natural resources and artificial capital in production (Fig. 1).

The American Society of Agronomy (1989) defines “sustainable agriculture” as “agriculture that, over time, improves environmental quality and the resource base on which agriculture relies;



Precision Agriculture: A Tool for Sustainable Agriculture, Fig. 1 Sustainability as described by the intersection of three disciplines: ecology, economics, and sociology

meets basic human food and fibre needs; is economically viable; and improves the quality of life for farmers and society as a whole.”

“Sustainable agriculture” is defined as “an integrated system of plant and animal production methods with a site-specific application that will:

- Ensure the human food and fibre requirements.
- Improve the quality of the environment and the natural resource foundation on which the agricultural economy is built.
- Make the best use of nonrenewable resources and on-farm resources, and use natural biological cycles and controls whenever possible.
- Maintain agriculture activities’ economic viability.
- Improve the living conditions of farmers and society as a whole.”

The basic objectives of sustainable agriculture are as follows:

- (a) Increasing farm income.
- (b) Promoting ecological sustainability, which includes:
 - (i) Protecting and improving soil quality.
 - (ii) Reducing reliance on nonrenewable resources like fuel, synthetic fertilizers, and pesticides.
 - (iii) Minimizing negative impacts on well-being, biodiversity, water quality, and other natural elements.
- (c) Encouraging agricultural families and communities to be stable and affluent.

4R Nutrient Stewardship for Precision Farming

Higher productivity, increased farmer profitability, improved quality of the environment, and improved sustainability are all aims of 4R nutrient stewardship. The “4R” stands for “right source, right rate, right time, and right location” in terms of nutrient management strategies. For years, these four elements have been the conventional core of fertilizer best management practices.

Fertilizers that are properly handled help agricultural systems give economic, social, and environmental advantages. Poorly managed fertilizer applications, on the other hand, can reduce profitability and increase nutrient losses, potentially contaminating water and air.

4R nutrient stewardship necessitates the application of best management techniques (BMPs) that maximize fertilizer efficiency.

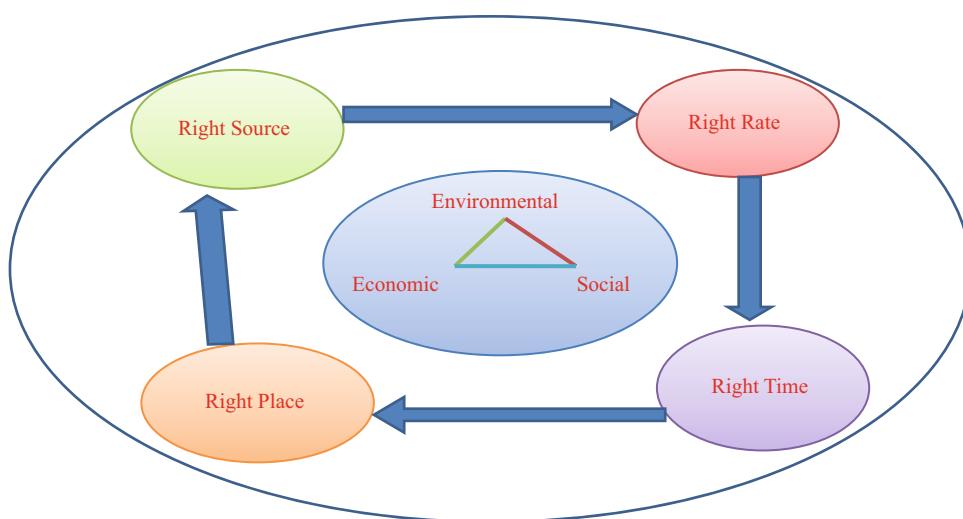
The purpose of fertilizer BMPs is to match nitrogen delivery to crop needs while reducing nutrient losses in the field. BMPs are chosen based on local soil and climatic circumstances, crop, management conditions, and other site-specific criteria, and those chosen for a given farm are depending on local soil and climatic

conditions, crop, management conditions, and other site-specific factors.

Other agronomic and conservation strategies that enhance 4R nutrient management include minimum-tillage farming and the use of cover crops. As a result, fertilizer BMPs perform best when used in conjunction with other agronomic and conservation techniques.

Components of Precision Agriculture

- I. Information/database: The variability in field may be spatial or temporal, soil properties differ from place to place, infestation of weed and insects also differs according to crop and previous year yield data of crop, and nutrient requirements form a basis for developing a better precision farming module. Climate (rainfall, temperature, humidity, solar radiation, wind velocity, etc.), soil physical and chemical properties including moisture level and inherent nutrient capacity and crop production, and its susceptibility to insect and pest and infestation of weed and stresses during crop growth period are the important database of precision agriculture.



Precision Agriculture: A Tool for Sustainable Agriculture, Fig. 2 4R for Precision Farming for sustainable agriculture

- II. Technology: Technologies include a vast array of tools of hardware, software, and equipment, e.g., Global Positioning System (GPS), geographic information systems (GIS), remote sensing, variable rate applicator, and yield monitoring and mapping.
- III. Management: Information management, decision support system (DSS), and identifying a precision agriculture service provider.

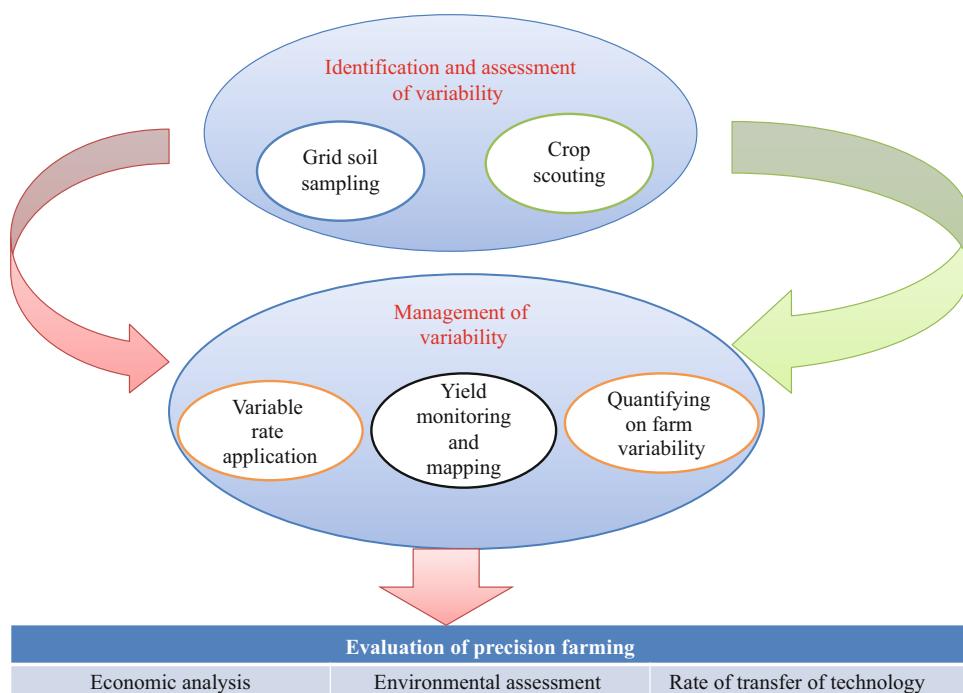
Steps in Precision Agriculture

There are some important steps during precision agriculture which should be followed for an efficient result. The steps are described as in Fig. 3.

- Identification and assessment of variability:** The identification of variability and their assessment is done by two methods, i.e., grid soil sampling and crop scouting. The variability in soil characteristics is very common and is

closely related with the nutrient management practices.

- Management of variability:** After the identification and assessment of variability, the management is done by three means: variable rate application, yield monitoring and mapping, and quantifying on farm variability.
- Evaluation of precision farming:** The evaluation of precision farming is done on the basis of economical, environmental, and the rate of transfer of technology. The technology used should be economical so many farmers can adopt that. There are many agricultural practices that are harmful for our environment so the use of precision farming should minimize the risk on environment. The transfer of technology from its origin to ultimate user means farmer must be considered for success of precision farming.



Precision Agriculture: A Tool for Sustainable Agriculture, Fig. 3 Benefits of precision farming and its evolution on different aspects

Benefits of Precision Farming

As awareness increases, farmers come to know the benefits of precision farming. The use of improved technologies in crop production as well as cattle management was found to increase the use efficiency of inputs and thereby increase the output. It was observed in many developed farm that per unit input the outcome was increased due to a better decision support system provided by new technologies and it also increased the security feelings in farmers.

More Metrics for Agriculture Monitoring

The technologies used in crop production made growers to monitor a number of parameters like amount and actual time of rainfall and nutrient management through soil analysis and according to crop demands, and it also made farmers easy to take any decision for a better management of their crops.

Improved Decision-Making Efficiency

When farmers use precision agriculture sensors to monitor moisture levels, plant health, and nutrient levels, they have long-term access to important real-time data. The sensor is used for monitoring the spot behavior and identifies growth either in positive or negative ways, any risk to crop, and production of crops to be known to site manager, thus reducing the risk to crop production.

Access to Farm Records

Applying software to transform farms makes data more accessible. Precision agriculture frees team members from the confines of the office. All relevant data is accessible at any time from any device, thanks to cloud-based technologies.

Better Crop Protection

Nowadays, with advancement of crop production technologies, the use of pesticides increases to a higher rate to protect the crop, but it also increases the cost of cultivation and the produce has very high residual quantity. The costly insecticides and pesticides are being used by the growers in very excessive amount to protect the crop from insect and pests, but on this account, the environmental sustainability is damaged which becomes a problem on both short-term and long-term basis. In this regard, the advanced technologies used in precision agriculture monitor the infestation of insects and pests in a particular crop timely and also suggest the application of chemicals only when required and protect crops more effectively.

Irrigation Management

As per the OECD, agriculture accounts for more than 70% of global water consumption. Given the global shortage of drinking water, proper allocation at farming locations is essential. Farming teams may identify exactly when to irrigate a field by using centralized command-and-control tools. Crops are better conserved as a result, and the management structure is more socially responsible. These are the advantages of precision agriculture in the IoT landscape for modern farming. The strategy is well worth implementing because it has a long list of benefits.

What Are the Advantages of Precision Farming?

- It will boost agricultural output and avoid soil degradation in arable land, allowing for long-term sustainable agriculture.
- It will decrease the use of excessive chemicals in crop production.
- Precision farming will make the most of available water resources.

- GPS makes it simple to survey agricultural lands. It is also possible to map yield and soil properties.
- Distribution of information about farming technology in order to increase the quality, quantity, and cost of agricultural crop production.
- By optimizing agrochemical products, it will reduce the danger to the environment, notably in terms of nitrate leaching and groundwater contamination.
- Nonuniform fields can be divided into subplots according to their specific needs.
- It allows for better resource management, resulting in less resource waste. Progressive technology is used in precision agriculture.

The following are some technologies used in PA:

Sensors. Sensors are used for monitoring the health of crops by using optical, chemical, thermal, electrical, radiation, and biological metrics. Nowadays, in many developed farms, farmers are using sensors for regular inspection of health of animals and these are attached to the animals.

Software for precision farming. In IoT-based precision agriculture technologies, controller tools are commonly used. IoT enhances software maintenance and brings new farm management tools, for example, an automated tractor which was controlled by remote from far away. In the present precision agriculture system, many machines can be operated and controlled simultaneously which increase the efficiency of equipment and provide a better result in a short time period. The potential of current precision agriculture and IoT allows for simultaneous control of dozens of equipment components.

Protocols for better connectivity. While some network protocols (such as Zigbee or Wi-Fi) function well over short distances, it is the long-range protocols that are most useful for precision agriculture. Cellular connections, LoRaWAN, LPWAN, and a few others are the most extensively used connectivity protocols in intelligent farming.

Location tracking software. Satellites are commonly used to assess soil moisture, crop

biomass, and a variety of other variables. Crop insurance firms, governments, scientists, policymakers, and commodity bodies use the data collected from this tracking system.

Barriers

The profitability and economic impact of PAT adoption are dependent on the size of management zones, differences within management zones, field shapes, soil fertility condition, costs and prices, and the types of PATs utilized (Robertson et al. 2012; Shockley et al. 2012). The three most common hurdles to further adoption were the same in the Prairies and Ontario, and they were also the three most relevant factors in the Midwest, according to agri-retailers (Lowenberg-DeBoer and Erickson 2019). The following were the most significant barriers to adoption across all regions:

1. Farm income pressures prevent precision agriculture use.
2. The cost of precision agriculture technologies and services is greater than the benefit received.
3. Producers lack confidence in the agronomic recommendations made based on site-specific data.

Limitations of Precision Farming

Precision farming adoption in underdeveloped nations, particularly India, faces numerous challenges. Some of these drawbacks are listed below in order of suitability for Indian conditions:

1. The users' culture and perspectives.
2. Land holding capacity is limited.
3. There aren't enough success stories.
4. Cropping system heterogeneity and market imperfections.
5. Infrastructure, land ownership, and institutional restrictions.
6. Lack of technical expertise on the ground.
7. Data availability, quality, and cost.

8. High initial investment.
9. Agricultural company/industries' technological intervention.
10. To increase research potential.

Conclusion

At present, the output and input ratios become more important than higher income point of view. The precise amount of all inputs like fertilizers, insecticides, and pesticides becomes more important. Precision farming provides farmers in developing nations, such as India, with several options to select specific crops and increase production and productivity. Using the PA system, farmers can generate high-yielding cultivars. Three components have been highlighted as part of the general PA adoption strategies in developing countries: "single PA technology," "PA technology bundle," and "integrated PA technology." These strategic components' appropriate application industries have been identified. By assisting the rural poor in improving their livelihood through high-tech farming, PA may provide a forum for industrial corporate social responsibility (CSR) engagement. The Indian government can help in this process by providing low-interest loans to the industry, encouraging them to engage in agriculture and PA operations. High-tech PA can contribute to India's next green revolution by generating significant rural riches in a sustainable and eco-friendly manner. In light of today's pressing need, a concerted effort should be made to leverage new technical inputs to turn the "Green Revolution" into an "Evergreen Revolution," halting migration from rural to urban areas.

The majority of the publications reviewed show that PA can help production agriculture achieve long-term sustainability in a variety of ways, for example, precision agriculture reduces the environmental pollution by reducing the fertilizer amount and its best time application makes it maximum utilization with minimum losses. Precision

agriculture is not only applicable for nutrient better management, but it also checks the infestation of insect, pest, and diseases in crop. The use efficiency of nutrients also increased in crop.

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