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The Role of Precision Agriculture for Sustainability and Environmental Protection

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Introduction

The world's human population presently stands at around 7.6 billion and is projected to achieve 11.2 billion by 2100. We will therefore require a food production and distribution system that can accommodate another 3.6 billion people ideally while consuming as little additional land and leaving a small environmental footprint, in order to maintain vital ecosystem services and conserve Earth's remaining wildlife (McLellan, 2018). Thus introduction and adoption of modern technology in the agricultural sector is predictable. Precision Agriculture is known as "smart farming" or "precision farming" is a key component of sustainable intensification. This combines remote sensing, global navigation satellite systems (GNSSs), geographic information systems (GISs), robotics, data analytics, artificial intelligence, and other new technologies into an integrated high-resolution crop production system.

Need of Precision Agriculture

In 1960's the 'Green revolution' has made our country self-sufficient in food production. In 1947, the country produced a little of food grains, in 2017-18; our farmers harvested over 284.83 million tonnes, taking the country to the second position in food grain production in the world (FAO). The production of food grains in six decades has increased more than fivefold. This has been possible due to high input application, *i.e.* increase in fertilization, pesticides, irrigation, higher use of high yielding verities (HYVs), increase in cropping intensity and increase in mechanization of agriculture. The country's requirement for food grains in order to provide for its population is projected to be 300 million tonnes by 2025. This implies that the crop output needs to grow at an annual average of 2 per cent, which is close to the current growth trend (Deshpande, 2017).

Variation in Soils and Crops and Management of Variability

Managing the variability can be achieved by two methods: the map-based and the sensor-based. With available technologies of GPS, remote sensing, yield monitoring, and

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soil sampling, the map-based method is generally easier to implement. This requires the following procedure: grid sampling of a field, laboratory analyzes of soil samples, generating a site specific map, and finally, using this map to control variable-rate applicator. A positioning system, like GPS, is required for this method. The sensor based method, on the other hand, measures the desired properties, such as plant and soil properties, by using real-time sensors in an 'on-the-go' manner and controls variable-rate applicator based on the measurements. For the sensor-based method, positioning system is not always needed. PA implementation can be encapsulated in three steps:

- i Collect information about variability.
- ii Processing and analyzing information to measure the significance of variability and
- iii Implementing change in the management of inputs (Auernhammer, 2001).

Precision Agriculture: Components and Concepts

Precision agriculture is a farming management idea based on observing, measuring and responding to inter and intra-field variability in crops. The practice of precision agriculture was enabled by the introduction of GPS and other technologies *i.e.* crop yield monitors mounted on GPS equipped combines, multi and hyper-spectral aerial and satellite imagery, information technology and geospatial tools.

1. Global Positioning System (GPS)

GPS is navigation system based on network of satellites that helps users to record positional information (latitude, longitude and elevation) with precision of between 100 and 0.01 m (Lang, 1992). GPS helps farmers to locate the exact position of field information, such as soil type, weed invasion, pest occurrence, boundaries, water holes and obstructions. The system allows farmers to consistently identify field locations so that inputs (seeds, fertilizers, herbicides, pesticides and irrigation water) can be applied to field, based on performance criteria and previous input applications (Batte and Van Buren, 1999).

2. Geographic Information System (GIS)

GIS is a powerful set of tools for collecting, storing and retrieving the data at will, transforming and displaying the spatial data from the real world for a particular set of purposes (Burrogh and McDonnell, 1998). GIS is a layer based and thematic system which provides the suppleness to overlay and review the indices for different changes in the site. GIS is a kind of computerized map, but its true role is using statistics and spatial methods to analyze characters and geography. Computerized GIS maps are different from conventional maps and hold various layers of information (*i.e.* soil survey maps, yield, crops, rainfall, soil nutrient levels and pests).

3. Remote Sensing (RS)

RS has a great potential for precision agriculture as it provides the solution of monitoring the spectral and spatial changes over time at high resolution (Moran *et al.*, 1997). The spatial-temporal changes provide a scale to understand the variability that has occurred over the period of time. Remote sensing data are used to differentiate crop species, locate stress conditions, identify weeds and pests, and monitor drought, soil and plant conditions. Sensors enable the collection of huge quantities of data without laboratory analysis (Chen *et al.*, 1997). Remote sensing provides a better option for PA, *i.e.* providing frequent turnaround time (24-48 hrs), high spectral resolution, high spatial resolution, and high temporal resolution (10-15 days) and low cost data.

Challenges of Precision Agriculture

- Data overflow for farm management. This problem has to be overcome by developing expert systems, data integration tools, and decision support systems.
- Lack of balanced procedures and strategies for determining application requirements on a localized basis and a similar lack of scientifically validated evidence for the benefits claimed for the PA concept.
- Labor intensive and costly data collection. Development of quick sensing systems must take place before PA can be widely practiced.
- Lack of technology transfer channels and workers. Educational programs involving researchers, extension specialists, industry and consultants are urgently needed.

Use of Precision Agriculture Technologies

Precision Agriculture research started in the US, Australia, Canada and Western Europe in mid to late 1980s. Although a significant research effort has been made, it is still only a portion of farmers who have adopted any type of PA technologies. Implementation of PA has mainly been through utilization of accessible field machinery by adding GPS and controllers to enable spatially-variable applications.

i Crop Growth Stages Monitoring

Precision agriculture can be used to monitor the crop growth. The maturity period, crop stresses such as nutrient and water stress, disease, pest and weed infestation can be identified by using RS and GIS. Information gathered using different sensors and referenced using GPS can be integrated to create field management strategies for nutrient, chemical, water application, cultivation and harvest.

ii **Weed, Insect and Disease Control**

Mapping of hotspots for disease, insect and weed infestations is something like a post-disaster management which is accepted when crop is almost destroyed. RS and GIS in integrated form offer a solution where mapping for the disease incidences can be carried out. Once mapped, the experts can actually recognize the causes which lead to the crop infestations. Mapping the disease incidences areas it can be spatially integrated with the agro- ecological zones which can help in making simulating the other hotspots for related infestation in future.

iii **Precision Manuring**

Farmers can improve management of manure applied to cropped areas simply by revolving the night time tethering sites of their animals. Through this strategy of precision manuring, they can deliberate manure application on the 'bad spots' that are most in need of nutrients and organic matter application. Conscious application of manure, compost and other fertilizers to low yielding areas of fields is a common strategy employed by small farmers (Vanlauwe *et al.*, 2010). The practice is particularly useful for small farmers, since they do not have enough land to overlook areas of declining soil fertility. Management of precision manuring at village level shows promise for enabling dryland communities to adjust the management of agro-pastoral systems across whole landscapes, consequential in larger and more sustainable yields (Taddesse *et al.*, 2003).

iv **Precision Conservation Agriculture**

Precision conservation agriculture assists farmers to be successful when applying conservation agriculture by tailoring practices to local circumstances (Jerich, 2011). Conservation agriculture is defined by three simple principles:

i) Minimizing soil disturbance
ii) Using crop rotations and or associations
iii) Keeping soil covered with crop residue (Giller *et al.*, 2011)

v **Climate Suitability and Crop Suitability**

Hyper spectral and multispectral images, consisting of reflectance from the visible, near infrared and mid-infrared regions of the electromagnetic spectrum, can be interpreted in terms of physical parameters (*i.e.* crop cover, crop health and soil moisture) and are useful for operations such as fertilization and pesticide application, irrigation management and stress mapping (Singh *et al.*, 2007). Nutrient contents of different crops such as rice (Stroppiana *et al.*, 2008), wheat, sorghum (Zhao *et al.*, 2005) have also been assessed using hyper spectral and multispectral RS data.

vi **Yield Monitoring**

Yield monitors are a grouping of several components. They include different sensors and components, including a user interface (display and key pad), data storage device, and a task computer located in the combine cab, which controls interaction and the integration of these components. The sensors measure the volume of grain flow, separator speed, and ground speed. In case of grains, yield is constantly recorded by measuring the force of the grain flow as it impacts a sensible plate in the grain elevator of the combine.. GPS receivers are used to record the location of yield data and create yield maps in all the yield monitors. Other yield monitoring systems include devices used in forage crops to keep track of moisture, weight, and other information on a per-bale basis (Davis *et al.*, 2005).

Benefits of Using Precision Agriculture

Misuse of fertilizers and pesticides and lack of awareness of the field parameters can decrease productivity and endanger the environmental balance. PA is about managing variations in the field precisely to grow more food using less input. All aspects of the environment; soil, weather, water varies from place to place. All these factors decide crop growth and agriculture success. Farmers have always been aware of this, but they lacked the tools to measure, map and manage these variations precisely. Thus, PA can make a difference to agricultural production facing the challenge of a growing population and can help farmers to achieve:

Conclusion

Precision Agriculture is still only a thought in many countries and support from the public and private sectors is needed to encourage its quick adoption. PA addresses both economic and environmental issues that bound agriculture today. In the light of today's urgent need, there should be a supreme effort to use new technological inputs to make the 'Green Revolution' as an 'Evergreen Revolution'. Precision agriculture provides a solution using a systems approach for today's agricultural problems such as the need to stability in productivity with environmental concerns. Ultimately it aims to increase economic returns, as well as reducing the energy input and the environmental impact of agriculture.