



Precision agriculture: Tools and techniques- A review

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Abstract

Precision agriculture is a capable technology of performing site specific managements by describes the different management zones. It helps to achieve cost minimization, yield optimization and maximization of benefits by using GPS, GIS, RS data acquisition, decision support system, variable rate technology (VRT), Normalized difference vegetation index (NDVI), sensor-controlled automatization, Site specific nutrient management and DRIS approach. While GPS and remote sensors can provide location specific data of different parameters, GIS is able to create georeferenced maps of a field; and controlled the rate of application of chemicals through VRA via decision support systems. However, there are some of the factors which limit its adoption of precision agriculture by the farming community over the world. But efforts are being made to improve adoption trend of precision agriculture and make agriculture a sustainable practice.

Keywords: DRIS, georeferenced, NDVI, precision agriculture, VRT

Introduction

Agriculture is the backbone of Indian economy, which accounts for almost 18.8 per cent of GDP and employs 75 per cent of the Indian population. There is a question how long we meet the demands of food grains of the growing population? This is a very difficult question to be answered, if we depend only on traditional farming. To meet the future demand and challenges we have to divert towards new technologies like precision agriculture for increasing the productivity agriculture. In 1961, India had 0.34 ha of available land per capita, which is reduced to 0.12 ha at present. It is very essential to develop eco-friendly technologies for maintaining crop productivity, sustainability & environmental quality. It has been recognized that soils and crops are not uniform within a given field. Over the last decade, various technical methods have been evolved to utilize modern technologies to respond to the field variability. Such methods are known as Geographic Positioning System (GPS) based agriculture, Site Specific Nutrient Management (SSNM), Remote Sensing and Precision Agriculture (PA).

The word 'precision' means exactness or accuracy. Precision agriculture is a management strategy that gathers processes and analyses temporal, spatial and individual data and combines with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, profitability, quality and sustainability of agricultural production (International Society of Precision Agriculture).

Precision agriculture (PA) is a farming management concept based on observing, measuring and responding to inter and intra field variability in crops. PA is also sometimes referred to as precision farming, satellite agriculture, as-needed farming and site-specific crop management (SSCM). Precision agriculture uses information technology (IT) to ensure that crops and soil receive exactly what they need for optimum health and productivity. It also ensures profitability, sustainability and protection of the environment.

The various techniques are being collaborated with the advanced technology like Global Positioning System (GPS), Geographical Information System (GIS), operational control through Real Time Sensors, remote sensors, telecommunication, mobile computation and advanced information processing models. Precision agriculture has overall potential to help alleviate the problems those the future world is going to face. One of the reasons for lack of success of this technology is lack of awareness among the farmers about when and how to use PA in the fields. Not only research but also motivation to the farmers provided through in field demonstrations, establishment so also monitoring their efficiencies will be helpful to create a success story of PA technology in agriculture. Sharma et. al. (2015) reveals that precision agriculture optimize production by using a key elements of IT, so as to increases the efficiency of agricultural inputs in the crops, improve the quality of the produce, increasing crop productivity by conserving the natural resources and maintain the environmental soundness. Gyarmati et.al. (2020) ^[11] reveals that the handling, storing and processing of the data and connecting to the different devices is the major significant challenge of the precision agriculture.

Component/tools or techniques of precision farming/geo-informatics

Precision farming in the form of farming location-specific practices is adopted considering the spatial variability of land to minimize the cost of inputs, maximize crop production with the minimal damage to the available resources like soil, water, environment etc. and human health.

The major components of precision farming are; Geographical information system (GIS), Geographical positioning system (GPS), Remote sensing, Variable rate technology, NDVI, SSNM, DRIS approach, Soil testing and yield monitoring etc.

1. Global Positioning System (GPS)

Global Positioning System as a satellite-based radio navigation system (with a complete set of at least 24 satellites orbiting the earth in a designed pattern) maintained by the US Department of Defence which provides accurate 3-dimensional location data *viz.*, latitude, longitude, and elevation, worldwide at any time, in any weather. There are two modes of GPS performance; single receiver mode which collects the timing information, timing is processed into position; and differential GPS mode (DGPS) using two receivers of which one receiver is mounted in a stationary position and the other is on the machine (Kumar *et. al.*, 2017) ^[13]. The field boundaries, acreage estimation, roads, irrigation systems, distances between points and weed and disease affected areas could be generated by examining the agricultural land Geographical Information System (Yousefi *et. al.* 2015).

2. Geographic information system (GIS)

Roger Tomlinson's pioneering work to initiate, plan, and develop the Canada Geographic Information System resulted in the first computerized GIS in the world in 1963. Geographic information system (GIS) is considered as the brain of PA (Kumar *et.al.*,2017) ^[13]. GIS is a computerized mapping system to acquire, store, analyze and display information that is specially referenced to the earth. It is software that imports, exports and processes spatially and temporally geographically distributed data. GIS system provides a way to overlay different layers of data, these data used for land use, irrigation management, the study of the crop, soil and environment etc. this system comprises hardware, software and procedures designed to support the compilation, storage, retrieval and analysis of feature attributes and location data to produce the map. Ojo and Ilunga (2018) ^[16] stated that the GIS database provides information about soil types, nutrient status, irrigation, topography, surface and subsurface drainage, quantity of application chemicals and crop production and it also establish the relationship between elements that affect a crop on a particular farming.

3. Remote sensing

Remote sensing (RS) is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites or sensors mounted on aircraft, by detecting the energy that is reflected from Earth. In another word, RS means to collect the information of an object without its physical contact. Remote sensors can be either passive or active. Passive sensors respond to external stimuli, most commonly the reflected sunlight from the earth's surface and records this natural energy while, active sensors use internal stimuli projected by the instrument itself to collect data about Earth. Yin *et al.* (2019) ^[25] has divided the remote sensing system in to three broad categories *viz.*, spatial foundation system, ground base system and remote sensing data storage system which overall include remote sensor, control and positioning system, carrier platform, data transmission and data pre-processing systems.

The interaction between electromagnetic radiation with vegetation or soil is detected by capturing the reflected radiation emitted by either an active or passive sensor and measuring this captured radiation presents the status of the soil or vegetation attributes. The electromagnetic radiations

used are usually visible, near-infrared (Mulla DJ., 2013) ^[15], infrared or microwaves. According to Castro Gomez MG (2017) ^[5] remote sensing system can be classified into two main classifications: optical and SAR (Synthetic Aperture RADAR). Usually Landsat and SPOT satellite images have commonly been used for agricultural applications over large geographic areas since the 1970s. Airborne multispectral imagery has been widely used in precision agriculture for assessing soil variability, mapping crop growth and yield variability, detecting crop insect infestations and disease infections and mapping water status.

Remote sensing has the ability to monitor the dynamic conditions of soil, plant, area under cultivation (with 95% accuracy), single crop cultivation area (within 10 days with 90% accuracy). For producer community in making decisions, the digitalized and georeferenced recorded observations are imported into the GIS workspace according to that delineations, maps, management zones are prepared (Tayari *et.al.* 2015) ^[22]. Remote sensing techniques play vital role in assessing crop condition and yield forecasting, acreage estimates of specific crops, detection of crop pests and diseases, disaster management, wild life management, water supply information and management, weather forecasting, range land management, and livestock surveys (Patil and Chetan 2017) ^[2].

4. Variable rate technology (VRT)

Chen *et.al.* (2013) ^[8] stated that the application of inputs precisely in variable type and quantity in different pieces of land according to the present status and requirement is the practice of variable rate technology (VRT) in precision agriculture. Variable-rate technology (VRT) allows fertilizer, chemicals, lime, gypsum, irrigation water and other farm inputs to be applied at different rates across a field. Variable-rate application (VRA) can range from the simple control of flow rate to the more complex management of rate, chemical mix and application pattern. VRA can match changes in crop yield potential with specific input rates resulting in a more efficient system and minimizing potential environmental impacts. VRT can be used to deal with spatial variability between management zones.

There are two types of VRT

1. Map-based control: a map of application rates is produced for the field before the operation. 2. Real-time control: decisions about what rates to apply in different locations are made using information gathered during the operation. This requires sensors to detect necessary information on 'on-the-go' and is usually designed for a specific job such as herbicide application.

The variable rate applicator has three components which include control computer, locator and actuator. The application map is loaded into a computer mounted on a variable-rate applicator. In variable rate technology and variable rate application, programmable machines attached with sprayers (Chen *et.al.*, 2012 & Shen *et.al.*, 2017) ^[9, 21] are available to deliver the correct amount of chemicals depending up on crop growth stage, crop condition and previously collected crop growth data. According to Hakkim *et al.* (2016) ^[12] A high degree of variation, it means higher variable rate application of inputs with more economical and environmental benefit in comparison with uniform management.

5. Normalized difference vegetation index (NDVI)

NDVI value given by Green Seeker. The NDVI is a common and widely used remote sensing index (Bhandari, Kumar & Singh, 2012). It is one of the earliest remote sensing analytical products used to simplify the complexities of multi-spectral imagery, now it is the most popular index used for assessment of vegetation.

Studies have shown that NDVI is effective to differentiate savannah, dense forest, non-forest and agricultural fields and to determine evergreen forest versus seasonal forest types (Pettorelli *et.al.* 2005) ^[18], and it is used to estimate various vegetation properties like the leaf area index (Tian *et.al.* 2017) ^[23], biomass (Zhu and Liu 2015) ^[28], chlorophyll concentration in leaves (Pastor Guzman *et al.* 2015) ^[17], plant productivity (Vicente Serrano *et.al.* 2016) ^[25], fractional vegetation cover (Dutrieux *et al.* 2015) ^[10] and plant stress (Chavez *et.al.* 2016) ^[7]. Such types of estimations are often derived by correlating remotely sensed NDVI values with ground-measured values of these variables. Butt B. (2018) ^[4] reveals that the reliability of NDVI directly determines the robustness of NDVI related models.

NDVI is calculated as the ratio between top of atmosphere reflectance of a red band (pred) and a near-infrared (NIR) band (pnir). The NDVI of a densely vegetated area will tend toward positive values, whereas water and built-up areas will be represented by near zero or negative values. It provides a crude estimate of vegetation health and means of monitoring the change in vegetation over time.

6. Site-specific nutrient management (SSNM)

Site Specific Nutrient Management (SSNM) is an approach of supplying plants with nutrients to optimally match their inherent spatial and temporal needs for supplemental nutrients by using different tools of SSNM such as remote sensing, GPS, GIS systems, VRT, yield monitoring. SSNM approach is based on feeding crops with nutrients when needed. SSNM relies on 5R's i.e. Right source, dose, time, place and method. The SSNM provide an approach for need based 'feeding' of crops with nutrients. The SSNM approach aims at increasing farmers' profit by achieving the goal of maximum economic produce of the crops.

The main features of Site-specific nutrient management were stated by Tiwari K.N., 2007 ^[24].

- The site specific application of primary (nitrogen, phosphorus & potassium) and secondary and micronutrients based on soil tests are followed.
- It further provides guidelines for selection of the most economic combinations of different nutrients.
- Optimal utilization of existing indigenous nutrient sources such as crop residues and manures.

The recent development in microprocessor and other electronic technologies for monitoring yields and sensing soil related variables are new tools available to make site specific farming a success. When measuring soil characteristics such as the harvest data, moisture and nutrients availability in the soil, satellite based positioning system, namely, geographical positioning system (GPS) can be used to identify the locations where the data are taken.

7. Diagnosis and Recommendation Integrated System (DRIS) approach

The nutrient diagnosis of crops is done with the help of chemical fertility analysis of soils, using the nutrient

requirements of the studied species and frequently the interpretation of nutrient concentrations in leaf tissue by using widely used methods *viz.*, critical levels and sufficiency ranges (Bangroo *et al.*, 2010 and Savita *et al.*, 2016) ^[1, 19].

DRIS, which is the acronym for "Diagnosis and Recommendation Integrated System", was proposed by Beaufils (1973), based on studies on physiology and plant nutrition, initially in rubber trees cultivated in Vietnam and then in maize and sugarcane in South Africa.. The diagnosis norms have been determined for several extensive forage, fruit, vegetable and timber (Bangroo *et al.*, 2010; Savita *et al.*, 2016) ^[1, 19]. RIS indices can be calculated for the identification of deficiencies, excesses, or ideal values of nutrients in a crop. Furthermore, DRIS indices develop the nutritional balance index that represents the global balance of the nutrients involved in the nutrition of the plant (Bangroo *et al.*, 2010; Chacon *et al.*, 2013) ^[11].

Conclusion

Precision agriculture uses the various agricultural inputs more efficiently including Seed, fertilizers, pesticides, Insecticides and irrigation water. More effective use of different inputs means greater crop yield and/or quality, without harming to the environmental quality. The developments are going rapidly for mapping infestations of insect, pest and disease via GPS and GIS receivers, variable rate spray operators are able to provide a permanent record of where and when the treatment took place back to the field manager by GPS data logger. It can address both economic and environmental issues that surround production agriculture today. Questions remain about cost effectiveness and the most effective ways to use the precision agriculture, but the concept of "doing the right thing in the right time at the right places & right quantity" has a strong intuitive appeal.

Due to small land holdings, heterogeneity of cropping systems, high cost of production, lack of local technical expertise and knowledge like computer analysis and decision making, technological gaps seen in the farmer are probably greater constraint in the success of precision agriculture. But by overcoming these issues, we can positively use precision agriculture for developments of environment friendly agriculture.

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