Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

**E-ISSN:** 2278-4136
**P-ISSN:** 2349-8234
JPP 2018; 7(2): 3974-3978
Received: 10-01-2018
Accepted: 17-02-2018

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# Role of precision agriculture in India

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**Abstract**
The important drivers that influence the intention to embrace Precision Agriculture (PA) technologies are identified in this review. Rather than using the traditional whole-field approach, precision agriculture involves the integration of new technologies such as Geographic Information Systems (GIS), Global Positioning Systems (GPS), and Remote Sensing (RS) to allow farm producers to manage within-field variability to maximise the cost-benefit ratio. Variable Rate Technology (VRT), which is available with farm instruments like fertiliser or pesticide applicators and yield monitors, has advanced quickly, fostering the expansion of precision agriculture. Site-specific management allows farmers to cut inputs while increasing outputs, which is appealing to them both. Simultaneously, by reducing inputs, fertiliser and pesticide run-off is reduced, enhancing the agro-environmental ecosystem's state. Many precision agricultural applications use remote sensing data, such as pre-growth soil fertility and moisture studies, crop growth and growth detractant monitoring (crop scouting), and yield forecasting. Although precision agriculture's adoption and expansion has been quick, some fundamental needs are required to completely develop and use this technology. Continued research and development of algorithms for radiometric and geometric correction of remote sensing data, as well as information extraction, are among these requirements. Additionally, timely, cost-effective remote sensing data or derived value-added products are required, as is the creation of decision support systems or other expert systems that integrate GIS, GPS, and RS technologies in a user-friendly manner. A following training and technology transfer programme is also required to speed up the acceptance and deployment of this technology in the agri-business sector.

**Keywords:** GPS, GIS, variable rate technology, remote sensing

## Introduction
In agriculture, new technology are rarely adopted immediately. Despite the fact that significant effort is put into encouraging users to adopt new ICT tools, adoption is a complex activity that is influenced by a variety of circumstances.

Precision Agriculture is a relatively new idea of farm management that was created in the mid-1980s, and the term "technology" in this study refers to the entire range of tools available for PA management (also called Precision Farming). PA's foundation centers on a concept of fit between multiple variables: according to Pierce and Nowak, PA allows people to do the right thing at the right time, in the right location, and in the right way. As a result, PA's applicability is based on the employment of technology to detect and decide what is "correct." Many aspects of PA have been investigated, with particular attention paid to related technology, environmental consequences, economic outcomes, adoption rates, and the factors that influence adoption and non-adoption. The environmental and economic benefits of PA have been confirmed by a number of publications. Despite this, both academic surveys and professional reports continue to reflect a low rate of PA use. Ex-post and ex-ante analyses of the adoption of PA technologies have been conducted. Ex-post research have revealed the motivations or reasons that have motivated, and likely continue to encourage, farmers to adopt new PA technologies, but ex-ante studies have allowed for the investigation of a new technology's acceptability prior to its implementation. While a comprehensive assessment of ex-post articles has already been published, a more comprehensive review that includes both ex-ante and ex-post analyses have yet to be published.

The examination of both ex-post and ex-ante studies is useful in the agricultural competition to explain the choices made by farmers when faced with new technology and their adoption. The goal of this research is to examine the drivers of PA adoption by merging and comparing ex-post and ex-ante studies to highlight any relationships between the two, while also offering a more holistic and thorough perspective of the subject. The paper is organised as follows: first, the review methodology is presented; second, accounts of previous ex-post research on technology adoption are provided; third, ex-ante research is presented, with a focus on the technology acceptance model in Pennsylvania; and finally, possible conclusions are presented.

**Data and Methods**

According to Harts [13], papers for this study were found in Scopus using various combinations of keywords, such as "precision agricultural adoption," "technology adoption," "technology acceptability," and "agriculture." There were almost a thousand articles and research findings discovered. The study articles were then selected to only include empirical studies published in peer-reviewed journals, while excluding work solely focusing on policy, energy, or environmental issues. During the reading phase, a snowball method was used to allow for the discovery of additional relevant publications. After that, 20 papers were chosen and split into two groups. Tables 1 and 2 contain a list of the publications that were chosen, as well as information on data sources, sample sizes, and the number of variables. The first series of studies examines PA adoption from an ex post perspective, taking into account the factors that influenced acceptance among groups of farmers who have already adopted a technology. The second collection of publications presents investigations on the intention to adopt, and hence the empirical context of these papers is made up of potential PA technology adopters.

**Role of remote sensing in precision agriculture**

For precision agriculture applications, a range of remote sensing systems have been employed or evaluated, ranging from the human eye to earth observation satellites. Indeed. The most widely utilised "remote sensing" technology in precision farm management applications may be visual observations recorded on a digital notepad geo-referenced to a GIS database. Aerial photography (colour and colour infrared) and videography are also widely used in precision agriculture for a variety of purposes. Although the majority of the sensors utilised functioned in the visible and near infrared portions of the electromagnetic spectrum, the microwave region has also proven to be useful. Data from RADARSAT has also been beneficial in determining crop and soil factors such as weed infestations and soil moisture. However, the spatial resolution is coarser (Hirose. 1997). A recent evaluation of image-based remote sensing for precision crop management is provided by Moran *et al*. (I997a). Input on soil and plant status and variability to the overall management and decision support system can be provided via remote sensing, which can be used for precision agriculture in a variety of ways. Remote sensing data make translating point observations, such as from a soil test sample, to dispersed information within the GIS a breeze. Several image categorization or geostatistical approaches are available. This spatial data can then be combined with other geo-referenced overlays in the GIS to identify both seasonally stable and seasonalIy variable management units, on which the farmer can base his or her management approach. Many of the soil and crop parameters of interest to farmers are highly dynamic over time, so the timely, repetitive coverage provided by remote sensing platforms, particularly satellite platforms, is an appealing source of monitoring data. This data can then be used in conjunction with management units to quickly assess potential problems and provide an effective solution. Precision agricultural applications can benefit greatly from this feedback loop.

**Seasonally variable soil units**

A typical field's management units are: The soil sample locations (marked by a cross) are utilised to create a series of nitrogen and potassium fertility contours, which are then overlaid with the soil type in this diagram (indicated by different shading). As a result of combining this data, three "management units" for fertilisation applications are created, as shown in the diagram. Prior to seeding, findings from point soil test samples taken using a grid or strati tied sampling technique can be translated to a spatial coverage for the entire field utilising air pictures, multi-spectral scanners, or high resolution satellite imaging. As mentioned in the preceding section, this is an important piece of information for regulating within-field variability. Surface reflectance of bare soil can be linked to a variety of physical and chemical characteristics of the soil, such as texture, nutrients, and calcium carbonate content. Organic matter, salinity, and moisture are all factors to consider. (Baumgardner *et al*. 1985) presents a thorough examination of soil retlectance qualities. This data can be utilised to aid in the administration of soil fertiliser and the analysis of seasonal growth trends. The use of colour photography to translate soil test sample data into a field fertility map. An inverted regression relationship develops between available Nitrogen derived from point samples and soil colour in this example can be used to make a map of nitrogen application that is spatially detailed. Dobson and Ulaby, 1986; Pultz *et al*. 1997) used SAR data to estimate near-surface soil moisture content. RADARSAT SAR and SPOT data were used to extract soil drainage information. The Ontario Soil Survey's drainage data is supplied as an overlay to aid with interpretation. The information gathered by remote sensing. Remote sensing techniques can also be used to build very precise digital elevation models (DEMs), which are beneficial in a variety of precision agriculture applications, particularly for irrigated market veggies. Gagnon *et al*. (1990) described a method for obtaining stereopairs from either aerial or satellite platforms that can be simply implemented on a desktop computer. A DEM can also be created using SAR sensors from aircraft and satellite platforms (Gray and Farris-Manning 1993; Vachon *et al*. 1995). Soil sampling is the most common application of remote sensing in precision agriculture for monitoring seasonally fluctuating crop conditions.

Early study using colour and colour infrared air photography revealed that a variety of agricultural pests, including wheat stem rust, com leaf blight, and root rot in field beans, could be detected. Hatfield and Pinter present a recent review (1993). Stress generated by the infection causes changes in the vegetation's retlectance, which can then be detected via remote sensing data. Weeds have distinct receptivity properties than the crops they infest, thus their position and extent can be mapped and targeted for pesticide administration. Remote sensing can offer the timely spatial coverage required for effective crop scouting, allowing for early and prompt attention to these growth detractants. The use of airborne SAR data to locate a Bertha Armyworm epidemic in a canola field. The area infested by armyworms has a darker SAR signature due to the loss of radar backscatter caused by the damaged crop canopy. The utilisation of cas; and SPOT-HRV multi-spectral data for weed identification using NOVI estimates Weeds cause odd NOVI values in this case, which are generally higher than the surrounding crop, which allows for the spatial mapping of the weed infestation. Using the usual approach based on vegetation indices, remote sensing data can also be used to estimate biomass throughout the growing season (Tucker *et al*. 1980). These biomass maps' temporal sequence can then be linked to the existing management plan and modifications made. To optimise the final yield, for example, if soil fertilisation is required.

Remote sensing data can also be used to construct maps of meterological characteristics that can be merged with biomass maps or Leaf Area Index (LAI) estimates in order to predict final yield, as pointed out by Moran *et al*. I997a. For management and yield prediction, multispectral satellite data is being used to estimate biomass time sequences. For comparison, a final yield map from a VRT yield monitor is also presented. The significance of remote sensing for obtaining information about soil and crop conditions has been repeatedly proved in study. Higher-resolution satellite data may be used to alter the cost per hectare for remote sensing applications in precision agriculture, resulting in more economic use of remote sensing. Continued sensor calibration algorithm development, including radiometric and geometric corrections. Image processing and GIS integration software that is available off-the-shelf. To encourage the use of remote sensing in precision agriculture, rapid data transfer capabilities are also required.

**RGB**

In the field, there is a patch of weak growth that may require more inputs. This site-specific crop data can also be utilised as input into crop growth models to anticipate yields. CCRS has also been active in the development of imaging spectrometry or hyperspectral remote sensing techniques for extracting quantitative information on crop productivity and crop stress. The goal is to improve the identification of within-field variation and understand the origin of spatial variances using hyperspectral data. Hyperspectral data from 1996 was used. Using limited linear unmixing, it was possible to map distinct target components on a pixel-by-pixel basis (Adams *et al*. 1986; Shimabukuru and Smith 1991). This method decomposes a pixel spectrum, which is frequently a mix of diverse materials, into its constituents (endmembers).

The proportions of the pixel spectrum's components are given as fractions between 0 and I. Figure 8 shows the endmember canola fraction image and accompanying cas; RGB image. This end member has obvious within-field variability. According to preliminary findings (Staenz *et al.* I997a), the fractions are most likely related to % cover. The percentage ground cover, among other factors, can subsequently be utilised to help estimate biomass. In general, the immixing technique is a useful tool for site-specific mapping, which captures variance within a field for several target components like litter, soil, and plant. Spectral immixing provides a more robust technique for the estimate of crop condition parameters taken from high spatial data than empirical derivations. CCRS is investigating the extraction of LA in this context! Using the crop end member fraction determined from spectral immixing on a per-pixel basis (Staenz *et al*. 1998). Because the immixing technique allows the separation of crop from other plant types such as weeds on a per pixel basis, the returned LAI is more accurate than that obtained from vegetation indices such as NDVl. Using plant liquid water absorption characteristics at 975 nm or 1180 nm in combination with physical and empirical models, the liquid water content of the vegetationcanopy can be determined on a field basis when hyperspectral data is gathered in the 900 to 1250 nm wavelength areas (Staenz *et al*. 1997b).

The amount of liquid water in the crop canopy is a good indicator of crop stress. CCRS is also looking at using hyperspectral data to derive chlorophyll content, another essential measure of crop health and productivity. In addition to developing crop production and stress indicators, there is a chance to map weed kind and position during pre- and post-emergence phases. Using a color-infrared combination, large weed patches were visually recognised early in the growing season, immediately after crop emergence, from the 1996 geographical data set (533, 620 and 818 nm). Resampling the original casi 4 m data revealed that visual delineation of major weed patches required spatial resolutions of 10m (Brown *et al*. 1997). It's more difficult to detect weed infestations during peak growth seasons, but plant fractions produced from spectral immixing, which indicate non-crop areas, can be linked to weed patches. This approach can be evaluated using several sites from 1996 and 1997. CCRS is also working on spectrum simulations of future sensor data obtained with anticipated multi-spectral and hyperspectral sensors onboard tiny satellites. This procedure will provide the band requirements for retrieving specific information in terms of position, width, and sampling. This will help to maximise the information content collected and, more importantly, ensure that future satellite projects satisfy the needs of users.

**Application of precision farming**

1. **Mount:** The inaccessibility and intricacy of Himachal Pradesh's Himalayan topography have hampered agricultural development. For planning sustainable mountain agriculture, defining production domains using mountain niches for PF is a crucial task. In partnership with the Centre for Geoinformatics Research and Training (CSK Himanchal Pradesh), the International Centre for Integrated Mountain Development in Nepal conducted a pilot study to develop a database and describe the primary production domains in Himachal Pradesh (Bhagat *et al.* 2005) [2]. The research was based on a survey of topographical maps (1:50,000) and satellite pictures of the region.
2. **Precision seeds for direct sowing:** Many vegetable crops are transplanted in India, but studies have shown that direct seeding of vegetable crops improves production and quality without reducing productivity. Precision planting is required for mechanical culture since it allows seeds to be placed at specific spacing's. Precision seeders include pneumatic precision planters for vegetable crops and pneumatic seed-metering machines for direct planting of small vegetable seeds (Ma *et al.* 1990).
3. **Irrigation water management:** Remote sensing combined with GIS, according to Mishra *et al*. (2005) [16], is an efficient and cost-effective method for dealing with spatial soil and water variability. Command irrigation is a community-based strategy in India, and using remote sensing and GIS to monitor moisture variability and crop water demand is effective. Growers and decision-makers will be able to implement PF practices with the use of this knowledge and a decision-support system (Gontia and Tiwari, 2005) [7].
4. **Application of jute bags in precision agriculture:** The horticultural tray was created for seedlings, resulting in significant improvements in quality, production, and cost-effectiveness. With various advantages over the traditional poly-bag technique, this is a fantastic assistance for high-rate seed germination and healthy seedling development. Jute is a low-cost, biodegradable, robust, non-toxic, hygroscopic, and less extensible fibre. Microorganisms are also resistant to jute fibres. Non-woven jute bags were shown to be the most successful in creating the essential microclimatic conditions for growing plants in trials at the National Institute of

Research on Jute and Allied Technology in Kolkata (West Bengal).

## Conclusion

Rather than using the traditional whole-field approach, precision agriculture involves the integration of new technologies such as Geographic Information Systems (GIS), Global Positioning Systems (GPS), and Remote Sensing (RS) to allow farm producers to manage within-field variability to maximise the cost-benefit ratio. Variable Rate Technology (VRT), which is used in farm implements like fertiliser or pesticide applicators and yield monitors, has progressed quickly, fostering the expansion of precision agriculture. Site-specific management allows farmers to cut inputs while increasing outputs, which is appealing to them both. Simultaneously, by reducing inputs, fertiliser and pesticide run-off is reduced, enhancing the agro-environmental ecosystem's state. Many precision agricultural applications use remote sensing data, such as pre-growth soil fertility and moisture studies, crop growth and growth detractant monitoring (crop scouting), and yield forecasting. This information aids the farm producer's decision-making process. Although precision agriculture's adoption and expansion has been quick, some fundamental needs are required to completely develop and use this technology. Continued research and development of algorithms for radiometric and geometric correction of remote sensing data, as well as information extraction, are among these requirements. In addition, timely and cost-effective remote sensing data or derived value-added products are required, as is the creation of decision support systems or other expert systems that integrate GIS, GPS, and RS technologies in a user-friendly manner. Following that, there will be a training and technology transfer programme to speed up the adoption and deployment of this technology. It is also a requirement in the agribusiness sector.

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