

Precision Agriculture in India: Opportunities and Challenges

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Precision Agriculture in India: Opportunities and Challenges

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Introduction

Agriculture is the backbone of our country and economy, which accounts for almost 30 per cent of GDP and employs 70 per cent of the population. Though this is a rosy picture of our agriculture, how long will it meet the growing demands of the ever-increasing population? This is a difficult question to be answered, if we depend only on traditional farming. To meet the forthcoming demand and challenge we have to divert towards new technologies, for revolutionizing our agricultural productivity. In the post-green revolution period agricultural production has become stagnant, and horizontal expansion of cultivable lands became limited due to burgeoning population and industrialization. In 1952, India had 0.33 ha of available land per capita, which is reduced to 0.15 ha at present. It is essential to develop eco-friendly technologies for maintaining crop productivity. Since long, it has been recognized that crops and soils are not uniform within a given field. Over the last decade, technical methods have been developed to utilize modern electronics to respond to field variability. Such methods are known as spatially variable crop production, geographic positioning system (GPS)-based agriculture, site-specific and precision farming (precision agriculture). The term 'spatially variable crop production' seems to be more accurate and descriptive than the term precision agriculture. The concept of Precision Agriculture avails the recent developments in sensors, green-house and protected agriculture structures. This technology can be meaningfully deployed for hot and extremely dry regions where water is scarce, soil is salty, temperature is high and rainfall low. It is also certain that even in developing countries, availability of labour for agricultural activities is going to be in short supply in future. The time has now arrived to exploit all the modern tools available by bringing information technology and agricultural science together for improved economic and environmentally sustainable crop production. Precision Agriculture is an integrated crop management system that attempts to match the kind and amount of inputs with the actual crop needs for small areas within a farm field. This goal is not new, but new technologies now available allow the concept of Precision Agriculture to be realized in a practical production setting.

Defining Precision Agriculture

Precision agriculture is a management philosophy or approach to the farm and is not a definable prescriptive system. It identifies the critical factors where yield is limited by controllable factors, and determines intrinsic spatial variability. It is essentially more precise farm management made possible by modern technology. The variations occurring in crop or soil properties within a field are noted, mapped and then management actions are taken as a consequence of continued assessment of the spatial variability within that field by adoption of site-specific management systems using remote sensing (RS), GPS, and geographical information system (GIS). Precision agriculture requires special tools and resources to recognize the inherent spatial variability associated with soil characteristics, crop growth and to prescribe the most appropriate management strategy on a site specific basis. It offers a potential step change in productive efficiency. The more suitable definition for Precision Farming in the context of Indian farming scenario could be: Precise application of agricultural inputs based on soil, weather and crop requirement to maximize sustainable productivity, quality and profitability. Today because of increasing input costs and decreasing commodity prices, the farmers are looking for new ways to increase efficiency and cut costs. Precision farming technology would be a viable alternate to improve profitability and productivity.

The Need for Precision Agriculture

The potential of precision farming for economical and environmental benefits could be visualized through reduced use of water, fertilizers, herbicides and pesticides besides the farm equipments. Instead of managing an entire field based upon some hypothetical average condition, which may not exist anywhere in the field, a precision farming approach recognizes site-specific differences within fields and adjusts management actions accordingly. Precision Agriculture offers the potential to automate and simplify the collection and analysis of information. It allows management decisions to be made and quickly implemented on small areas within larger fields.

Components of Precision Agriculture

In Precision agriculture, the field is broken into “management zones” also called ‘grids’ based on soil pH, nutritional status, pest infestation, yield rates, and other factors that affect crop production. Management decisions are based on the requirements of each zone and precision agriculture tools such as GIS, GPS, etc., are used to control zone inputs. The exact location can be identified with the help of one of the main precision farming technology of Global Positioning System (GPS), while application on the exact location can be made with the help of advanced equipments available. To accomplish this, the farmer must mount a GPS receiver on the tractor/ system applying the chemical so that the equipment knows its location in the field. An in-vehicle computer must contain the fertilizer/pesticide (or whatever needs to be applied) – need map, which compares to the field position data recorded from the GPS receiver. In addition to fertilizer/pesticide requirements, plant population can also be chosen to optimise soil nutrients and plant variety selection can be chosen to take advantage of the field conditions. Crop yield can also be monitored to create maps that show the high and low production areas of a field for improved management decisions.

Technologies used in Precision Agriculture

In order to collect and utilize information effectively, it is important for anyone considering precision farming to be familiar with the modern technological tools available. The vast array of tools include hardware, software and the best management practices. These are described briefly in the following paragraphs.

Mapping

The generation of maps for crop and soil properties is the most important and first step in precision agriculture. These maps will measure spatial variability and provide the basis for controlling spatial variability. Data collection occurs both before and during crop production and is enhanced by collecting precise location coordinates using the GPS. The data collection technologies are grid soil sampling, yield monitoring, RS and crop scouting. During crop production, the data are collected through sensing instruments such as soil probes, electrical conductivity and soil nutrient status. Mapping can be done by RS, GIS and manually during field operations.

Global Positioning System (GPS) receivers

Global Positioning System satellites broadcast signals that allow GPS receivers to compute their location. This information is provided in real time, meaning that continuous position information is provided while in motion. Having precise location information at any time allows soil and crop measurements to be mapped. GPS receivers, either carried to the field or mounted on implements allow users to return to specific locations to sample or treat those areas.

Yield monitoring and mapping

In highly mechanized systems, grain yield monitors continuously measure and record the flow of grain in the clean-grain elevator of a combine. When linked with a GPS receiver, yield monitors can provide data necessary for yield maps. Yield measurements are essential for making sound management decisions. However, soil, landscape and other environmental factors should also be weighed when interpreting a yield map. Used properly, yield information provides important feedback in determining the effects of managed inputs such as fertilizer amendments, seed, pesticides and cultural practices including tillage and irrigation.

Grid soil sampling and variable-rate fertilizer (VRT) application

Soil cores taken from random locations in the sampling area are combined and sent to a laboratory to be tested. Crop advisors make fertilizer application recommendations from the soil test information. Grid soil sampling uses the same principles of soil sampling but increases the intensity of sampling. For example, a 20-acre sampling area would have 10 samples using a 2-acre grid sampling system (samples are spaced 300 feet from each other) compared to one sample in the traditional recommendations. Soil samples collected in a systematic grid also have location information that allows the data to be mapped. The goal of grid soil sampling is to generate a map of nutrient requirement. Grid soil samples are analyzed in the laboratory, and an interpretation of crop nutrient needs is made for each soil sample. Then the fertilizer application map is plotted using the entire set of soil samples. The application map is loaded into a computer mounted on a variable-rate fertilizer spreader. The computer uses the application map and a GPS receiver to direct a product-delivery controller that changes the amount and/or kind of fertilizer product, according to the application map.

Remote sensing

Remote sensing is collection of data from a distance. Data sensors can simply be hand-held devices, mounted on aircraft or satellite-based. Remotely-sensed data provide a tool for evaluating crop health. Plant stress related to moisture, nutrients, compaction, crop diseases and other plant health concerns are often easily detected in overhead images. Electronic cameras can also record near infrared images that are highly correlated with healthy plant tissue. Remote sensing can reveal in-season variability that affects crop yield, and can be timely enough to make management decisions that improve profitability for the current crop. Remotely-sensed images can help determine the location and extent of crop stress. Analysis of such images can help determine the cause of certain components of crop stress. The images can then be used to develop and implement a spot treatment plan that optimizes the use of agricultural chemicals. Satellite Remote sensing has provided a tool for acreage estimation one month in advance, with more than 95% accuracy and in mono-crop area yield estimation with more than 90% accuracy ten days in advance. The most popular procedure is to take images from satellites such as LANDSAT or SPOT. Finally, images are used for generating maps and calibration of the measurement, assuming that measurements are taken in field to ground-truth accuracy. These images allow mapping of crop, pest and soil properties for monitoring seasonally variable crop production, stress, weed infestation and extent within a field.

Geographic information systems (GIS)

Geographic information systems (GIS) are Computer hardware and software that use feature attributes and location data to produce maps. An important function of an agricultural GIS is to store layers of information, such as yields, soil survey maps, remotely sensed data, crop scouting reports and soil nutrient levels. Geographically referenced data can be displayed in the GIS, adding a visual perspective for interpretation. In addition to data storage and display, the GIS can be used to evaluate present and alternative management by combining and manipulating data layers to produce an analysis of management scenarios.

Quantifying on Farm Variability

Every farm presents a unique management puzzle. Not all the tools described above will help determine the causes of variability in a field, and it would be cost-prohibitive to implement all of them immediately. An incremental approach is a wiser strategy, using one or two of the tools at a time and carefully evaluating the results.

Soil Variation

Soil variation is a spatial variable. Water-holding capacity or organic matter variation, along with topography, provides even a more interesting view of a field in which a producer places inputs or disturbs the soil. Other variables could be layered within this field to create a series of interacting elements. The central question is how to quantify soil variation. Collection and analysis of the samples only provides one portion of the base layer of information. Individual samples represent points; to be of value, they must be interpolated. There are as many interpolation schemes as there are sampling schemes. These schemes include central tendency, proximal, inverse distance methods, splines, and geostatistical. None of these methods or schemes are described herein, but all have been used to determine variability across a field. Topographic variation within fields can be collected from topographic maps, but the resolution on these maps is often insufficient to provide the necessary detail about variations within fields. Topographic maps can be generated from differential or kinematic geographic positioning systems. The role of topographic variations on water use, plant growth, soil processes, yield, surface runoff, and groundwater hydrology has not been quantified for agricultural fields.

Variability of Soil Water Content

It is well established fact that soil water content in a field varies over time and location and this temporal and spatial variability in soil water content patterns may have profound implications for Precision Agriculture in general, and water management in particular. Knowledge of the underlying stable soil water distribution could provide a useful basis for precision water management and lead to savings in energy, water, equipment cost, labor, and improved production efficiency.

Time and Space Scales

Precision Agriculture requires an understanding of time and space scales. Time scales are critical because operations occur when they will benefit the crop most. Space scales become a fundamental principle of field management because inputs and cultural practices are varied with soil type, pest population, or crop maturity. The challenge is to determine how to use time and space scales to advantage in developing an improved understanding of agricultural management. To fully achieve the goals of precision agriculture, management must be applied in a space and time context. The challenge of monitoring in space and time is important to document the changes that are naturally occurring within a field. To fully realize the potential impact of principles of precision agriculture on environmental quality, however, will require the design and implementation of experiments in space and time.

Opportunities and Challenges

Precision Agriculture can have a positive impact on environmental quality. The opportunity exists to show producers how changing production practices will not place crops at risk and produce positive economic and environmental benefits. Conducting experiments on precision agriculture will require field or farmscale studies and perhaps watershed-scale adoption of new management practices. Completing this type of study will require: 1. Appropriate questions that can be addressed at the field scale. 2. Methods for measuring environmental endpoints that will demonstrate the efficacy of management practices. 3. Commitment to multiple years of study to overcome meteorological variation. 4. Adequate monitoring equipment for crop production, soil properties, and environmental quality in order to understand the changes occurring due to the management practices. 5. Use of comparison fields or farms in which no changes are made to provide a validation of the improved practices. 6. Cooperation of producers to implement the practices with minor modifications across years so that variations can be isolated to the management practice and not producer influence. 7. Data base structure that includes geographic information layers and accurate global positioning system equipment to position any treatments in the same area across years. 8. Funding sources that will allow for long-term studies across large areas. 9. Interdisciplinary teams that will address the critical problems in experimental design, implementation, and evaluation of results. 10. Commitment from the scientists, producers, and educators involved to maintain interest in the project over a sufficient period of time to allow the original objectives to be achieved. These factors are critical to the development of a research effort on precision agriculture. The tools are available to address these questions. The scale of the study will require fields or sub basins of watersheds rather than experimental plots or strip trials within fields. This places an additional constraint on the design and implementation of these types of studies and will require integrating producers into the research discussion at the project development stage. One problem that has been a barrier to producer involvement has been the willingness of producers to place new management practices on fields without some assurance that profit margins will not be compromised. This aspect needs to be considered in any study design. One important problem that will need to be addressed is how researchers begin to ask critical questions about the linkage between new management practices that are differentially applied to the landscape and environmental quality endpoints. Development of the proper question and creating an experimental design to demonstrate the effectiveness of the practice with a high degree of confidence will require a different mindset than is often seen in current agricultural research. As research proceeds, the educational community must be involved so it understands how to communicate these impacts and changes to the wide array of audiences. There are different tools for the conduct of these studies, and educational efforts will require a different approach to training and information dissemination. The challenge is for the whole agricultural community to understand this problem and what opportunities exist to address the problem.

Conclusions

Precision Agriculture gives farmers the ability to use crop inputs more effectively including fertilizers, pesticides, tillage and irrigation water. More effective use of inputs means greater crop yield and/or quality, without polluting the environment. However, it has proven difficult to determine the cost benefits of Precision Agriculture management. At present, many of the technologies used are in their infancy, and pricing of equipment and services is hard to pin down. This can make our current economic statements about a particular technology dated. Precision Agriculture 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 technological tools we now have, but the concept of “doing the right thing in the right place at the right time” has a strong intuitive appeal. Ultimately, the success of Precision Agriculture depends largely on how well and how quickly the knowledge needed to guide the new technologies can be found. The approach required to be adopted by the policy makers to promote Precision farming at farm level: 1. Promote the precision farming technology for the specific progressive farmers who have sufficient risk bearing capacity as this technology may require capital investment. 2. Identification of niche areas for the promotion of crop specific organic farming. 3. Encourage the farmers to adopt water accounting protocols at farm level. 4. Promote use of micro level irrigation systems and water saving techniques. 5. Encourage study of spatial and temporal variability of the input parameters using primary data at field level. 6. Evolve a policy for efficient transfer of technology to the farmers. 7. Provide complete technical backup support to the farmers to develop pilots or models, which can be replicated on a large scale. 8. Policy support on procurement prices, in formulation of cooperative groups or self help groups. 9. Designation of export promotion zones with necessary infrastructure such as cold storage, processing and grading facilities.

The Future

Opportunities will continue for Precision Agriculture studies. Tools will become available to apply chemicals, fertilizers, tillage, and seed differentially to a field and collect the yield or plant biomass by position across the field. Remote sensing technology will allow us to observe variation within a field throughout the growing season relative to the imposed management changes. Monitoring equipment exists for capturing the surface water and groundwater samples needed to quantify the environmental impact through surface runoff or leaching. The technology exists to capture the volatilization of nitrogen or pesticides from the field into the atmosphere from modified practices. The future direction of agriculture will depend upon the research community's ability to conduct this type of study, with confidence from the environmental and producer communities that changes will benefit the environment and increase the efficiency of agricultural production.

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