Precision Agriculture: Tomorrow's Technology for Today's Farmer

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Abstract

Recent advances in communication technology and wireless sensor networks have paved way to new trends to emerge in agriculture sector. It is time now to exploit all the modern tools and techniques available by bringing together the aspects of information technology and agricultural science for improved economic and environmentally sustainable crop production. This promising new trend of precision agriculture and precision farming distinguishes itself from traditional agriculture by its level of management wherein instead of managing whole fields as a single unit, management is customized for small areas within fields. This goal is not new, but technologies now available allow the concept of precision agriculture to be realized in a practical production setting. This paper presents an overview on the precision technology transfer in agriculture sector, current status of precision farming and strategies for its implementation.

Introduction

Precision Agriculture is generally defined as information and technology based farm management system to identify, analyze and manage variability within fields for optimum profitability, sustainability and protection of the land resource. In this mode of farming, new information technologies can be used to make better decisions about many aspects of crop production. Precision agriculture highlights the increased efficiency that can be realized by understanding and dealing with the natural variability found within a field. The goal is not to obtain the same yield everywhere, but rather to manage and distribute inputs on a site specific basis to maximize long term cost/benefit. 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 alternative to improve profitability and productivity (Figure 1) [1]. Applying the same inputs across the entire field may no longer be the best choice [2]. 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 alternative to improve profitability and productivity (Figure 2a) [2].

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 (Figure 2b) [1]. Farmers usually are aware that their fields have variable yields across the landscape. These variations can be traced to management practices, soil properties and/or environmental characteristics. A farmer's mental information database about how to treat different areas in a field required years of observation and implementation through trial-and error.

Today, that level of knowledge of field conditions is difficult to maintain because of the larger farm sizes and changes in areas farmed due to annual shifts in leasing arrangements. 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.

Wireless Sensors in Precision Agriculture

The development of WST applications in precision agriculture (Figures 3 and 4) makes possible to increase efficiencies, productivity and profitability while minimizing unintended impacts on wildlife and the environment, in many agricultural production systems. The real time information from the fields will provide a solid base for farmers to adjust strategies at any time (Figures 3 and 4) [3].

Wireless sensors have been used in precision agriculture to assist in

(1) Spatial data collection

(2) Variable-rate technology

(3) Supplying data to farmers.

Spatial data collection

This system consists of a data collection vehicle, a manager vehicle, data acquisition and control systems on farm machines. It is able to conduct local field survey and collect data of soilwater availability, soil compaction, soil fertility, biomass yield, leaf area index, leaf temperature, leaf chlorophyll content, plant water status, local climate data, insect-disease-weed infestation, grain yield, etc. The data collection vehicle retrieves data from farm machines via a WLAN, analyze, store and transmit the data to the manager vehicle wirelessly [4].

Variable-rate technology

Variable rate technology is being used in the development of an automated fertilizer applicator for tree crops. The system consists of an input module and real-time sensor data acquisition, a decision module for calculating the optimal quantity and spread pattern for a fertilizer, and an output module to regulate the fertilizer application rate. Data
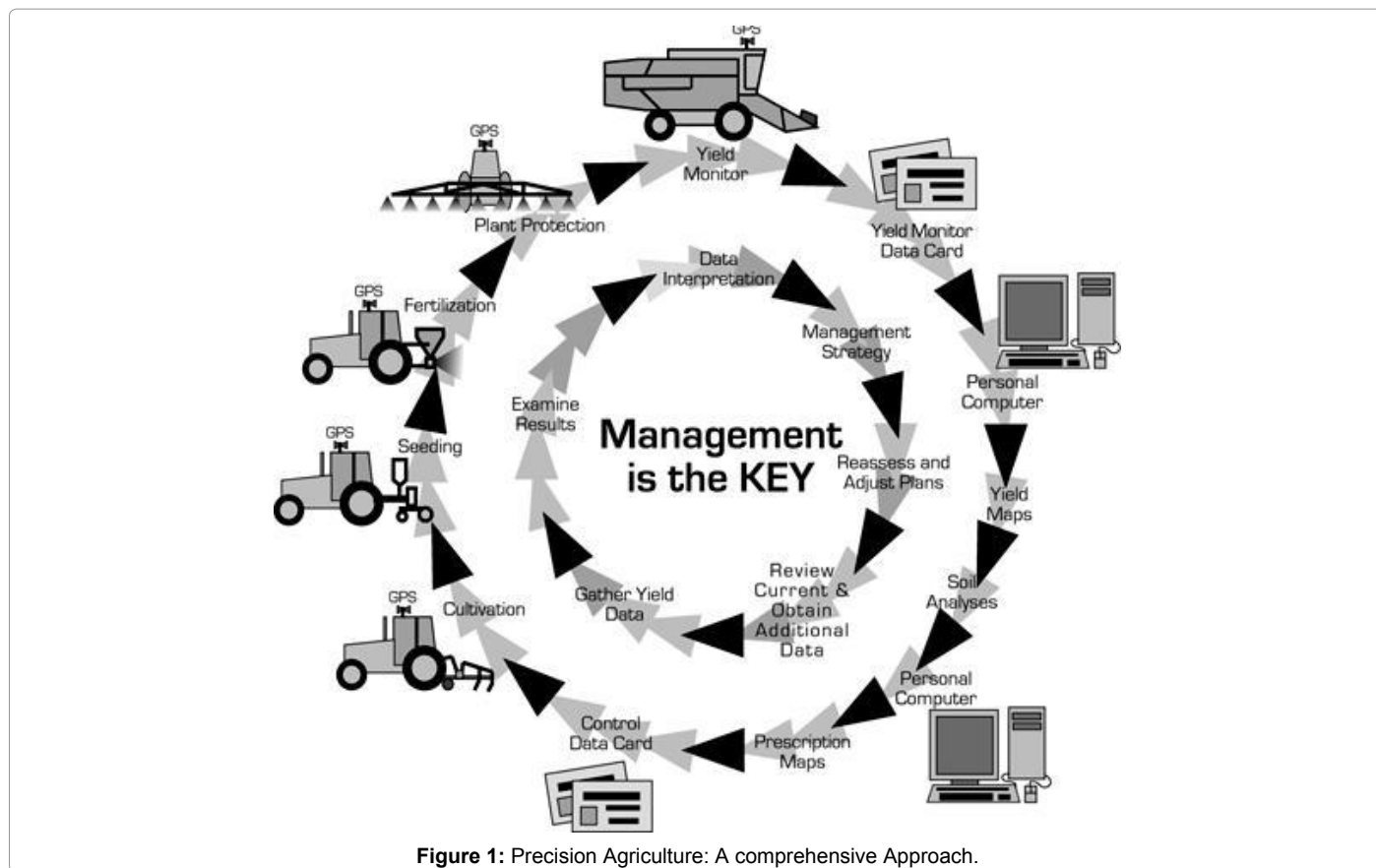
Figure 1: Precision Agriculture: A comprehensive Approach.

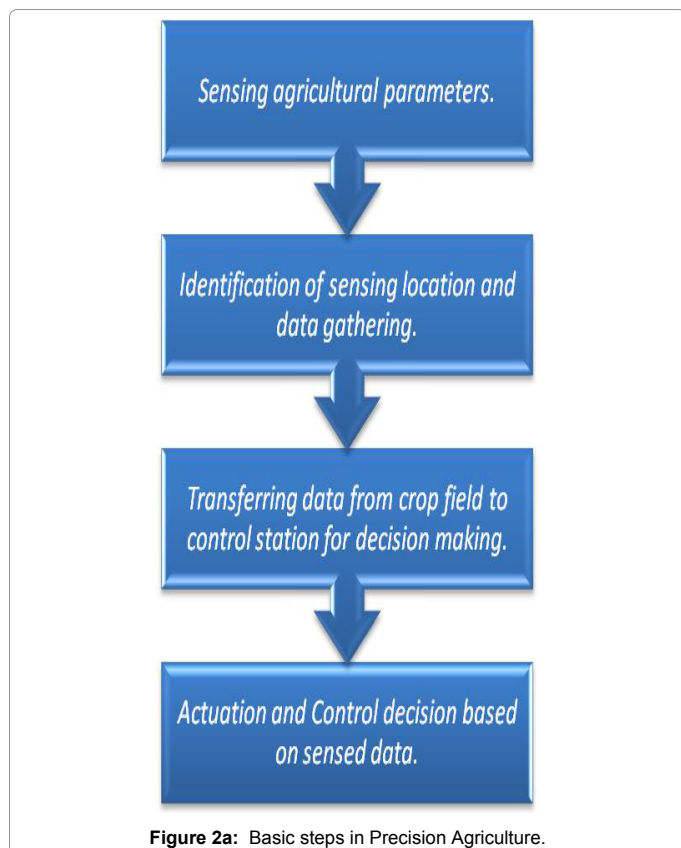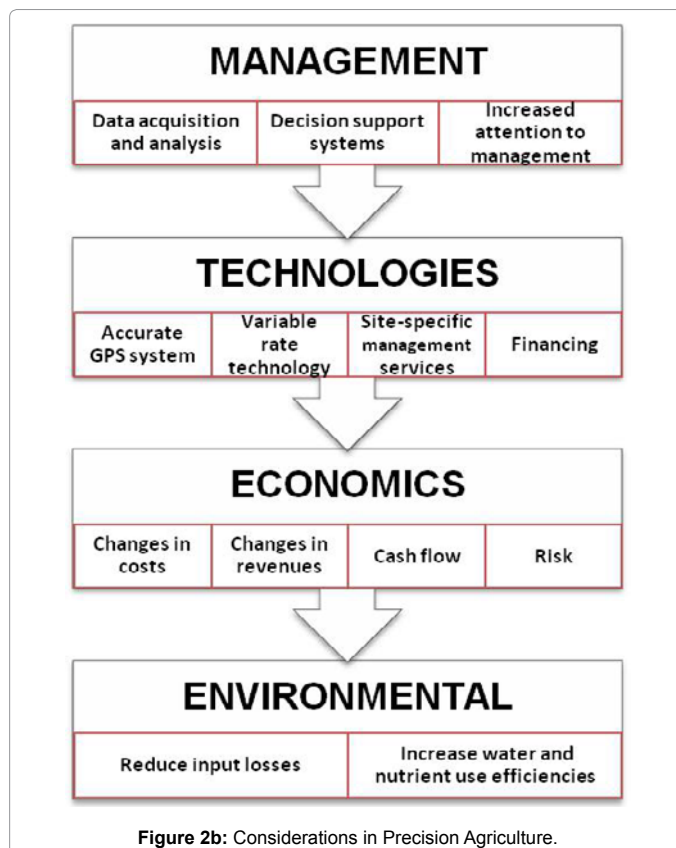**Figure 2a:** Basic steps in Precision Agriculture.

Figure 2b: Considerations in Precision Agriculture.

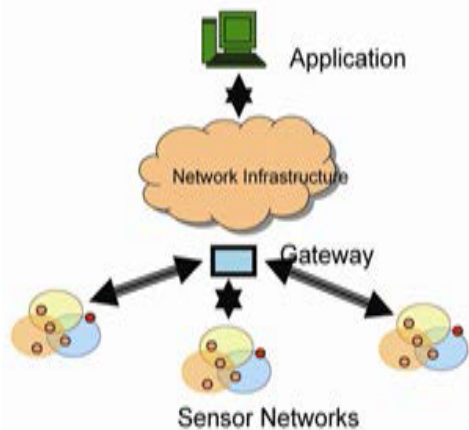**Figure 3:** Application of Wireless sensors in Precision Agriculture.

Figure 4: Proposal of remote sensing architecture in precision agriculture.

communications among the modules are established using a bluetooth network [5].

Supplying data to farmers

It involves a web server which provides information on pest, disease infestation and weather forecasts. Farmers can download the information directly via Internet and use them for operation scheduling [6].

Tools of Precision Agriculture

In order to gather and use information effectively, it is important for anyone considering precision farming to be familiar with the technological tools available. These tools include hardware, software and recommended practices [1].

Global Positioning System (GPS) receivers

Global Positioning System satellites broadcast signals that allow GPS receivers to calculate their position. 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. Uncorrected GPS signals have an accuracy of about 300 feet. To be useful in agriculture,

the uncorrected GPS signals must be compared to a landbased or satellite-based signal that provides a position correction called a differential correction (Figure 5) [1].

The ability of DGPS to provide real-time submeter-or even decimeter-level accuracy has revolutionized the agricultural industry [7]. GPS applications in precision farming include soil sample collection, chemical applications control, and harvest yield monitors (Figures 5 and 6).

When collecting soil samples, GPS is used to precisely locate the sample points from a predefined grid (Figure 5). After testing the soil samples, information such as nitrogen and organic material content can be obtained. This type of information is mapped and used as a reference to guide farmers to efficiently and economically treat soil problems. When GPS is integrated with an aerial guidance system, the field sprayer can be guided through a moving map display. Based on the sprayer's location, the system will apply the chemicals at the right spots, with minimal overlap, and automatically adjust their rate. This, in addition to increasing productivity, ensures that chemicals and fuel are used efficiently.

Yield monitoring and mapping

The yield monitor is intended to give the user an accurate assessment of how yields vary within a field. Although a yield monitor can assist grain producers in many aspects of crop management, the device was never intended to replace scales for marketing grain. A yield monitor by itself can provide useful information and enhance on-farm research. Yield data can be accumulated for a specific load or field, thereby facilitating the comparison of hybrids, varieties, or treatments within test plots. For example, all yield monitors can measure grain mass and harvested area on a load-by-load or field-
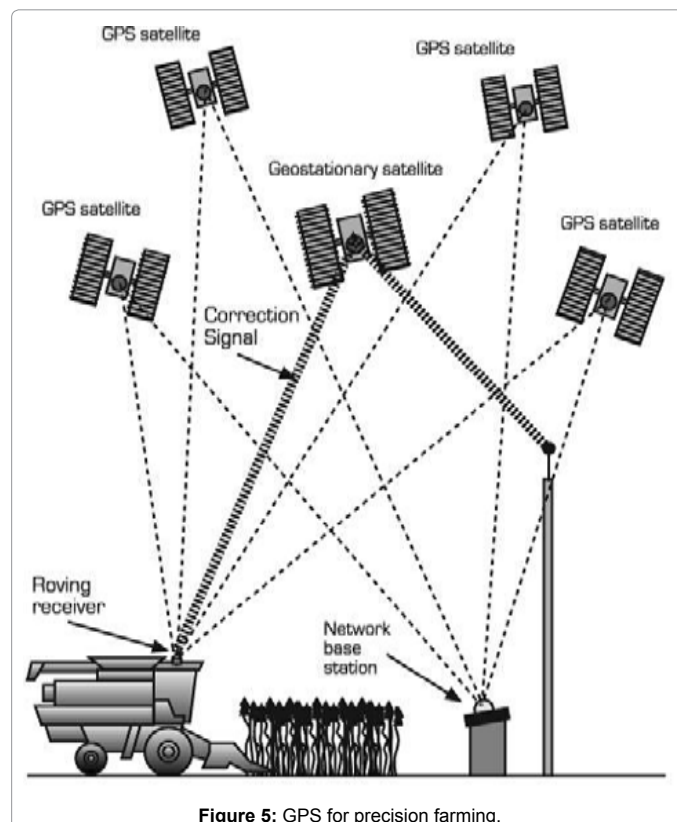

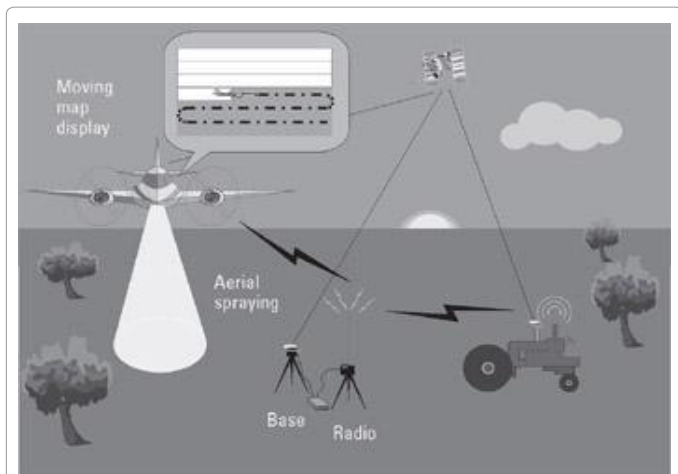**Figure 5:** GPS for precision farming.

Figure 6: GPS for precision farming.

by-field basis. This feature allows an operator to get instantaneous readout in the field of accumulated grain weight, harvested area, and average yield. With many yield monitors, these values can be exported to a personal computer and stored in nonvolatile memory for further analysis or printing via specialized software packages or more standard word-processing and spreadsheet software. When linked with a GPS receiver, yield monitors can provide data necessary for yield maps. Yield measurements are essential for making sound management decisions. moisture, and header height. The sensors are interfaced with both analog to digital and direct digital inputs. Yield is determined as a product of the various parameters being sensed. It is important to understand the function of these components to further understand the interaction of the yield monitor, the combine operator, and the combine dynamics (Figure 7).

Yield Monitor

Yield monitors are a combination of several components, as shown in Figure 6. They typically include several different sensors and other components, including a data storage device, user interface (display and key pad), and a task computer located in the combine cab, which controls the integration and interaction of these components. The sensors measure the mass or the volume of grain flow (grain flow sensors), separator speed, ground speed, grain (Figure 8).

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

Recommended soil sampling procedure is to take samples from portions of fields that are no more than 20 acres in area. 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 for the 20-acre area. Grid soil sampling uses the same principles of soil sampling but increases the intensity of sampling. 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 a map of nutrient needs, called an application map.

Figure 9 Suggested grid sampling pattern and density. Blue markers are the intersections to sample. Red markers represent soil cores collected about grid point for compositing in to one sample for analysis (Figure 10).

Samples may be collected for more than one area of a field which

fall in to the same range of yield, soil color, etc. and thus the same zone (Figures 9 and 11).

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 (Figures 12 and 13).

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. New image sensors with high spectral resolution are increasing the information collected from satellites. 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 used
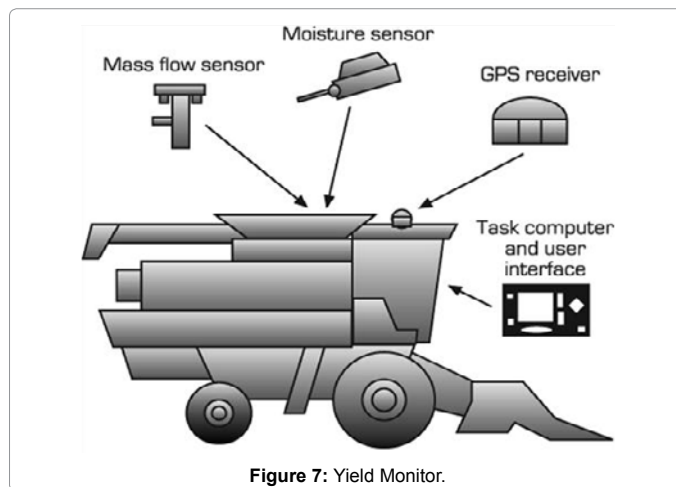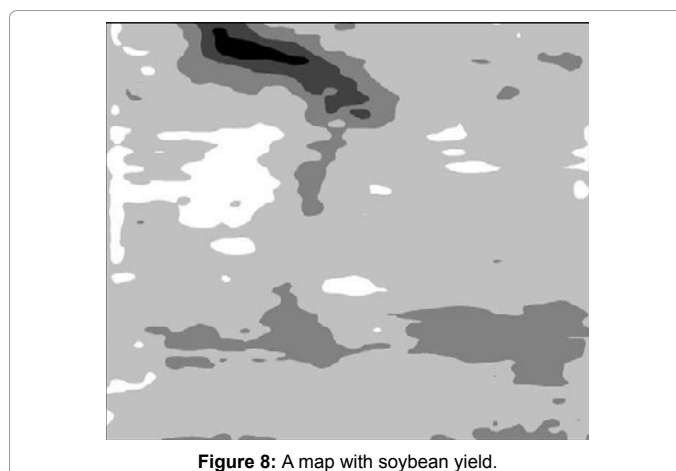

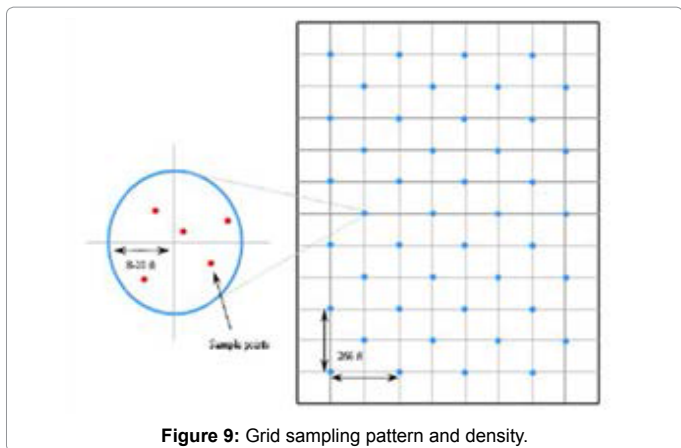**Figure 7:** Yield Monitor.

Figure 8: A map with soybean yield.

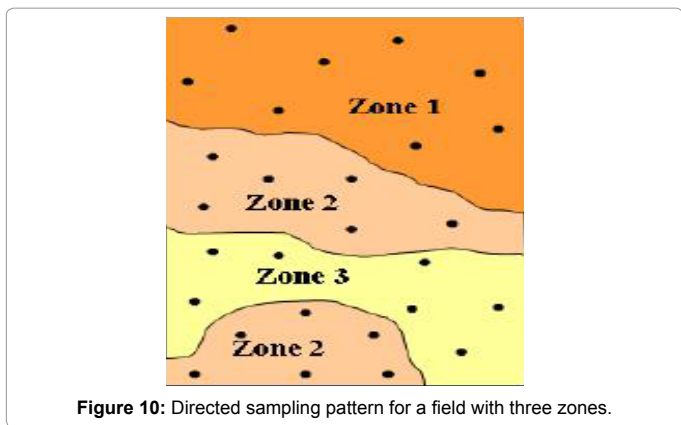**Figure 9:** Grid sampling pattern and density.

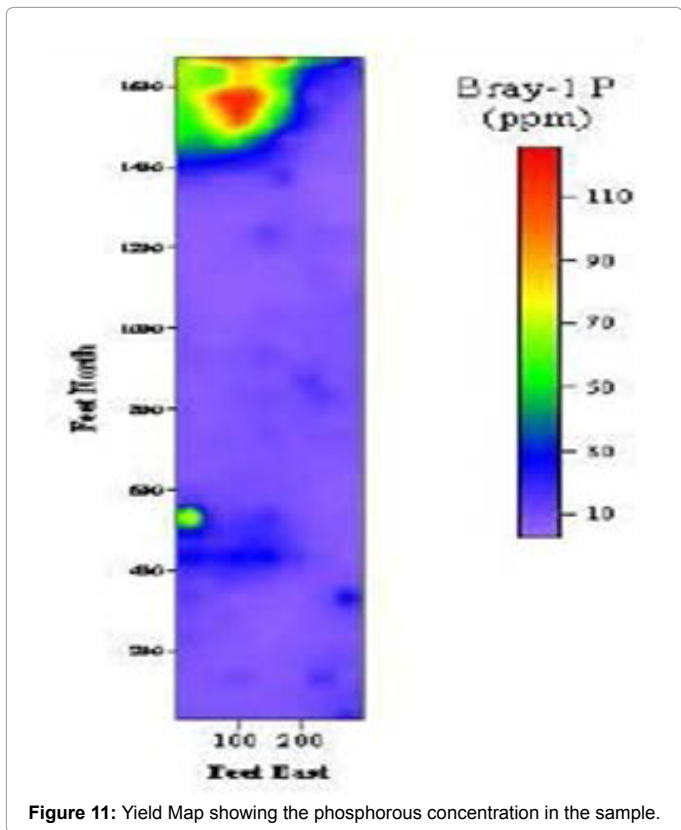**Figure 10:** Directed sampling pattern for a field with three zones.

Figure 11: Yield Map showing the phosphorous concentration in the sample.
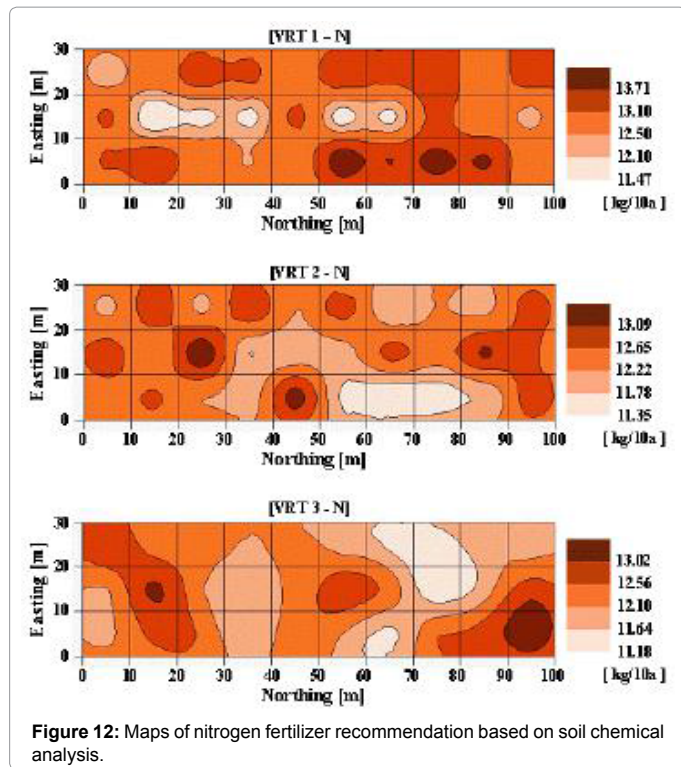

Figure 12: Maps of nitrogen fertilizer recommendation based on soil chemical analysis.
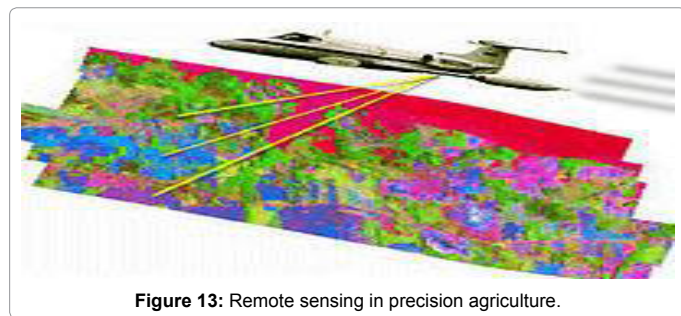

Figure 13: Remote sensing in precision agriculture.

in tandem with scouting 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.

Crop scouting

In-season observations of crop conditions may include:

- Weed patches (weed type and intensity)
- Insect or fungal infestation (species and intensity)
- Crop tissue nutrient status
- Flooded and eroded areas

Using a GPS receiver on an all-terrain vehicle or in a backpack, a location can be associated with observations, making it easier to return to the same location for treatment. These observations also can be helpful later when explaining variations in yield maps.

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.

1. Strategies

Precision farming is still only a concept in many developing countries and strategic support from the public and private sectors is essential to promote its rapid adoption. Successful adoption, however, comprises at least three phases including exploration, analysis and execution.

2. Outlook

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.. In the light of today's urgent need, there should be an all-out effort to use new technological inputs to make the 'Green Revolution' as an 'Evergreen Revolution'.

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.

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