PRECISION FARMING AND GEOGRAPHIC SYSTEMS

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Summary

Global market economy and the growing concern about environment have been moving agricultural production into the area of conflict between economy and ecology. Increased efficiency in agricultural productivity via plant breeding, mechanization, and management techniques have all been important factors in maintaining the balance between food supply and world demand. Necessary improvements in the farmer's profit were gained by higher yields mainly as a result of higher doses of fertilizer. However, over-fertilization leads to a higher environmental burden. Therefore efforts are necessary to gain a balance between nutrient supply and nutrient uptake.

Essential nutrients and pest control will continue to be the critical link between production of food to meet world needs and long-term agricultural sustainability. Coupled with this need to increase output, farmers are coming under increasing pressure to produce food resources in an environmentally friendly manner, by the reduction of pesticides and nutrition inputs. The twin pressures of environmental constraints and efficient use of inputs are driving the movement towards precision in arable crop operations and targeting of inputs such as chemicals and fertilizer. To reduce environmental impact and optimize the use of inputs, it is necessary to take into account the spatial variability in above and below-ground environments that is inherent in almost every agricultural field. Precision agriculture, the targeting of inputs according to

locally-determined requirements, has become a topic of interest in research and development and in the farming community. It has been driven primarily by the significant technological advances that have been made in in-field positioning by GPS (global positioning systems), by the development of remote sensing systems with better resolution, geographic information systems (GIS), and by the increasing integration of electronics into field machinery. This chapter discusses and describes the technology and requirements involved.

1. Introduction

Agriculture as a whole, and farming systems specifically, are continuing to change in response to economic, technological and social trends. The focuses now are on the profitability as well as the environmental impact of agricultural activities. Increased efficiencies in agricultural productivity, via plant breeding, mechanization and management techniques have all been important factors in maintaining the balance between food supply and world demand. Farmers are coming under increasing pressure to produce food resources in an environmentally friendly manner, by the reduction of pesticides and nutrition inputs. Essential nutrient and pest control will continue to be the critical link between production of food to meet the world's needs and achieving long-term agricultural sustainability. Over-fertilization leads to a higher environmental burden; therefore, efforts are necessary to gain a balance between nutrient supply and nutrient uptake.

Agricultural ecosystems are inherently variable entities. To reduce environmental impact and optimize the use of inputs, it is necessary to take into account the spatial variability in above and below-ground environments inherent in almost every agricultural field. Innovative agricultural techniques known as site-specific farming, prescription farming, precision farming, or precision agriculture (PA), apply a combination of technologies such as global positioning systems (GPS), remote sensing (RS), electronic sensors and devices, and geographic information systems (GIS) in order to provide the necessary information to make the local management of the agricultural activities at within-field detail feasible. See also *Advanced Geographic Information Systems.*

PA is a better usage of resources and control mechanisms to improve production efficiency, reduce input costs, and reduce environmental impact. PA focuses on a level of detail smaller than the size of an individual field. It can be described as a new concept for sustainable utilization of agricultural resources, and this can be achieved by managing agricultural systems based on information and knowledge. The difference between PA and site-specific management (SSM) can be summarized as follows. The term "precision agriculture" should probably be applied more generally to the use of information technology across all aspects of agriculture, in which case SSM forms one component, of it: the management of agricultural crops at a spatial scale smaller than that of the whole field.

The essence of PA is to obtain more data on production processes and to convert that data into information that can be used to manage and control those processes. Information can be characterized by various attributes, including timeliness, accuracy, objectivity, completeness, clarity, and convenience. These attributes can be applied to the crop information used in, and information about, PA techniques.

PA can be presented as three management or conceptual components: data collection, data analysis/interpretation, and application/variable rate treatment. Another way of presenting those components is shown in Figure 1, in the form of cycles and the technology/operations involved in SSM.

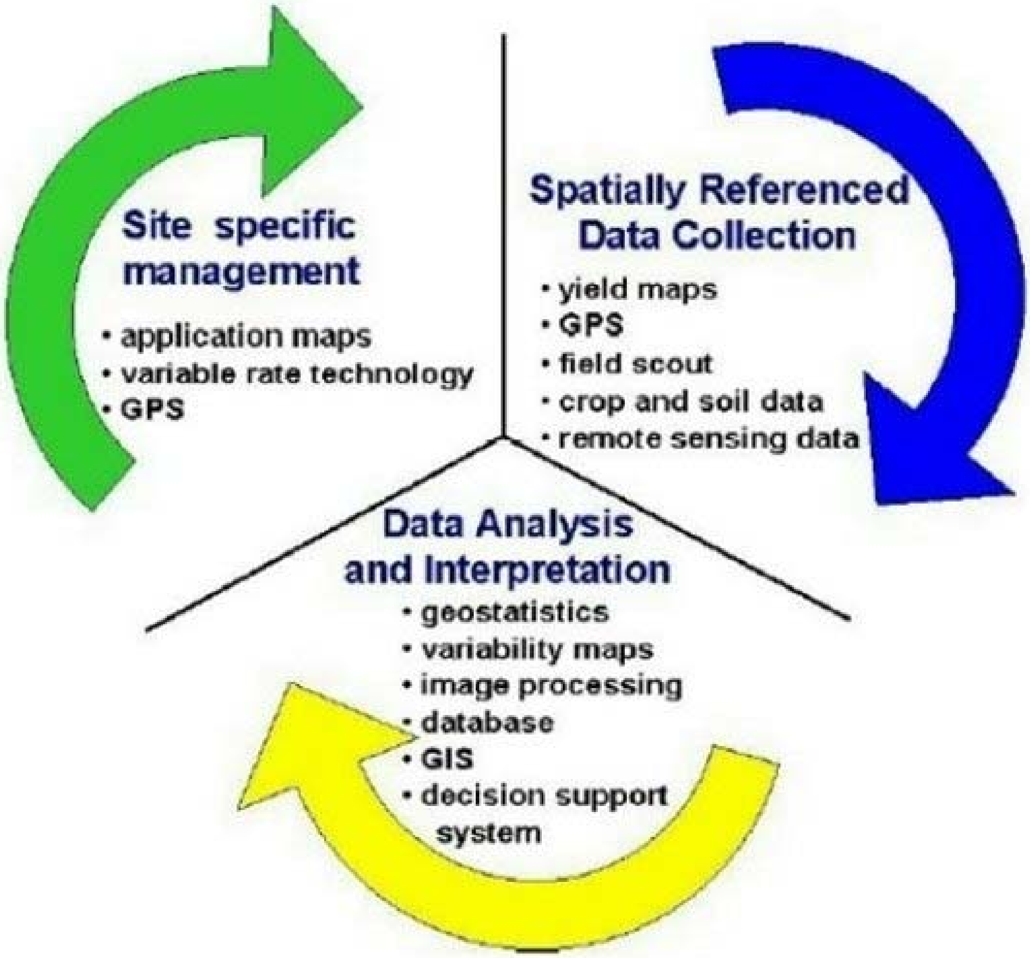

Figure 1. Data processing and management cycles for SSM

The cycles presented in Figure 1 also reflect the three criteria that should be satisfied in order for SSM to be justified:

1. Significant within-field spatial variability exists in factors that influence crop yield.
2. Causes of this variability can be identified and measured.
3. The information from these measurements can be used to modify crop management practices to increase profit or decrease environmental impact.

In Figure 2, PA is shown as a set of data, expressed in the form of maps, derived from different sources of the so-called "geotechnologies" (for example, GPS, remote sensing, GIS), and showing how they are related in order to be integrated and form a decision support system, which could help to define SSM activities.

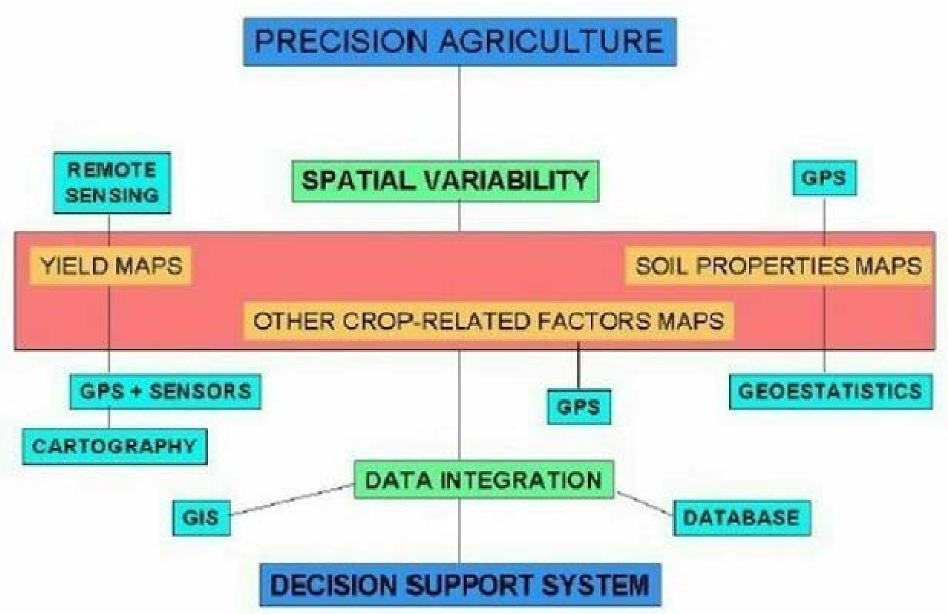

Figure 2. Precision agriculture shown as a set of data maps, geotechnologies, and a decision support system

This view of PA reflects the one that it is related to understanding the spatial variability of soil properties, crop status and yield within a field, identifying the reasons for yield variability, making farming prescription and crop production management decisions based on variability and knowledge, implementing SSM operations, evaluating the efficiency of treatment, and accumulating spatial resource information for further management decision making.

The main required technologies for PA and SSM are available and improving. The list includes GPS, GIS and remote sensing, quasi-real time sensing technologies for spatial variable acquisition, spatial data processing and mapping tools, decision support systems for crop management based on modeling, incorporating simulation with expert systems, intelligent farm machinery or appropriate technological tools for treatment, and system integration software standardization.

Within-field soil and plant property variability, one of the bases for SSM and PA, surfaced as early as 1929. The modern manifestation of the concept is a result of environmental awareness and economically viable technological innovations, which allow global positioning, precision application of variable inputs, and measurement of variable yields. The availability of positioning systems was a key to intensifying the research and actual use of PA and SSM.

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Biographical Sketch

Jansle Vieira Rocha graduated in agricultural engineering at the State University of Campinas (Unicamp), Brazil, in 1985, where he also got his M.Sc. in Agricultural Machinery, in 1988. In 1992 he finalized his Ph.D. in Applied Remote Sensing at Silsoe College, Cranfield Institute of Technology, England. Since 1993 he has been a Lecturer at the Faculty of Agricultural Engineering, at Unicamp, São Paulo State, Brazil, where he is in charge of the undergraduate and postgraduate disciplines of GIS and Remote Sensing, the Geoprocessing Lab, and is the head of the Geoprocessing Group. In 1999 was promoted to Assistant Professor in Geoprocessing. His main research topics are GIS and remote sensing applied to agriculture and the environment, with applications in watershed management, land use planning, crop yield estimates, and precision agriculture.