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PRECISION AGRICULTURE: AN INFORMATION REVOLUTION IN AGRICULTURE

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The increase of agricultural productivity can be seen as a continuum. However, there has been major steps in the historical progress made by agriculture. The last most significant advances corresponding to the introduction of the tractor and associated machinery, followed by agrochemical and hybrid seeds. They brought very significant increases in farm productivity.

Recently, a major new step has been accomplished. Cochrane (1993) indicates that " farming in America began to cross another watershed in the 1980s.... in which the steps in the production process will be fully integrated and the entire process strictly controlled". "The essence of this mature industrial age of agriculture is CONTROL - control over the input of resources into established processes or into new and improved technological processes".

From the mid 1970s into the early 80s, a better awareness of soil and crop condition variability within fields developed from better field investigation methods including soil survey, soil sampling, aerial photograph, and crop scouting. Indeed, in the late 1970s, CENEX, Farmers Union Central Exchange, Inc., and the computer company Control Data Corporation, both based in the Twin Cities, Minnesota (MN), started a joint venture called "CENTROL - Farm Management Services" (D. Fairchild, 1988). The objective was to use more information on soil and crop conditions for each field during an entire growing season to improve management and farm profitability. CENEX developed a network of Agricultural Consultant Services while Control Data was responsible for information management and the development of farm databases. An important outcome of this program was a much better awareness of soil and crop variability within field and potential benefits of management within fields by zones rather than whole fields. This and the commercialization of the first microcomputer resulted in the decision to build a spreader capable of changing on-the-go the blend and rate of fertilizer. The project was initiated in the early 1980s by SoilTeq, Waconia, MN. The first commercial VRTs (Variable Rate Technology applicator) were used in 1995 by CENEX in Renville, MN and Quincy, Washington State. Microcomputers made possible, the development of farm equipment computers and controllers, the production of site specific management maps using geographic information system (GIS), the electronic acquisition and process of spatial field data to build farm geographic record keeping systems, the positioning of machines using global positioning system (GPS), and the development of the first sensors.

This was the beginning of a new agricultural management concept called "Farming by Soil Types", presently generally called "Precision Agriculture " (PA). Quickly, it generated a strong interest mainly because of associated new technologies, the concept makes good sense, and it offers new routes for ag-industries and ag-businesses. Today, it can be said that the PA concept has been considered worldwide for most common cropping systems and some specialty crops.

After great excitement on the technological aspect, it is now realized that PA is not just the injection of new technologies but it is rather an information revolution, made possible by new technologies. The most critical development was the capability to electronically, on-the-go, record spatial data about soil and crop conditions. In the past, most farmers had very little information about crop management. If any, data were more likely for accounting purposes, not agronomics. Now, the spatial information is the base for significantly improved crop management –improved risk management. It is starting a new revolution helped by technology: PA is an information technology revolution. It has happened in manufacturing industries years ago, more recently in food retailing, and now it is entering agriculture.

Presently, precision agriculture is still much in infancy. PA is a holistic agricultural system but, today, only a few parts of the whole system are available. Adoption of PA practices is still at a early stage. A survey send to agricultural retailers in the U.S. is based on a sample of dealers already offering PA services (leaders) and a second more random survey (Akridge and Whipker, 1998). The survey indicates that adoption by growers of PA practices is still limited. Growers uses of PA services from the leader sample are soil sampling with GPS (40 %), field mapping with GIS (31 %), and yield monitoring (26 %) (Table 1).

Table 1. Growers use of PA services in 1998: precision leaders vs. random dealership sample

Grower use of	DEALERS	
	Precision	Random
Soil sampling w/GPS	40 %	8 %
Field mapping	55 %	29 %
Field mapping w/ GIS	31 %	6 %
Yield monitor	26 %	14 %
Enhanced seed	70 %	52 %
VRT: manual	20 %	18 %
controller (single)	20 %	7 %
controller (multi)	19 %	4 %

(From: Akridge and Whipker, 1998)

However, the survey shows that a large group of dealers are progressively offering PA services. The most common PA practices offered by leader dealerships are (Table 2): soil sampling with GPS (82 %), site specific agronomic interpretations (77 %), field mapping with GIS (74 %), yield map analysis (61 %), and variable rate applications of fertilizers with a simple controller (59 %).

Principal barriers for adoption of PA by growers are cost (49 %), attitude-slow adopter (41 %), new skills (21 %), and cropping system (11 %) (Table 3).

Table 2. PA services offered in 1998: precision leaders vs. random dealership sample

Services	DEALERS	
	Precision	Random
Custom application of: - fertilizer	65 %	40 %
- pesticide	55 %	40 %
Others : soil sampling: - grid	80 %	26 %
- soil survey	28 %	35 %
- none	4 %	20 %
Precision : soil sampling w/ GPS	82 %	28 %
field mapping	88 %	34 %
field mapping w/ GIS	74 %	24 %
yield monitor: sale	38 %	8 %
yield map analysis	61 %	12 %
agronomic interpretation	77 %	22 %
VRA: manual	42 %	23 %
controller (single)	59 %	17 %
controller (multi)	31 %	7 %

(From: Akridge and Whipker, 1998)

Table 3. Barriers for adoption of PA by growers in 1998: precision leaders vs. random dealership sample

Barriers	DEALERS	
	Precision	Random
Cost	49 %	42 %
Slow adopter	41 %	38 %
Cropping program	11 %	31
Management expertise	21 %	13 %
Other	4 %	11 %

(From: Akridge and Whipker, 1998)

Another survey, the 1996 Agricultural Resource Management Study (ARMS) studied the use of precision agriculture on farms planting any corn for grain production and provide some additional clues on adoption patterns (Daberkow and McBride, 1998). Table 4 indicates that younger and better educated farmers are more likely adopters. Non-adopters were directly associated with their education level: 62 percent with a high school or a lower level, 24 percent with time in a college, and 14 percent with a college degree. Adopters were more likely fulltime producers and the most frequent crop a corn-soybean rotation.

Table 4. Some characteristics of corn producers related to PA adoption (1996 USDA-ARMS survey)

Farm operator characteristics	Adopters	Non-adopters
Age (years)	49	52
Age distribution: less than 50 yr.	69 %	48 %
Education: high school or less	37 %	62 %
attended college	35 %	24 %
completed college	27 %	14 %
Major occupation: farming	91 %	75 %
Other	9 %	25 %
Acres harvested by crop: corn	48 %	39 %
soybean	37 %	28 %
wheat	6 %	9 %
other	9 %	24 %

(From: Daberkow and McBride, 1998)

This is confirmed by a more recent survey executed in four North Central states (IL, IN, IA, and WI) to determine the level and factors influencing the adoption decision of PA practices (M. Khanna, et al., 1998). Table 5 indicates that non-adopters have a lower education level, no computer, less experience, a part-time occupation, and a smaller farm. Other conclusions on causes for non-adoption are:

- uncertainty on returns
- investments on new equipment and information acquisition systems
- lack of demonstrated impacts on yields

PA, based on detailed spatial information, will bring agriculture to a higher, more precise, farm management level. K. Olson, 1998, wrote: "with the increasing complexity of farming, the increasing risk farmers are exposed to, and the increasing pressure to lower production costs, the management is for improved information technology, greater information processing, and better decision aids". This requires very substantial efforts in R & D, particularly in the development of optimum site specific management practices and in educational programs at all levels: technical, college undergraduate and graduate, and professional.

Recently, agriculture related magazine articles have included remarks from PA producers and ag-dealers such as: "we have tools but we still haven't learned what to do with the data", "the more data we have, the better off we are", "progress will be made in stages", and "this is not a silver bullet".

Table 5. Characteristics of adopters of an advanced application technology

Characteristics	Farmers	
	Adopters N= 144	Non-adopters N= 610
Less than 50 years of age	48 %	42 %
Less than High School education	38 %	54 %
Less than 25 years of experience	42 %	36 %
Full time	93 %	88 %
Ownership of a computer	68 %	41 %
Average farm size (ha-ac)	496-1226	308-760

(From: Khanna et al., 1998)

Recent surveys are showing that the infrastructure of PA services is developing and the adoption by producers of some practices is in continuous increase. Much R & D is in progress in universities, government agencies, and industries (Robert et al. 1998). But needs are important, as highlighted by the 1999 NCR-180 Site-Specific Management Agricultural Experiment Station research committee survey, in engineering technology, management, understanding of natural condition variability, profitability, environmental protection, and technology transfer. The most frequent research topic needs were ranked as follow:

1. Development of real-time sensors for soil and plant characterization
2. Remote sensing techniques for soil and crop condition detection, and management
3. Quantification of PA impacts on the environment
4. Development of protocols for sampling procedures
5. Economics of PA practices
6. Quantification of spatial and temporal natural resources variability
7. Methods for data analysis and interpretation
8. Understanding relationships between yield, natural conditions, and input variables
9. Development of practical crop models for PA management
10. Development of improved spatial data analysis methods
11. Development of yield sensors
12. Methodologies for developing soil and crop SS prescriptions
13. Development of educational programs

Agricultural history shows that any significant technological enhancement of agricultural management took much development, education, and time before used by a majority of producers. It took, for example, more than 30 years to see tractors fully utilized. A similar course should be expected for precision agriculture, a holistic system requiring substantial new tools and skills. Precision agriculture - information technology - is the agricultural system of the future because it offers a variety of potential benefits in profitability, productivity, sustainability, crop quality, food safety, environmental protection , on-farm quality of life, and rural economic development.

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