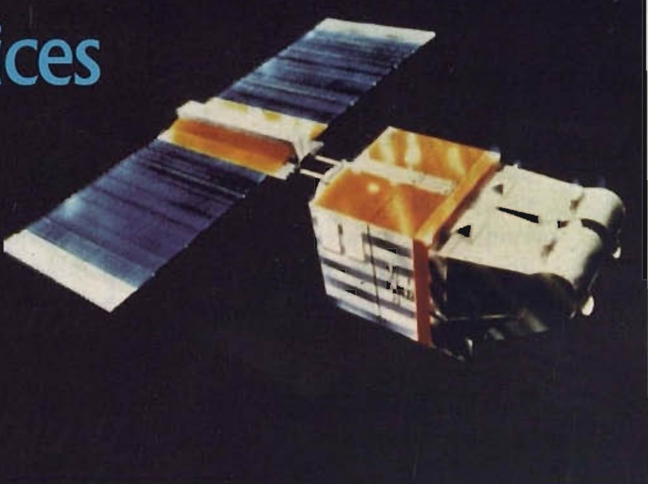
Adoption Rates for Selected Crop Management Practices

Implications for Precision Farming



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by Stan Daberkow

Recent innovations in the computer, aerospace, and communications industries allow farmers to accumulated vast amounts of spatially detailed information for making sub-field management decisions. Sub-field management, or precision farming, bases crop management on the spatial variability of soil characteristics, landscape, pests, and microclimates that are present within most fields (Petersen, et al.). By utilizing one or more information processing technologies, precision farming permits farm operators to apply fertilizers, pesticides, varieties, crop rotations, irrigation water, and even tillage systems based on attributes spatially distributed throughout a field.

Variable management within fields holds the promise of both economic and environmental benefits. However, the voluntary adoption of precision farming technologies is likely to be most dependent on the economic or private benefits even if significant societal benefits arise from reduced degradation of soil, air, and water resources. Furthermore, economic benefits are not likely to be shared equally across all agricultural regions, farms, crops, or farmers nor are all components of precision farming likely to be adopted. Economic benefits, in the form of increased profits from greater yields or reduced input use, will vary by the extent of spatial variability of yield-limiting factors; value of input and yield changes; capital and variable costs associated with non-uniform application of different inputs; education level, risk preferences, and skills of the operator; and, for some farm areas, the availability of precision farming products and services. Given the degree to which these factors vary across the U.S., adoption rates for precision farming will also be uneven.

Optimism in the precision farming industry

Popular farm magazines tout the arrival of the information technology revolution, and agricultural trade shows feature products and services commercially available for farmers interested in adopting precision farming. One agricultural newsletter estimated that farmers used 9,000 yield monitors in 1996, twice the number in use in 1995 (Kiplinger). Furthermore, Kiplinger forecasts farmers will use another 5,000 yield monitors in 1997, with over half connected to a Global Positioning System (GPS). A 1996 survey of 450 large U.S. and Canadian corn and wheat farmers revealed that 90 percent expect to adopt some form of precision farming within 5 years (Finck). A survey of 470 farm input suppliers indicated their optimism about precision farming technology (Akridge and Whipker). The survey asked dealers to estimate what share of their customers were likely to adopt specific precision farming components within the next three years. Some 25 percent of the input dealers reported that more than 30 percent of their customers would adopt field mapping; 25 percent reported that at least 30 percent would adopt yield monitors; 16 percent believed that at least 30 percent would adopt controller-driven Variable Rate Technology (VRT); 15 percent indicated that 30 percent would buy a GPS unit; and 13 percent reported that 30 percent would use a Geographic Information System (GIS). Another information technology, the Internet, was reportedly being used by 10 percent of all farmers, but use was expected to increase to 40 percent in the next few years (Vogt). One consultant noted that in the Red River Valley, 40 sugar beet fields were grid sampled in

Table 1. Increase in per acre net cash income from 10 percent input or yield change, U.S. average, 1994

Input or yield change:	Wheat	Soybeans	Corn	Cotton	Sugar Beets	Potatoes
			(dollars per acre)			
Seed use decline	0.75	1.38	2.27	1.48	3.79	18.59
Fertilizer use decline	1.67	0.93	4.61	3.82	6.04	13.11
Pesticide use decline	0.57	2.45	2.52	4.99	7.01	10.86
Decline in all variable inputs	6.00	7.58	14.71	27.70	41.93	75.79
Yield increase	11.01	21.96	29.63	42.10	84.85	162.25

Sources: USDA (1995), Economic Indicators of the Farm Sector: Costs of Production, 1994. ECIFS 14-3, Economic Research Service, Wash., DC.
Patterson, P. and R. Smathers (1993), Southeastern Idaho Crop Enterprise Budgets: Russet-Burbank Commercial Potatoes, University of Idaho Cooperative Extension Service, Idaho Falls, ID.

1993, 400 fields in 1994, over 1,000 fields in 1995, and even higher numbers were expected in 1996 (Bergland, Centrol of Twin Valley North Dakota, pers. comm.). While such forecasts may prove accurate, this article suggests that, based on the adoption rate of other technologies, precision farming will be adopted on an evolutionary rather than revolutionary pace and the adoption rate will vary by crop.

Economics of precision farming by crop

Several studies have noted that the adoption of precision farming and other management practices will likely be crop specific and biased toward input-intensive crops (Fernandez-Cornejo and Kackmeister, Lowenberg-DeBoer and Boehlje). Due to differing agro-climatic conditions (nutrient requirements, pest infestations, soil productivity, topography, weather, etc.), input use levels and management requirements differ among crops and regions. Much of the capital and labor costs of precision farming technology is related to sensing and recording detailed spatial or temporal information about yields, soils, landscape, or pests. Producers weigh the annual costs (that is, equipment, consultants, training, etc.) of adoption against the expected value of increased yield and/or input use declines.

Yield monitor and GPS in a beta tester's combine.

Photo courtesy Ashtech

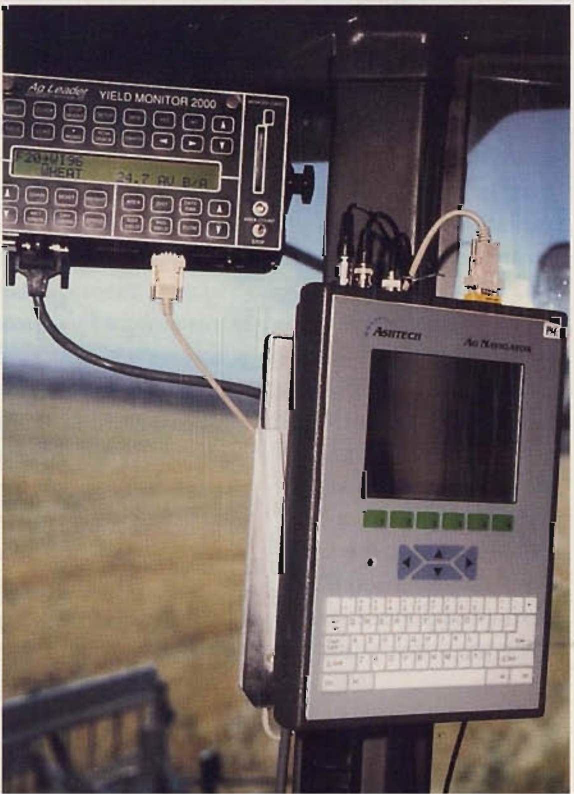


Table 1 indicates the potential benefits, by major crop, from a technology that reduces input use or increases yields by 10 percent, everything else unchanged. For example, for corn the table shows that if pesticide use can be cut by 10 percent, while yields and the level of other inputs remain unchanged, net cash income will increase by $2.52 per acre, on average. The more input-intensive crops, which are also the most highly valued on a per acre basis, would seem to have the most incentive to adopt such technology. Furthermore, a technology which only reduced the use of one or two very inexpensive inputs (lime and sulfur, for example) would be less attractive than a technology which reduces the costs of several inputs. Even more importantly, increased yields, along with reduced input costs, can generate substantial net revenue gains. Of course, if the technology is much more costly to apply to a higher valued crop, as may happen if the soil grids must be much smaller or pest scouting must be done more often, the increase in net revenue may not necessarily be greater for such crops.

Given the acres and farms producing low-value, bulk commodities, researchers and information technology developers may focus their efforts on lowering the costs of precision farming components for these farms. High value, or input intensive, crops cover the least acreage and smallest number of farms—implying a small market for precision farming technology (table 2). Although little hard data is available, some observers believe corn, soybean, and wheat farmers have been the early adopters of precision farming. Precision farming research, development, and marketing interests may have concentrated on those crops with the largest number of farms and acres. Furthermore, yield monitors, a critical technology used to assess field-level variability and often the first-adopted component of a precision farming system, are commercially available only for corn, soybeans, and wheat, although experimental monitors are available for potatoes and cotton.

Published studies on the economics of precision farming report mixed results. For example, one of the most comprehensive reviews of the literature on the economics of precision farming was con-

About the Data

The U.S. Department of Agriculture annually surveys producers of the major field crops (that is, wheat, corn, soybeans and cotton) and fall potatoes regarding agricultural input use levels and the extent of cropping practice adoption. The survey is probability based and utilizes area tracts of specific crops as primary sampling units, except for winter wheat and potatoes. Winter wheat and potato samples are selected from a list of producers and a specific field is identified during the interview process. Only the major producing states are included in the survey and, in aggregate, account for 80–90 percent of the acreage planted of each surveyed crop. In total, the nearly 12,000 samples represent over 170 million acres, which was just over 50 percent of the U.S. cropland planted in 1994. The range of the coefficient of variation (CV) for the table 3 point estimates for fertilizers applied and pesticides applied depend on the percentage of acres treated. CV's were less than 20 percent if 55–75 percent of the acres were treated with an active ingredient and between 1–10 percent if 75 percent or more of the acres were treated. (Agricultural Chemical Usage: 1994 Field Crop Survey, National Agricultural Statistics Service, Washington, D.C.)

ducted by Lowenberg-DeBoer and Swinton. Based primarily on research reports that focused on phosphate and potassium fertilizer application in wheat, corn, and potatoes, they concluded that precision farming was rarely profitable when all costs, including training and education, were included. However, the likelihood of profitability would increase if several variable inputs, such as pesticides, seeds, and nitrogen, were managed on a site-specific basis. Other intangible benefits may have accrued to precision farming adopters who gained more detailed spatial information about their land base and could translate this information into economic benefits as additional years of data accumulate. Conversely, Schnitkey, Hopkins, and Tweeten, using a dynamic approach to analyzing precision phosphorous and potassium application in corn-soybean rotations, concluded that for many fields economic returns exceeded costs. However, they point out that "...precision farming will not have positive benefits in all fields."

Adoption rates of selected management practices for major U.S. crops

Several studies of technology adoption emphasize the importance of the compatibility of a new practice, product, or service with the current farming operation. For example, Schueller notes that in the case of precision farming, "Good spatially variable control cannot be achieved unless good farm management practices are already in place." U.S. agricultural research and extension institutions have a long history of providing producers with information on crop management practices. These recommended practices, often called Best Management Practices (BMPs), supposedly improve the environment, farm profits, or both.

The success of precision farming is dependent on two BMPs in particular: soil testing and crop scouting. Farmers typically soil test to quantify residual nutrient levels, organic matter, and pH and then add fertilizers, lime, sulfur, or micro-nutrients accordingly. Intensive soil testing, often in grids from 0.5 to 4 acres, has become an integral step in quantifying spatial variation, recommending variable rate nutrient and pesticide applications, and understanding within-field yield variation. Similarly, farmers

Table 2. Number of U.S. farms, acres harvested and value of crops sold by type of crop farm, 1992.

Type of Crop Farm	Number of Farms	All Cropland Harvested (1,000 acres)	Cropland Harvested per Farm (acres)	Value of All Crops Sold per Farm ($)	Value of All Crops Sold per Harvested Acre ($)
Cash grains	405,008	159,361.8	393	73,345	186
Wheat	62,144	34,256.8	551	57,556	104
Soybean	75,068	17,118.5	228	22,249	98
Corn	140,252	47,577.8	339	81,883	241
Rice	6,687	3,317.8	496	153,327	309
Other cash grains	120,857	57,110.9	473	86,358	183
Field crops	250,338	33,310.5	133	56,537	425
Cotton	20,447	12,606.0	617	220,181	357
Sugar beet and cane	4,202	2,974.2	708	400,828	566
Potato	4,546	2,505.5	551	441,553	801
Tobacco	90,826	3,219.8	35	26,719	754
Other field crops	130,317	12,004.9	92	27,219	295
Vegetables and melons	29,605	3,703.0	125	204,255	1,633
Fruits and tree nuts	89,514	4,765.2	53	100,470	1,887
Horticulture specialties	39,712	877.8	22	190,548	8,620
General crop	48,847	8,533.9	175	56,280	322
Total	863,024	210,552.2	244	80,201	329

Source: U.S. Dept. of Commerce, 1992 Census of Agriculture, Selected Characteristics of Farms by SIC.

Table 3. Adoption rates of selected management practices on major U.S. crops, 1994

	W. Wheat	Soybeans	Corn	Cotton	F. Potatoes	Total 7 crops[a]
Acres surveyed (1,000)	32,930	43,750	62,500	10,023	1,140	170,043
Sample size	1,245	2,974	4,573	1,063	1,256	11,879
			(percentage of planted acres)			
Nutrient management practices:						
Lime applied	1.3	4.4	4.8	3.7	6.5	3.4
Sulfur applied	11.9	2.0	10.5	20.2	57.9	8.6
Nitrogen applied	85.7	12.9	97.2	86.4	99.5	71.5
Phosphate applied	50.0	20.4	83.1	54.4	97.6	58.2
Potash applied	15.0	25.4	71.7	37.2	90.5	41.0
Soil test (N, P, and K)	18.3	30.1	41.5	33.7	85.5	32.3
Nitrogen soil test only	16.5	12.9	22.3	29.9	78.7	20.1
			(percentage of nitrogen tested acres)			
Applied rec. rate of N	78.8	75.2	83.9	81.3	75.9	82.6
Applied > rec. rate of N	7.3	4.7	6.7	8.7	10.0	6.0
			(percentage of planted acres)			
Tissue test for N	NA	0.5	1.4	12.0	61.1	1.8
N inhibitor applied	1.7	0.5	9.3	3.9	4.5	4.3
Pest managment practices:						
Herbicides applied	46.5	98.3	97.9	93.6	83.4	87.5
Insecticides applied	11.6	0.5	26.6	70.9	87.5	17.0
Fungicides applied	0.3	0.1	NR	8.7	79.8	1.4
Land scouted for pests	79.5	76.5	77.0	88.2	NA	53.2
Consultant/dealer scout	7.9	7.1	10.9	49.5	51.3	8.8
Herbicide banded	NA	NA	13.7	42.9	2.7	9.8
Herbicide spot treatment	NA	NA	3.6	14.4	0.5	3.9
Cultural practices:						
Conservation-tillage	17.0	49.5	42.2	0.6	8.8	35.9
Same crop rotation (3 yr.)	43.3	6.7	21.5	68.9	2.4	24.2
Irrigated acres	6.0	6.7	10.9	47.2	77.0	10.4

Source: USDA, 1994 Cropping Practices Survey.
NA=not applicable/available.
NR=none reported.
[a] Includes spring and durum wheat acreage.

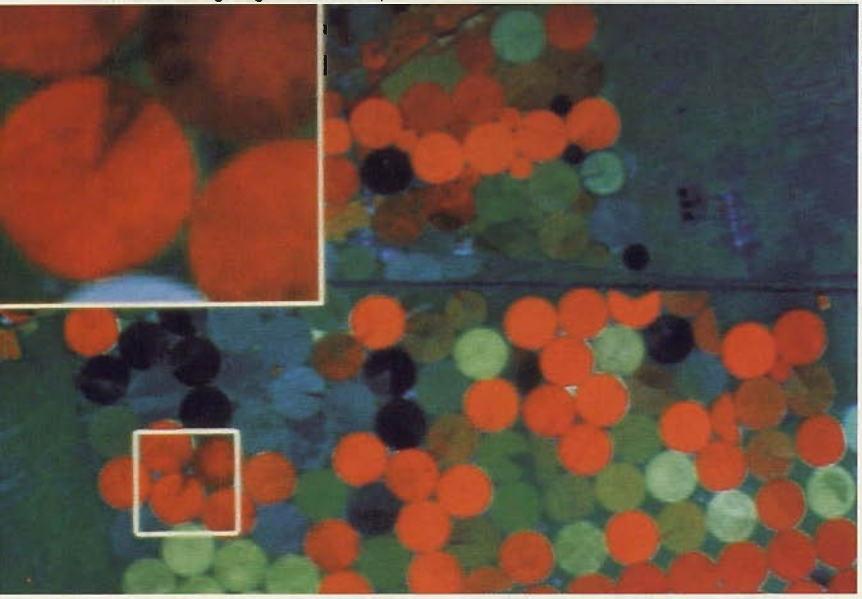
can use systematic crop scouting to identify the spatial distribution of pest populations, determine economic thresholds, and treat the pest when and where appropriate. Spot treatment for weeds could be considered a crude form of precision farming, where operators only treat weed patches, not the entire field, during routine field operations.

Whither precision farming?

While there is much optimism regarding the economic and environmental benefits of precision farming, the relatively slow adoption of recommended crop management practices may slow its adoption. Management practices such as soil testing, crop scouting by professionals, and spot treatment—practices that are critical precursors to or components of precision farming—have only been modestly adopted in the U.S., as shown in a recent national USDA survey (see box). Farmers annually soil-test only about one-third of the planted acreage of the major U.S. crops (table 3). Furthermore, farmers who did test for nitrogen did not follow fertilizer recommendations on nearly 20 percent of the acreage. While producers reported that a large part of the planted acreage of most crops was scouted for pests, only a small share of this acreage was scouted by professionals. Other management practices, such as tissue testing for nitrogen, nitrogen stabilizers, and herbicide management through banding and spot treatment, were used on less than 10 percent of the aggregate field crop acreage. However, higher value crops, although accounting for a relatively small acreage, are much more intensively managed. Precision farming advocates will clearly have to demonstrate to a larger number of producers that such nutrient and pesticide management practices as soil testing and crop scouting are economically beneficial, or at least beneficial when combined with precision farming, before precision farming adoption will proceed at a more rapid rate.

Since precision farming is intended to assist farmers in making input application rate decisions, the greatest aggregate gains from adoption will likely flow from those inputs used on large numbers of acres. Nitrogen, phosphates, and herbicides are used on over 80 percent of the planted acreage of most crops, whereas such inputs as lime, sulfur, insecticides, fungicides, and irrigation water are not widely used. The wide variety of adoption rates among crops illustrates the necessity to analyze technology adop-

A satellite image of irrigation fields. The inset shows field variability within each circular plot of land. (The near-infrared band in the image contains information about crop stress. The darker portion of the inset field reveals possible crop damage due to a malfunctioning irrigation device.)



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tion from a crop-specific perspective. As precision farming technology costs decline and application encompasses inputs beyond nutrients and pesticides, the potential for adoption obviously increases.

Government agencies with a responsibility to conserve or protect human health and the environment, and which serve as a source of funds for technology R&D, can also affect the rate at which farmers adopt precision farming. If precision farming provides public benefits—by lowering risks to our water, air, food, endangered species, wetlands, and highly erodible lands—then public expenditures to promote the adoption of precision farming may be an efficient use of taxpayer monies. For example, if voluntary adoption is profitable but slow, the public sector could provide technical assistance (such as demonstration sites or hardware and software training) to farmers during the early phases of the technology learning curve. If adoption does not occur because precision farming costs farmers more than it returns, government programs might cost-share some of the expense. Alternatively, a pollution tax or a tax on a polluting input, designed to internalize the costs of polluting, could make precision farming more financially attractive. From a broad societal viewpoint, public promotion of precision farming, either through subsidies or taxes, may prove a less costly way of dealing with environmental protection than abatement or cleanup after contamination (Khanna and Zilberman).

■ For more information

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The views expressed here are those of the author and do not necessarily reflect the views of the United States Department of Agriculture.