

**MAPPING THE FUTURE OF
PRECISION AGRICULTURE:**
Opportunities for ag input and machinery
manufacturers and retailers

Management Summary

January 2000

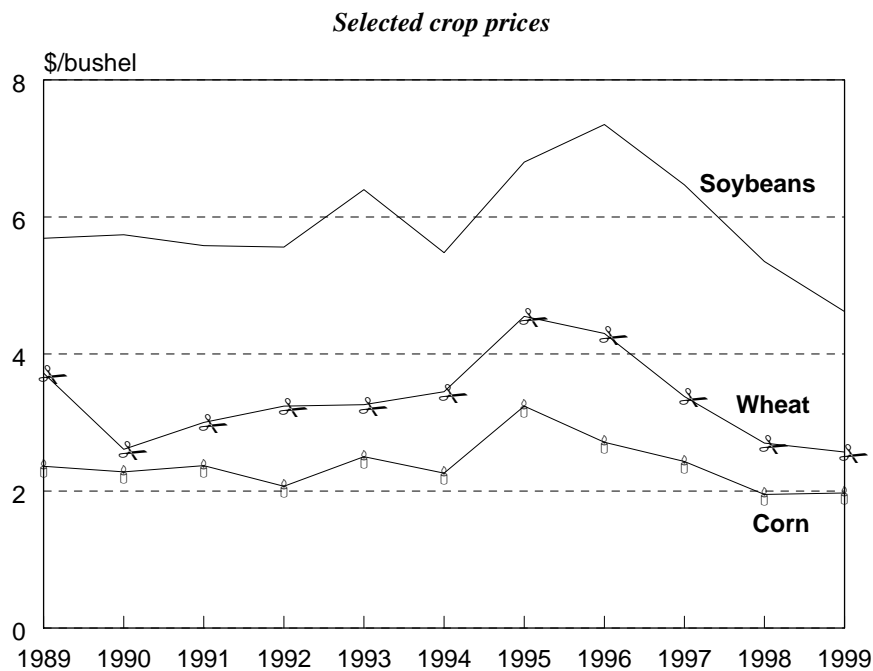
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MANAGEMENT SUMMARY

1. A PROFILE OF THE AG INDUSTRY

The state of the agriculture economy

The agriculture community has been turned on its head over the past two years by an economic crisis that has been likened, with a degree of exaggeration, to the Great Depression. A variety of factors, including a struggling Asian economy and large stocks of many commodities, have contributed to the crisis, and some analysts are predicting a continuation of the current situation for the foreseeable future. The graph below tracks the prices of some of the major North American agricultural commodities.



Source: United States Department of Agriculture, ERS

Despite supply gluts in many commodities, USDA has estimated that farm income for 1999 was slightly higher than farm income for 1998. However, USDA notes that higher than average cash receipts for some crops (particularly fruit, nursery and greenhouse products) and increases in government payments through emergency aid offset some of the low grain prices.

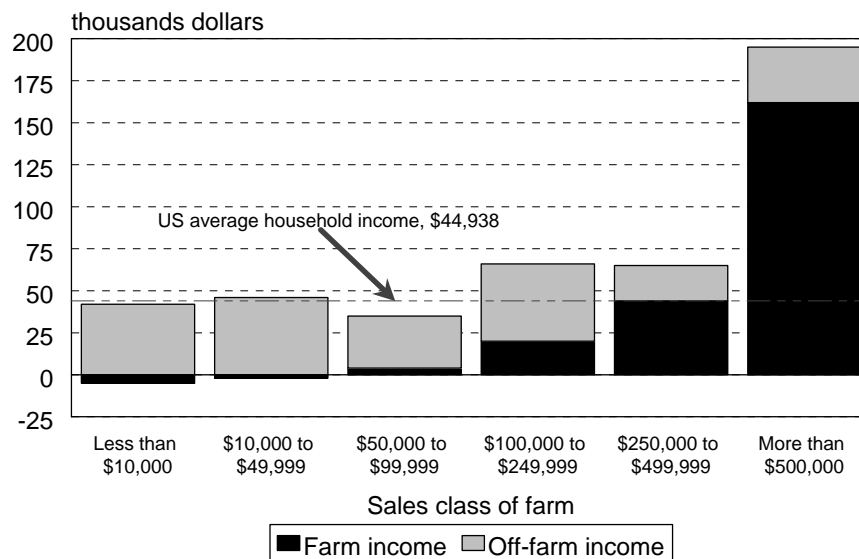
A profile of today's farm and farmer

The face of the farm in America is changing. It is no longer the small, diversified family farm of the 1950's. In recent years, the size of farms has grown, the number of farms has shrunk, and the farms that remain are being run more and more like corporations. The trend has been toward fewer, bigger farms. The trend has leveled off in the past few years, but further consolidation is likely.

The breakdown of farms in the United States and Canada is very similar. The largest number of farms are small farms, but large farms control most of the land. In recent years, the number of farms in the largest sales classes has increased, while the number of mid-sized farmers has decreased. In the United States, the number of small farms has increased just slightly, while in Canada the number of small farms has declined.

The average farm operator household income is on par with that of all households in both Canada and the United States. As the graphic below depicts, however, for smaller farms, most income is from off-farm sources.

Average farm operator household income as compared to average US household income



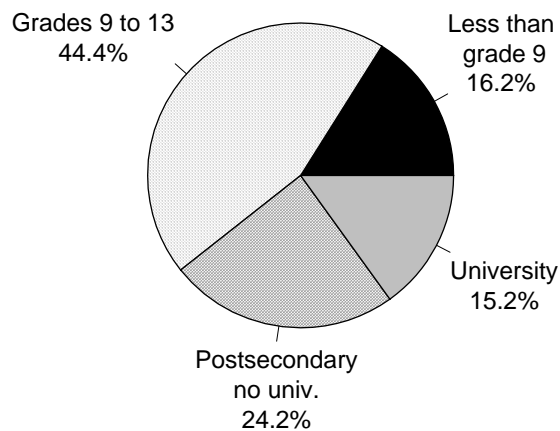
Source: United States Department of Agriculture, ERS

Farmers are a unique demographic group. The average North American farmer is older than the population as a whole. While only about 28 percent of the total American population falls into the Baby Boom Generation (defined as those born between 1946 and 1965), almost 50 percent of farmers fall into this category. In Canada, only 16 percent of the farmers are under the age of 35, with the average farmer age hovering around 48.

While US farmers tend to be older than the rest of the population, they also tend to be less educated. More than 80 percent of Americans have a high school degree, while only about 40 percent of American farmers have a high school degree. Farmers with college degrees are also about half that of the population as a whole.

In Canada, farmers have followed the national averages a little more closely. The graphic below shows the breakdown of Canadian farmers into various education levels.

Education levels of Canadian farmers, 1996



Source: Statistics Canada

Ag input and retailing industries

The use of **pesticides** is mostly dependent upon the number of acres of crops planted in a year, although site and year specific factors such as infestations of pests and the general economic state of the industry can also play a role. Pesticides were originally introduced for commercial agricultural use in the late 1940's and 1950's. However, it wasn't until the 1970's that pesticides

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became widely used on almost all farms. The pesticide business in the United States is worth about \$9.3 billion and about C\$1.4 billion in Canada according to the Crop Protection Institute. Approximately two-thirds of the crop protection markets in the US and Canada represent herbicide sales. Major row crops account for more than 80 percent of herbicide use, about 50 percent of insecticide use but only 13 percent of fungicide use.

The two major influencers on the crop protection markets today are consolidation and biotechnology. The table below outlines the major players in the industry. However, in the past year, Monsanto has been purchased (although the deal is not finalized) by a pharmaceutical company, Novartis and Zeneca have agreed to join forces as Syngenta, and Rhone-Poulenc and AgrEvo have become Aventis.

US agrochemical sales (\$ million)

Company	1997	1998	Percent change
Monsanto	1,214.1	1,381.6	13.8
Novartis	1,231.4	1,205.6	-2.1
Cyanamid	934.0	916.4	-1.9
Zeneca	871.3	889.9	2.1
DuPont	951.1	877.1	-7.8
Dow AgroSciences	747.8	779.4	4.2
Bayer	459.8	476.5	3.6
BASF	545.4	464.7	-14.8
Rhone-Poulenc	451.1	436.6	-3.2
AgrEvo	287.8	300.5	4.4

Source: Agrow

On the biotechnology front, the advent of Roundup Ready crops has turned the traditional herbicide market upside down. Common soybean herbicides such as trifluralin, imazethapyr and pendimethalin have seen their usage rates drop by 20 percent, 63 percent and 33 percent respectively between 1997 and 1998. In that same time, the use of Roundup increased by almost 89 percent.

The **fertilizer** markets in the United States and Canada, like the pesticide markets, depend largely on the acreage of various crops that are planted, and in particular, corn acreage. The Corn Belt region of the United States, including Ohio, Indiana, Illinois, Iowa and Missouri, uses more commercial fertilizer than any other region in North America. This heavy use of commercial

fertilizer is largely due to the fact that corn, one of the major crops in this region, is a primary crop consumer of fertilizer. Almost all acres of corn, potatoes and rice are fertilized, as opposed to only 75 percent of cotton and wheat and about one-third of soybeans.

The **seed** industry, like the crop protection industry, has been turned upside down in recent years by a series of buyouts, mergers and joint ventures. Almost all of the large seed companies are now a part of larger ag input or life science companies. Despite these changes, the general structure of the market has remained the same. The seed industry is dominated by a few major players. Dean Cavey, the president of AgriCapital Corp., has estimated that the top ten North American seed companies control 75 percent of the market, while the remaining 300 seed companies battle for the remaining 25 percent of the industry.

The total value of the US seed market is estimated to be between \$6.5 and \$7 billion by USDA. The Canadian market is much smaller and is estimated to be less than US\$1 billion. Relative to other farm production expenses, seed costs are relatively low, typically consisting of less than 4 percent of total production costs. However, seed costs are increasing faster than many other costs of production due to the use of biotechnology. Genetically modified seeds are typically more expensive than traditional hybrid seeds per unit (bag), and as genetically modified seed use increases, it is only logical that total seed expenditures will also increase.

The approximately \$12 billion **farm equipment** industry in North America is dominated by a few big players. Some of the major players in the industry are listed in the table below, along with estimates of their North American sales from farm machinery. New Holland and Case have announced their intentions to merge.

Company	Farm equipment sales (millions)
Deere & Company	\$5,700
Case Corporation	\$1,820
New Holland	\$1,290
AGCO	\$950

Source: Annual reports and Hoover's Online

The sales trend in this industry in recent years has been negative. Since the record-setting sales years of 1996 and 1997, most companies have seen decreases in sales and have cut back on their manufacturing numbers. The industry's health is heavily reliant on the health of the overall ag industry, which has been on the decline for the last couple of years. Farmers simply resist buying

new equipment in difficult financial times. Due to the predictions regarding the general ag economy, most ag equipment companies are not predicting banner years in 2000 either.

Farmers in the US and Canada spend over \$35 billion per year on fertilizer, crop protection products, seed and fuel. Most of these inputs are purchased through one of a number of types of **ag input retailers**. Ag input retailers can be broken down into four categories. These categories are defined in the box below.

Traits of four types of distribution companies

Farm Cooperatives

- Usually farmer owned, so farmer feels a connection and a sense of trust with the organization.
- Can be a chain of stores throughout a region.
- Usually carry a variety of input types, so are very convenient.
- If they offer their own brands of seeds, chemicals and other inputs, they may not carry any or just a small selection of other brands of inputs, thereby decreasing a farmer's flexibility.
- Can offer services including application of crop protection and fertilizer products, precision agriculture equipment, financing and consulting.
- Can be vertically integrated and offer farmers post-production services such as grain storage.
- Examples include GROWMARK, Farmland Industries, and Southern States.

Retailers

- A chain of stores or a single store that is not farmer owned.
- Carry a variety of inputs and brands, so offer the farmer a high degree of convenience.
- Can offer farmers services including application of crop protection and fertilizer products, precision agriculture equipment, financing, and consulting.
- Examples include United Agri Products (UAP) and Helena Chemical.

Farmer-Dealers

- Utilized almost exclusively by the seed industry.
- Farmers in specific locations serve the farming community in their area.
- Because of community ties, the farmer-dealer can offer customers a trusting relationship.
- Farmer-dealers may not have the intimate knowledge of the product, particularly the new, high tech products, to pass on to the customer.
- A very time intensive and inconvenient process for both the farmer-dealer and the customers, as each brand of seeds has its own farmer-dealer for a particular area. Farmers may have to meet with several farmer-dealers in order to obtain the necessary seeds for planting, and farmer-dealers have to meet with each farmer in their sales area individually.

Specialty Retailers

- Are typically small and local and have only one or two offices. This allows them to know the farmers that they work with relatively intimately and to develop a trusting relationship with them.
- Pesticides and fertilizers are most commonly sold through specialty dealers.
- Often offer application services, thereby increasing the convenience and service to the farmer.
- Because they specialize in a limited range of inputs, they have a great deal of product knowledge to share with the farmer.

In addition to offering a variety of inputs, many retailers today are offering services to farmers that range from custom application of inputs to crop consulting to offering site-specific farming services.

The ag equipment and machinery sectors also sell the majority of their goods through a system of retail stores. These stores are typically affiliated with a particular brand of farm machinery, and often deal in used as well as new equipment. As discussed earlier, sales of farm machinery depend largely on the state of the farm economy. In other words, recent years for farm machinery dealers have been difficult.

2. WHAT PRECISION AGRICULTURE HAS TO OFFER TO FARMERS

Precision agriculture (PA) in its most basic definition is a farm management strategy that matches inputs with the needs of the plants. Using this very simple definition, farmers have been using a version of precision agriculture for decades. Most farmers use some degree of soil testing to decide how much fertilizer to apply, and farmers often turn to seed dealers, consultants and ag input retailers for suggestions about what types of seed grow best in their region.

However, precision agriculture as it is to be discussed in this study goes a step further, using the latest technological breakthroughs to manage the farm not just on a field by field basis, but on an acre by acre basis. While definitions of precision agriculture may vary slightly, they all carry three themes: it is a farm management strategy, it uses the latest technology and it provides data on a scale smaller than the field as a whole.

Today's precision agriculture

Precision agriculture as defined above requires a combination of old techniques and new technologies. Many of the basics of old farm management strategies, such as crop scouting, are still valid in the new world of precision agriculture. The focus of this section, however, is going to be on the new technologies that have become available to farmers. New technologies are being developed continuously, so this list will grow over the coming decade.

GPS is the foundation for many of the other technologies of precision agriculture. GPS is a network of satellites that can help determine precise locations on Earth. The system uses receivers to pick up satellite broadcast signals and calculate a position by triangulation. This data is used in precision agriculture to map things such as yields across a field or soil test results. This system allows farmers to pinpoint differentiation within a field and treat the field based on this information.

Geographic information systems are a combination of computer hardware and software that help in storing, organizing, retrieving, analyzing and producing images of data. Data from other

precision agriculture equipment and techniques such as yield monitors and grid soil sampling can be stored and analyzed in these systems. For instance, a GIS allows a farmer to overlay a yield map and a nitrogen map (from grid soil sampling) to help the farmer determine a relationship between the two.

Grid soil sampling is an updated version of traditional soil sampling, with significant enhancement from GPS. In grid soil sampling, soil samples are collected on the basis of a grid laid out across an entire field, with the exact location of each soil sample being measured and recorded via GPS. The grid units can be 1, 2, 2.5-acre grids, or others as determined by the farmer. The soil samples can then be tested for a variety of traits, including but not limited to nitrogen, phosphorous, potassium and pH levels. The data from such an exercise can then be mapped and paired with other technologies such as variable rate application.

Remote sensing, as the name implies, is sensing and collecting data from a distance. Typically this is a measurement of light reflectance of a field from an airplane or satellite. This data allows farmers to determine patterns of variability of vegetation in a field and crop plant health. Remote sensing images often reveal problems with moisture, nutrients and crop diseases. These images can then be used in combination with other data to determine a treatment for a field.

Variable rate technology is equipment that is used to vary the rate of application of an ag input across a field. Variable rate technology can currently be used for fertilizer, pesticide and seed application. Variation of application is usually determined by grid soil sampling and maps. Today's technology allows variation to be controlled automatically via computer data, instead of on the driver's command.

Yield monitoring is the use of a yield monitor to continuously measure and record yield data during harvest. The yield monitor is most often linked to a GPS unit and thereby associates a yield measurement with a specific location in the field. This data can then be mapped and used to analyze the field's productivity in order to make decisions for inputs for the following year. Reliable yield monitors are currently only available for soybeans, corn, wheat and barley are being developed for sugarbeets and potatoes. Cotton monitors are also available, but reliability has been questionable.

In addition to these new technologies there are a number of programs becoming available that can make input recommendations based on data plugged into the program. Examples would include process models, which simulate crop growth based on agronomic theory, and artificial intelligence systems, which can make recommendations derived from computer based learning.

At this point farmers, crop consultants, farm managers and other traditional members of the “decision team” for ag inputs evaluate the recommendations and decide on a final action.

A complete list of players involved in specific aspects of new precision agriculture technologies is long and diverse. The table below lists some of the major players in each segment, and it is worth noting that the land grant university system is heavily involved in the development of new precision agriculture technologies and techniques. This list is not meant to be comprehensive, but merely to give examples of companies involved in precision agriculture. A more extensive list can be found at www.precisionagriculture.com.

Precision agriculture - industry players

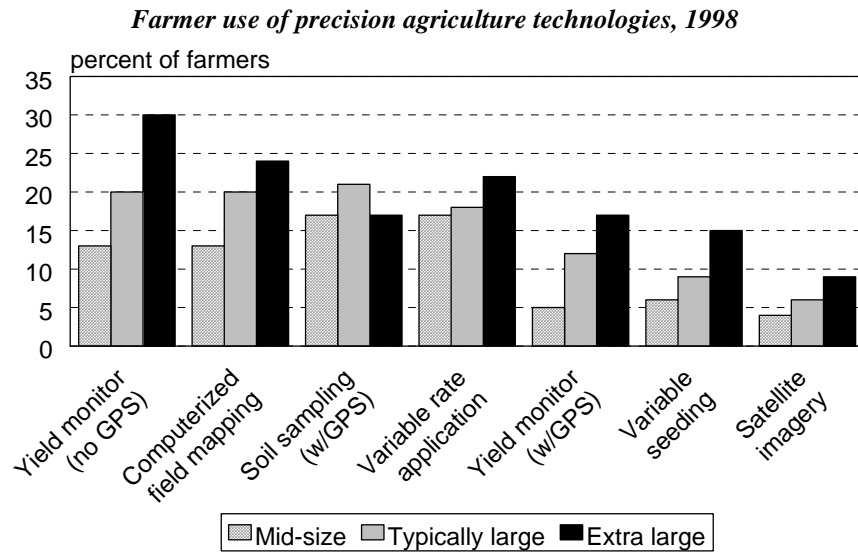
GPS/DGPS receivers	Remote sensing/ spacial imagery	Yield monitors	Computer software
Accutrak Systems Ltd.	Agri ImaGIS	Agtron Enterprises	AGRIS Corporation
Northstar Technologies	MicroImages Inc.	HarvestMaster	Ag-Chem Equipment Co.
Omnistar	Resource 21	Micro-Trak Systems	AgriTrak
Premier GPS Inc.	Spot Image Corp	Midwest Technologies	Cenex/Land O'Lakes
Ag-Chem Equipment Co.	Avcan Technologies	Satloc	ENVI
Magellan	Positive Systems	Spectrum Technologies	FMS/Harvest Computer
NovAtel Communications Position Inc.	Space Imaging		Farm Works Software
Starlink Inc			GIS Solutions
Trimble Navigation Ltd.			mPower3
			RDI Technologies
			SSI

Measuring rates of use of precision agriculture has its difficulties, as it is not uncommon for farmers to adopt one piece of technology and not another. For instance, a farmer may use grid soil sampling and variable rate application of inputs, but may not use a yield monitor. While the effectiveness of such a strategy is debatable, it is nonetheless not unusual to find farmers who have adopted bits and pieces of the precision agriculture family of technologies, but not the whole regimen. Overall, adoption rates have been relatively low. Precision agriculture usage is not

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widespread at this time. However, adoption rates for mid-size to large farms are promising, despite the fact that these groups make up a small percentage of the total farming population.



Source: Purdue University Research Foundation

While larger farmers are more likely to adopt precision agriculture than smaller farmers, soybean and corn farmers are also more likely to be precision agriculture adopters than farmers of other crops.

***Use of precision agriculture technologies by crop
Percent of farmers surveyed***

Technology	Corn/Soybeans	Wheat/Barley	Cotton
Yield monitor (no GPS)	27	18	7
Computerized field mapping	35	11	15
Soil sampling w/GPS	38	8	12
Variable rate application	27	14	10
Yield monitor w/GPS	27	3	6
Variable seeding	9	12	5
Satellite imagery	12	0	6

Source: Purdue University Research Foundation

There are several reasons for relatively low and slow adoption up to this point, particularly amongst certain types of farmers. The first is the cost. The price of a complete precision agriculture program is high. The table below outlines prices for popular precision agriculture equipment and services, as estimated by USDA.

The price of precision

Item	Cost range (per acre)
Grid soil sampling (plow depth, 3-acre grid)	\$3-7
Grid soil sampling (4-foot depth, 3-acre grid)	\$16-22
Yield monitor	\$1.45-1.66
GPS receiver	\$0.75-1.45
Scouting package, weekly	\$4
VRT controllers, various applicators	\$1-5
Variable rate fertilizer application	\$3-7

Source: USDA, "Green Technologies for a More Sustainable Agriculture"

Note: For equipment, these figures assume 3-year life for usefulness, 6 percent interest rate, 3 percent repair cost, and 1000 acres.

Another reason that many farmers may be slow to adopt precision agriculture is that the equipment often requires a great deal of training to use efficiently. In addition to the opportunity costs associated with the time a farmer would have to spend learning to use the equipment, there is also a monetary cost for installation and training. The high-tech nature of precision agriculture is another possible explanation of relatively low adoption rates. As discussed in Section 1, more

than 45 percent of US farmers are over the age of 50, making them “adult-learners” of computer skills. Finally, reliable precision agriculture equipment is not available for many crops.

Despite the direct costs and time necessary for precision management, many farmers have chosen to adopt the new technology. Those farmers that are adopting the technology say they do so because they believe that the use of precision agriculture techniques will improve their profits. The University of Illinois Extension’s 1998 survey found that 40 percent of Illinois farmers “strongly agreed” that GPS technology would increase profits through the more efficient use of ag inputs. Almost all farmers (96 percent) at least agreed with this statement. More than 85 percent of these farmers also agreed or strongly agreed that precision technology would increase profits through increased yields.

A review of the evidence

The jury is still out on when and where precision agriculture techniques can have a positive impact on a farmer’s bottom line. Numerous agronomic, environmental and economic studies have been done to try to determine the precise benefits of various precision agriculture technologies, but results have varied significantly. The following table summarizes some of the studies that have been completed on precision agriculture. Note the very mixed economic results, even within individual studies. These mixed results do not mean that there are no decision rules for economically implementing precision agriculture. Mixed results simply mean that the decision to use or not use precision agriculture is less straight-forward and will require more stringent scrutiny on the part of the farmer.

Summary of the review of evidence

Study topic	Authors	Profitable?
N management of irrigated corn in central Kansas	Snyder, Havlin, Kluitener and Schroeder	Mixed
Variable rate lime application in Indiana	Bongiovanni and Lowenberg-DeBoer	Yes
Variable rate nitrogen application in corn	English, Mahajanashetti, and Roberts	Mixed, but mostly positive; also environmental benefits
Patch spraying herbicide in cereal	Heisel, Christensen and Walter	Yes
Variable rate nitrogen application in corn	Mahajanashetti, English and Roberts	Mixed
Variable rate planting in corn	Lowenberg-DeBoer	Mixed
Site specific management of P and K	Lowenberg-DeBoer and Aghib	No, but decreased variability
Variable rate seeding of corn	D.G. Bullock, D.S. Bullock, Nafziger, Doerge, Paszkiewicz, Carter and Peterson	Mixed; always provided some value, but in some cases it was probably not enough to cover extra costs
Variable rate nitrogen and water application in seed potatoes	Watkins, Lu and Huang	Yes for variable rate watering; no for variable rate nitrogen
Variable rate fertilizer Application in sugarbeets	Cattanach, Franzen and Smith	Yes

3. CATALYSTS FOR CHANGE

The changes occurring around precision agriculture and agriculture in general can be grouped into three broad categories. The first set of changes involves the competitive environment of agriculture and includes issues such as farm consolidation, increasing input costs and information management. Technological evolution also is impacting the precision ag market, as new technologies are introduced and the prices of technologies drop. Finally, environmental pressures such as ground water pollution also will have a role in determining the future of precision agriculture.

The increasingly competitive farming environment

Farming is no longer the small, family operation with the purpose of subsistence that it once was. Today, while many farms are still run by families, the size and purpose of the farm has changed. Many factors are changing the face of farming and making it a more competitive business - one in which the benefits of precision agriculture may be needed to survive and prosper. Some of the forces that are changing the competitive environment include farm consolidation and industrialization, rising input costs and a tight farm credit market.

Farm consolidation and industrialization are not new phenomena, but they do offer new opportunities to the precision agriculture sector. Both consolidation and industrialization will create more business-oriented, savvy and presumably financially secure farmers that have the money to spend on technologies that will improve their operational efficiency. Farming is a high risk business in which economies of scale play a fundamental role in the success of a farmer. Many farm expenses, such as equipment, are set expenses that are not solely based on the number of acres farmed.

Economies of scale in agriculture

Gross sales of farm	Ratio of net income to gross income	Percent of all farms*
\$50,000 - \$99,999	17	7.1
\$100,000 - \$249,999	21	9.4
Over \$250,000	22	7.6

*Numbers are approximate based on 1998 USDA data. The remaining 75.9 percent of farms have sales less than \$50,000.

Source: USDA, ERS

The increasing number of farms in higher sales classes in and of itself is likely to increase the potential market for precision agriculture equipment and services. As noted earlier, adoption rates of precision agriculture management techniques increases with increasing farm size.

In addition to consolidation, industrialization is a major trend identified by USDA and other researchers. That is, drastic and relatively rapid changes have occurred in the ways that farmers produce and market their goods, and farms are generally starting to act more like businesses in the sense that they are trying very hard to be as efficient as possible and to manage risk. Contracting is one way in which farmers have attempted to industrialize.

Contracting can speak to the future of precision agriculture in two ways. First, it shows a willingness of some farmers to become better businessmen through improved efficiency and risk management. Precision agriculture, like contracting, can be used by farmers to make their operations more efficient.

Precision agriculture also has value within the realm of contracting. A lot of crops that are grown under contract are high-value or specialty crops that fetch a premium price. The reason that many companies contract the production of these crops out to farmers is that they want to ensure a quality, consistent supply of the raw materials that they need to make a product. The better or more precise the management of a specialty crop, the more likely it is that the farmer will be able to produce a quality, consistent supply. In other words, precision agriculture can help farmers sell themselves to food companies as top crop managers and better candidates for contracts than other farmers.

Precision agriculture also offers farmers the potential to control costs or at least get more bang for each buck of their input costs by ensuring that each of these inputs is used efficiently. A good example of a way in which precision agriculture can help reduce costs and increase margins is through the use of variable rate seeding. Genetically modified seeds have been adopted by farmers at a phenomenal rate. In 1999, about two-thirds of the soybean acreage in the United States was planted with genetically modified seeds. While seed companies tout the advantages of this new technology, there is one clear drawback: the seed is more expensive. Monsanto charges a technology fee for Roundup Ready soybeans of about \$6.50 per 50-pound bag. When prices are low, these cost increases can be tough for farmers to swallow, even with the possibility of herbicide cost savings due to the use of Roundup Ready seeds. Variable rate seeding adjusts the rate of seeding so that valuable seed is not wasted on land that will not be very productive no matter what the seeding rate.

If the value of farmers' crops continues to be low, and companies can sell farmers on the cost-savings benefits of precision agriculture in areas where input costs are increasing or make up a significant portion of total input costs, then the market for precision agriculture will boom. Of course, with the current ag economy, the key to selling precision agriculture will be proving its ability to save farmers money in other areas.

In today's highly competitive farm environment, precision agriculture and the data that it provides can offer farmers multiple "fringe benefits." In addition to helping farmers produce crops more efficiently, and possibly more environmentally, precision agriculture may help a farmer prove land values, an insurance claim or obtain credit.

In terms of farm land value, precision agriculture data such as fertility maps and yield maps can help a farmer assess the value of land. This can help the farmer in two ways. First, it can help a farmer sell land at a premium if he or she has data to back up a claim that the land is worth a premium because of its productivity. On the other side, precision ag data can help a farmer decide whether or not a farm that he or she is considering purchasing is worth the asking price.

"Bankers all across the state are telling me they will be using the guarantee program more aggressively in the coming year than they have in the past. What I gather from many of them is a level of nervousness that has not been seen for some time. Our own loan officers have told me that they don't know what kind of rabbit they will pull out of the hat for the coming year to patch our customers' operations back together for yet another year."

-Scott Stofferahn, FSA executive director for North Dakota in the October 1999 Fedgazette

Also, in times of depressed agricultural prices, like the present, it can be difficult for cash-strapped farmers to obtain credit, or to obtain the amount of credit that they want. Precision agriculture data can help farmers obtain financing by offering data and near proof of the value and necessity of some types of inputs.

New technological developments

Technological advancements are making precision agriculture equipment easier to use, more useful in its applications, and cheaper. In addition to advancements in technology, farmers are constantly improving their knowledge of computers and high tech ag gadgets, making the equipment more appealing to a larger portion of the farming community.

The past several years have seen a significant decline in the price of basic precision agriculture equipment, such as GPS units and yield monitors. Farmers are also being drawn to the

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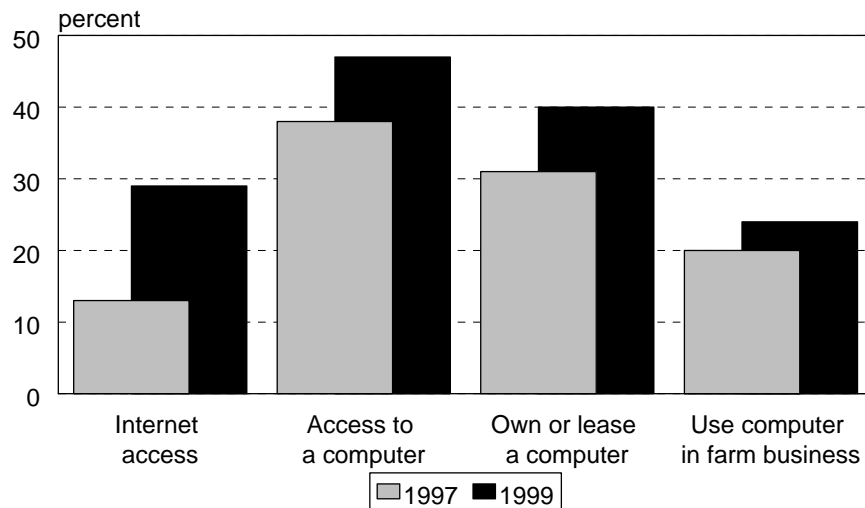
technology by the fact that many of the kinks are out of the equipment. In addition to better, cheaper traditional precision agriculture tools, new tools constantly are being developed and commercialized for the average farmer. The table below outlines some of the new and/or improved technologies being developed for use by farmers. Note that not all developments are covered in this table, but the table is rather a sampling of some innovations. Also, many of the advances listed below are not yet commercially available.

Technological advancements in precision agriculture

What it is	What it can do
Tomato yield monitor	Measure and map tomato yields.
Peanut yield monitor	Measure and map peanut yields.
Sugarbeet/potato yield monitor	More accurately measure and map sugarbeet and potato yields.
“Smart” tractor sprayer	Applies fertilizer and herbicide only as needed by “seeing” weeds and sensing fertility on the go.
Organic matter sensor	Attaches to a planter or fertilizer truck to measure organic matter.
Soil electrical conductivity instrument	Various applications including measuring topsoil depth.
Sugar content reader	Measures sugar content of beets on the go.
Precision guidance of ag implements	Guides ag equipment to ensure precise application of inputs without human error.
Parallel swathing	Use of GPS to guide equipment drivers to prevent skipping or overlapping applications. It replaces foam markers and allows the driver to go faster.
New satellites (potential for 50 new satellites before 2007)	Increase temporal resolution. New data will be available every 2,3 or 5 days versus every 2-6 or 16 days. This can help measure yield potential in fields.
Precision beet planter	Drops beets from a shorter distance off the ground (a few inches versus up to 2 feet), decreasing spatial variability of plants.
Remote sensors	Can help determine such factors as soil texture, pH levels and soil moisture.
X-rays in harvesters	Help determine grain flow rates for better, more accurate yield data.
Improved spectral resolution	Can determine finer differences in colors in fields.
Improved spatial resolution	Will allow satellites to go from 40 measurements per acre to 4046 measurements per acre.

While the technologies used in farming are continuously being improved, so is the knowledge base farmers rely on. As discussed in Section 2, many farmers are adult-learners of computer skills and can often shy away from using high tech gadgets in day to day operations. However, USDA has been tracking computer use on farms for several years, and the data are promising.

Farmer use of computers in the United States



Source: USDA, NASS

Computer usage by percent of farms

Sales class	Internet access	Access to computer	Own or lease a computer	Use computer in farm business
\$1,000-\$9,999	25	42	34	14
\$10,000-\$99,999	27	46	38	26
\$100,000 & over	43	68	62	53

Source: USDA, NASS

Canada has seen similar growth in computer usage by farmers. Statistics Canada found that 21 percent of farmers not only have computers, but use them for farm management. The growth rate has been phenomenal, with the percentage of farmers using computers on the farm more than doubling between 1991 and 1996.

Environmental pressures

In addition to improved efficiency and the lure of larger profit margins, precision agriculture has promised farmers, regulators and the public alike a way of minimizing any adverse environmental impact of agriculture. Considering the recent attention given to environmental issues and the likelihood that this attention will continue or grow, precision agriculture may play an important role in protecting the image of agriculture as well as the environment.

The turn toward environmental sensitivity in the agricultural ring can be seen in the implementation of the Food Quality Protection Act, which was passed in August of 1996. The zealotness with which the Act has been enacted is evidence of the growing environmental concern that is pushing North American agriculture to not only act with environmental responsibility, but to prove that it is acting with environmental responsibility. In addition to these regulations and programs, concern over drinking water safety also has led to the development of standards for the management of ag input application. Contamination of the ground and surface water is one of the most sensitive of agro-environmental problems. Water has long been the concern of the government, environmentalists and the average citizen alike. This concern has led to a variety of legislation, including the Clean Water Act and Safe Drinking Water Act and government programs such as the Conservation and Wetland Reserve Programs.

Additionally, the National Resource Conservation Service (NRCS) division of the USDA is in the process of developing nutrient management standards to address current water problems. The goals of the standards will be to eliminate the overuse of fertilizers on soil which can eventually lead to the contamination of nearby water sources as well as other health hazards. Training on these nutrient standards and measurements will be included in future crop consulting training, and the proposed standards will require that records be kept either by the administrator of the tests or the grower. Results will have to be produced upon demand.

Much of the regulation of ag inputs in Canada is mandated by the individual provinces and not by the national government. Each of the provinces in Canada, however, has standards in place that are similar to those in the United States. The Canadian version of nutrient management planning includes three consecutive annual soil tests to determine phosphorous and potassium levels, and requires records of the tests to be kept on file for at least six years. The farmers are responsible ultimately for implementing their own plan, and are therefore given a considerable amount of input into the development of the nutrient management plan. Some software programs and information packages are made available to farmers from the government to help them develop their plan.

Precision agriculture offers a multitude of ways for farmers to be environmental stewards and to battle mounting fears of agriculture pillaging the environment. First, precision agriculture techniques may provide farmers with a way to cut input application while maintaining or improving output. Also, by potentially cutting usage and closely monitoring what inputs are being applied, farmers can reduce the risk of tolerance of pests to common pesticides. Precision agriculture also can help farmers predict and prevent damage to lands that may be sensitive to runoff or leaching. Finally, precision agriculture will help defend against accusations of environmental aloofness by providing scientifically sound evidence to support management decisions.

4. A VISION OF AGRICULTURE IN THE FUTURE

This section synthesizes all of the information about farmers, the ag economy and the uses for precision agriculture from the past three sections to create a vision of farmers and precision agriculture for the future. It categorizes farmers into various player types and prioritizes these player types into potential precision agriculture targets for the future.

Farmer player types

It is clear from the information in this study that farmers are a diverse group of people with very different needs, beliefs, and motivations. However, properly segmenting the farmer population can allow ag input companies and retailers to prioritize and focus the role that they choose to play in precision agriculture and the approach that they take toward their farmer customers. The following chart summarizes our categorization of player types.

Distinguishing features of farmer player types

Corporate farmers

- Not meant to be a legal definition
- Annual gross sales over \$250,000
- Over the age of 50, unless inherited a large amount of land at an early age
- Some full- and part-time staff to help with farm work
- Uses computers in farm management
- Already utilizes precision agriculture in his operation, and is open to new uses
- Is continuously updating and upgrading equipment

Young farmer

- Under the age of 35
- Is relatively well-educated and probably has a college degree
- Has a small operation averaging about \$100,000 per year in sales, but is trying to grow
- Very comfortable with technology and computers and uses computer on the farm
- Already uses some precision agriculture and would like to use more
- Credit and net worth are holding him back from expanding his operation

Part-time or hobby farmer

- Over the age of 35 years
- Has an off-farm job that accounts for most of his household income
- Under \$100,000 per year in gross sales
- Has a computer and may use the computer for farm management purposes
- Because of his off-farm responsibilities, time and convenience are valuable
- Off-farm income allows him the funds to purchase some precision agriculture equipment, but the time needed for training and data analysis is a hindrance

Retiree

- Over the age of 65 years
- Small farm, although at one time, he may have farmed more land
- Does not use a computer at all
- Does not invest in much new equipment or new technologies

Mid-sized struggler

- Annual gross sales between \$100,000 and \$250,000
- Over the age of 35
- No off-farm job himself, but his wife works off-farm
- Has some part-time help for the farm work
- Has a home computer for his children's use that he is beginning to use on the farm
- Uses some precision agriculture technology, and would like to use more if finances permit

Subsistence farmer

- Annual gross sales less than \$100,000, and probably closer to \$50,000
- No college education and no computer or computer skills
- Few prospects for off-farm employment
- Seldom upgrades or updates equipment or farm technologies
- Does not use precision agriculture because of financial constraints

Farmers are a diverse group, and some farmers will not fit clearly into one farmer type category or another. Some farmers will have characteristics that span more than one category. However, most farmers can be described by one of these categories, and categorization of these customers can help companies identify potential customers and to direct programs and advertisements toward these customers. It can also help companies determine the needs of their customer base and develop programs to meet these needs.

Also, over time, farmers may evolve from one player type into another. For instance, today's young farmer may be tomorrow's hobby farmer or mid-sized struggler. Given enough time or a large inheritance at an early age, today's young farmer may even be tomorrow's corporate farmer. However, as time passes and farmers evolve, so too will their propensity to use precision agriculture technologies. In other words, the definitions of player types will change over time, and one farmer will be a member of a variety of different types at different points during his career.

The market tomorrow

Based on what is known about farmers from various surveys and anecdotal evidence from precision agriculture companies, ag input retailers and farmers themselves, it becomes clear that certain traits in farmers can help predict precision agriculture adoption rates. The first of these predictors is age. The younger the farmer, the more likely he is to be an adopter of precision agriculture. Comfort with technology is one of the biggest factors contributing to this phenomenon, although the desire for a competitive edge in the future also plays a role. An older farmer that is near retirement is less likely to want to invest in technology that is not necessary, but offers the promise of long-term, future benefits. After all, this older farmer may not be in business long enough to fully enjoy the rewards of new technologies.

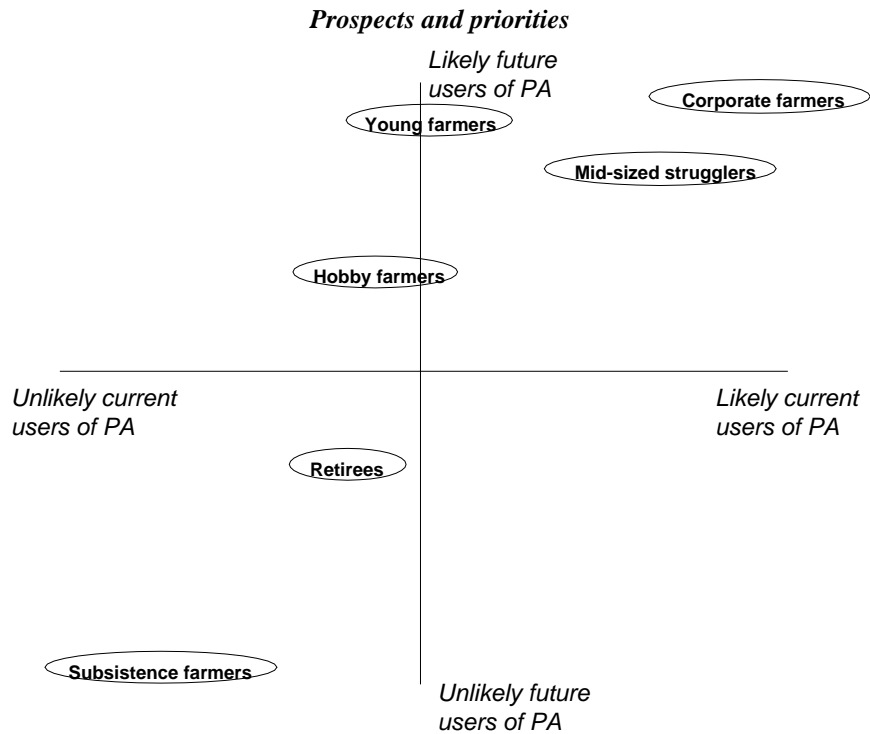
Farm household income can also be used to predict precision agriculture usage. Precision agriculture technology is not required to farm. Therefore, those farmers with higher disposable income are more likely to purchase precision agriculture equipment than those with little extra money to spend.

Of course, the correlation between farm household income and farm size is not a direct one. Farm household income for many smaller farms exceeds the income of many medium-sized farms simply because small farmers are more likely to have off-farm employment to supplement income. On the other hand, larger farms, such as those operated by the mid-sized strugglers, may not have as much disposable income to spend on the latest precision agriculture equipment. So

when translated into precision agriculture adoption, small farmers may have higher adoption rates because off-farm income gives them the disposable income to spend on this equipment. Adoption rates may then dip for mid-sized farmers, as a large percentage of these farmers do not have off-farm jobs and therefore have less household income to spend on precision agriculture. For the largest farms, household income is higher despite the producer not having off-farm employment, so precision agriculture adoption rates rise.

To a certain degree, education also will play a role in precision agriculture adoption rates. For instance, those farmers with at least some college education are more likely to understand the agronomic principles behind precision agriculture and the benefits that precision agriculture has to offer. A higher level of education, particularly in younger farmers, may also give the farmer a level of comfort with technology that less educated farmers may not have. However, this relationship is less likely to be linear than some of the other relationships discussed in this section. Any degree of agronomy or technology training that would occur at the college level is likely to have a significant impact on precision agriculture adoption.

Considering these relationships and the farmer types described earlier in this section, a clear picture begins to develop of what types of farmers have already adopted precision agriculture and which ones are likely to adopt in the future.



In addition to these various farmer types, the types of crops grown and the geographic location of the farm can play a significant role in predicting precision agriculture usage. Certain types of crop farmers are more likely than others to adopt precision agriculture. This phenomenon is

largely due to the equipment which is available to farmers today. For instance, reliable yield monitors are still in development or are very new for crops such as sugarbeets and potatoes. Therefore, farmers of these crops are less likely to be immersed in precision agriculture than corn and soybean farmers, as corn and soybean yield monitors have been available for several years.

Regional discrepancies in adoption rates can be attributed to a variety of factors. First, as discussed above, is the variation in crops grown from region to region. Differences in risk are also a reason for regional variations in adoption of precision agriculture. The productivity of land and the likelihood of weather or other uncontrollable problems will affect how a farmer spends his money. Investing money in new equipment of any sort, let alone the type of equipment that is not an absolute necessity, is a risk for farmers that have less certain farm outcomes from year to year. In other words, while corn and soybean farmers are most likely to purchase precision agriculture equipment, it is corn and soybean farmers in the fertile and more prosperous Midwest that are more likely to adopt precision agriculture than corn and soybean farmers in the South, where yields per acre are lower and more variable.

Scenarios for the future

Considering the make-up of the farmer community today, various scenarios for the future of the precision agriculture market begin to emerge. The scenarios described at the end of this section are based on the farmer types described above and are merely possibilities for the future. The scenarios are meant to stimulate further thinking about potential farmer targets for precision agriculture products and services and what ag input and machinery manufacturers and retailers need to do in order to take advantage of the opportunities presented by precision agriculture in 2010.

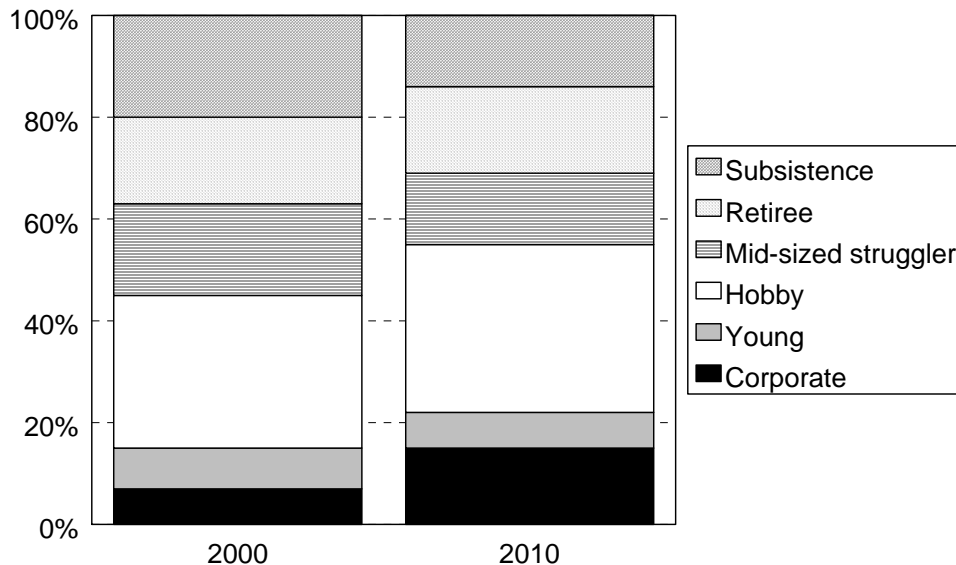
What farmers need from ag input and equipment manufacturers and retailers in terms of precision agriculture will change drastically over the next decade. Some farmers will rely less on their traditional sources of products, services and information and some will rely more, but one thing is certain: **farmers of the future will need someone to handle their precision agriculture service needs, opening a large window of opportunity for all companies that work with and have contact with farmers.**

During the next ten years, farmers may shift between groups. Many of the young farmers will graduate to become hobby farmers, mid-sized strugglers, or eventually even corporate farmers. Most importantly, these shifts will not be even. Certain farmer types will lose numbers or proportional significance, while others will gain.

The general mood of consolidation and the economic strains in the industry will certainly mean fewer farmers in the future. Rules of economics and economies of scale will almost ensure that the corporate farmers will become a larger percentage of all farmers. At the same time, the percentage of subsistence farmers is likely to decline as this group moves to areas with more jobs outside of agriculture. The number of young farmers is also likely to lose ground in the future as the prospects in production agriculture decrease and the appeal of working in other areas of agriculture or other industries all together gains appeal. Those mid-sized strugglers that are not successful in expansion or specialization also are likely to dwindle in numbers as the economics of production agriculture simply make them unable to compete.

While several farmer types will lose ground in the future, others are likely to hold their own. Hobby farmers are still likely to remain a large group of farmers in the future, as farmers from other groups, particularly the mid-sized strugglers and young farmers are unable to sustain their standard of living and move to off-farm work for additional income.

Make-up of farmer population today and in the future



All of this information can be accumulated to determine estimates for the current and future value of the precision agriculture market. We estimate that some form of precision agriculture management is being used on 20 to 40 million acres of farmland in North America today. Using the precision agriculture cost estimates from USDA (see Section 2), we calculate that the current precision agriculture market, including services, is about \$250-500 million in size.

Assuming that technology develops in a way that allows the aforementioned precision agriculture practices to be utilized on a wider variety crops and that the various farmer types shift in the manners described above, **the future potential for the precision agriculture market in the next ten years may be as high as US \$2-3 billion, with 100 to 150 million acres under precision management.** Of course, a variety of factors will play a role in determining the future success of the precision agriculture movement, not the least of which will be technological development and shifts away from farmer types that are unlikely to use precision agriculture. It is possible that it will take more than 10 years for the market to reach this milestone. However, for those who do not think that the market can ever be this large, remember that the seed market has grown in value from a mere US \$750 million in 1965 to over US \$7.5 billion today.

5. STRATEGIES FOR CAPTURING VALUE FROM PRECISION AGRICULTURE

The focus of this section is to outline actionable strategies for the various players in the precision agriculture sector, including ag input manufacturers, ag equipment manufacturers, precision agriculture equipment makers and retailers or dealers.

Keys to success in the precision agriculture arena

While ag input manufacturers, equipment companies and ag input retailers are each going to have their own specific set of strategies to follow, there are a few overarching themes that all current or future players in this market should keep in mind. First, it will be essential to the future success of the precision agriculture market that companies ***communicate the value*** of precision management and of specific precision agriculture tools to farmers. Also, it will be important for companies getting involved in the precision agriculture market to have a ***balance of high-tech knowledge and agricultural knowledge***. ***Choosing a target audience*** will also be critical to a successful precision agriculture program, as certain farmers are simply more likely to adopt precision agriculture management than others. Finally, it will be imperative for any company that desires a future in the high-tech precision agriculture world to have an ***Internet site and strategy***.

First, the definition of value in precision agriculture is all too often limited to cost savings. In other words, value is defined by how much money precision agriculture will save a farmer on fertilizer, seed or other expenditures. However, precision agriculture has so much more to offer. The graphic below lists some of the other benefits to farmers from precision agriculture. Those at the top are the most obvious, attractive and easiest to explain to farmers. However, they are also often the most difficult to prove on a consistent basis.

It is important to note that different farmers will give different weights to each of the values mentioned below. Some farmers may be avid environmentalists, putting the environmental benefits at the top of the list of precision agriculture's values. Farmers in certain regions or involved in certain types of crop production may also have varying interests and opinions on each of the values listed above, and it is very possible that the weight of each of these values could shift over time. Therefore, it is very important for companies with an interest in precision agriculture to constantly monitor these values and adjust advertising and focus to meet the changing wants and needs of farmers.

Value of precision agriculture to the producer

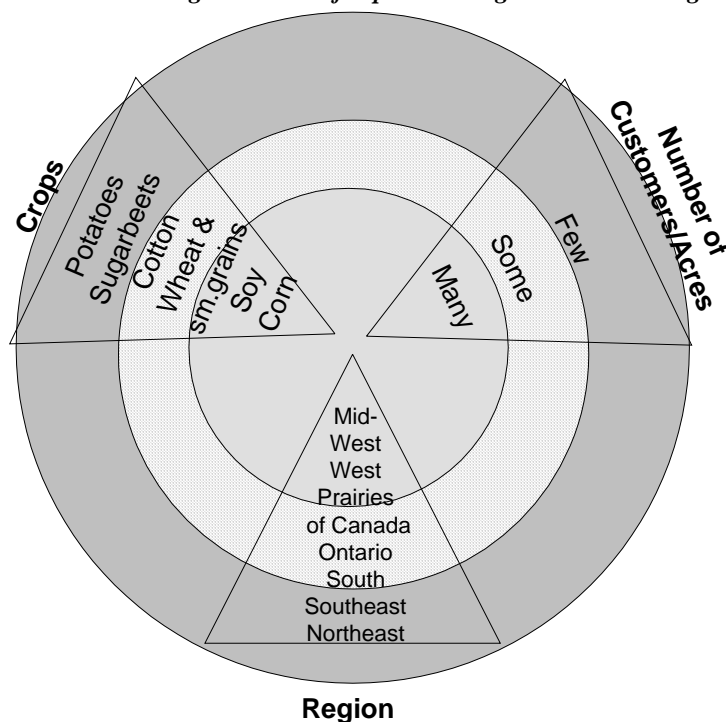


Precision agriculture mixes two very different worlds: agriculture and high technology. Agriculture is traditional and often described as slow to change. It conjures up images of a slower, steadier pace to life and a mature marketplace. Technology, on the other hand, implies constant and rapid change, new business models and a market segment of enormous potential growth.

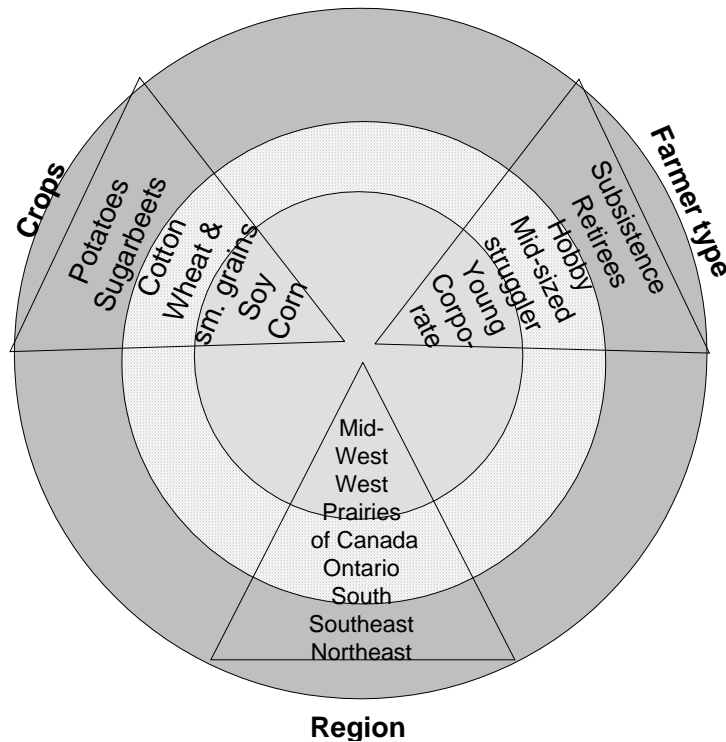
Combining the two effectively can be a challenge. Too much of a technology tilt could alienate farmer customers, while too much of an agricultural tilt could stifle innovation. In other words, agriculture companies getting involved in precision agriculture will have to make a concerted effort to act, at least to some degree, like a technology company that can innovate and adapt to change quickly. Technology companies getting involved in the precision agriculture market will be best served by getting to know more about the farmer customer and the way that the agricultural supply chain works.

Communicating the values of precision agriculture and balancing agriculture with technology can be costly ventures. In order to maximize the potential of precision agriculture programs, companies need to choose a target audience and focus attention on those areas with high potential for precision agriculture use. The graphics below outline both the retailers and farmers that are most likely to purchase and benefit from precision agriculture. Those groups defined in the center circle should be the highest priority to companies looking for precision agriculture opportunities.

Retailer target audience for precision agriculture training



Farmer target audience for precision agriculture



In recent years, the Internet has become a tool for everything from advertising to educating to purchasing. As discussed in Section 2, farmers are also riding the Internet wave, and a growing number of them are using their computers and the Internet for farming purposes. As the number of farmers turning to the Internet for information increases, so too will the potential for business benefits to grow for those companies that utilize the Internet medium to reach farmers. As the transition towards this new technology occurs, those companies that do not develop Internet strategies are going to be at a distinct disadvantage to those companies that use the Internet to forge relationships with farmers, help farmers solve problems, and help farmers communicate with their product and service providers.

Precision agriculture companies

In addition to the four general keys to success discussed earlier in this section, **compatibility, functionality and upgradeability** will be obvious keys to success for these companies in the next ten years. One of the biggest hurdles that the industry has to overcome is the perception by some farmers that precision agriculture is both confusing and risky. While having a good product will be a necessity for precision ag equipment companies in the future, a product will not be a success without a distribution strategy. **Distribution strategy will separate the winners from the losers in the next ten years.** Distribution strategy will be particularly important to smaller precision agriculture equipment companies that do not have a national presence or reputation, let alone a global one.

Distribution options for precision agriculture equipment manufacturers include direct sales to farmers and input retailers, sales through input retailers to farmers, and sales through ag equipment manufacturers to farmers. Some precision agriculture companies are already utilizing all of these distribution channels. It is also likely that some precision agriculture equipment manufacturers will find specific distribution channels more appealing or logical. However, the degree of use of each of the distribution strategies also will change in the future.

Strategies for success

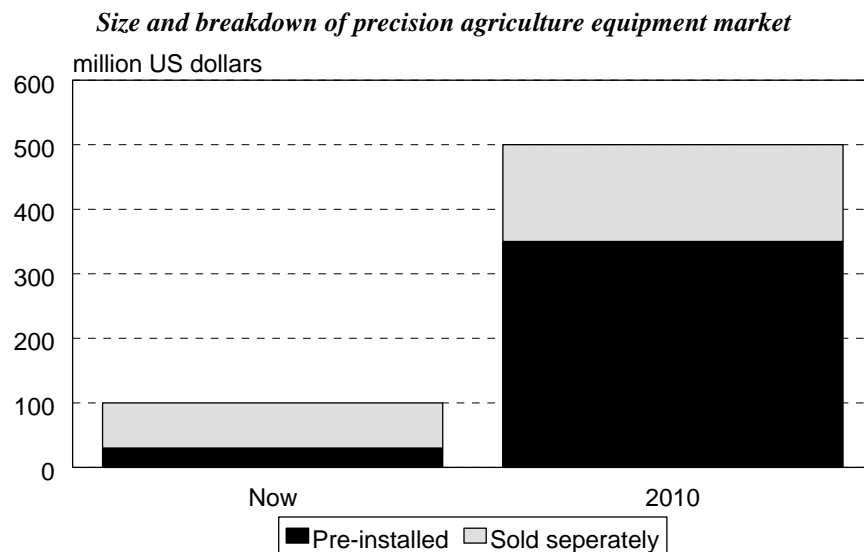
- Provide a quality product that meets the highest standards for compatibility, functionality and upgradeability.
- Be sure that customer service is readily available either from the manufacturer or from a reseller.
- Balance technology with a knowledge of agriculture and farmer. This will be particularly important for this segment of the precision agriculture chain, as this is where product development occurs.
- Communicate the value of precision agriculture in general and of your product specifically to farmers, potential resellers (retailers and ag equipment manufacturers) and farmer influencers such as banks, farm managers and insurance companies.
- Partner with resellers, particularly ag equipment manufacturers and input retailers, that will provide considerable customer exposure.
- Choose your farmer and reseller target audiences for your products wisely. Recognize that products may have to be changed or enhanced in order to cross over to new crops or regions of the country.
- Use the Internet to put farmers in touch with the sellers of your products, whether they are retailers or members of your own sales force. The Internet should also be used as a tool to put customers in touch with customer service, but not as a customer service tool in and of itself.

Ag equipment companies

Precision agriculture offers ag equipment companies a way to differentiate themselves in a way that will add value in the eyes of the farmer. A tractor (or combine) that is already equipped with a yield monitor, GPS unit and in-tractor computer monitor offers several advantages to farmers. First, it will likely reduce the cost of the precision agriculture equipment to buy it as a small “option” on a big-ticket item rather than to buy from another retailer and have to pay for installation. It will also eliminate the cost and hassles of installation. Purchasing major farm equipment with more than one piece of precision agriculture equipment already installed also eliminates the worry of compatibility.

Right now, the major ag input manufacturers are offering some precision agriculture equipment pre-installed in machinery. However, in relation to total sales, precision agriculture is still a minuscule percentage of machinery companies' business. In the future, the importance of this business will grow, but will probably never account for more than a small percentage of the total company sales simply because of the price difference between a piece of heavy ag equipment and piece of precision agriculture equipment.

The graphic below shows both the growth in the overall precision agriculture equipment market as well as how this equipment will be sold. The pre-installed market is the most relevant to ag equipment manufacturers, although, as discussed above, equipment manufacturers may be poised to handle a part of the market for precision agriculture equipment that is sold apart from machinery. Note that the market below does not include any of the services that are associated with precision agriculture.



In sum, the precision agriculture business will always be a very small part of total ag machinery sales. However, in ten years, a large percentage of all of the ag machinery sold will come equipped with precision agriculture tools. In an industry with a shrinking number of customers, precision agriculture will offer ag equipment companies a field of growth for the future.

Strategies for success

- Partner with premier precision agriculture equipment companies to provide a seamlessly integrated, pre-installed precision agriculture package.
- Focus precision agriculture efforts in areas where the company already has a machinery presence. If the company does not have a significant presence in the cotton market, then precision programs should not be tailored for this segment of the production population.
- Sell farmers on the value of precision agriculture in general and on the convenience of purchasing precision agriculture equipment pre-installed.
- Provide or arrange maintenance and repair service for the precision agriculture equipment, and be sure that staff is properly trained to handle this new type of equipment. However, avoid becoming involved in production areas that wander too far from the company's core competencies and are better served by other members of the production chain.
- Use the Internet to let farmers know about the company's precision agriculture program and the pricing of various options.

Ag input manufacturers

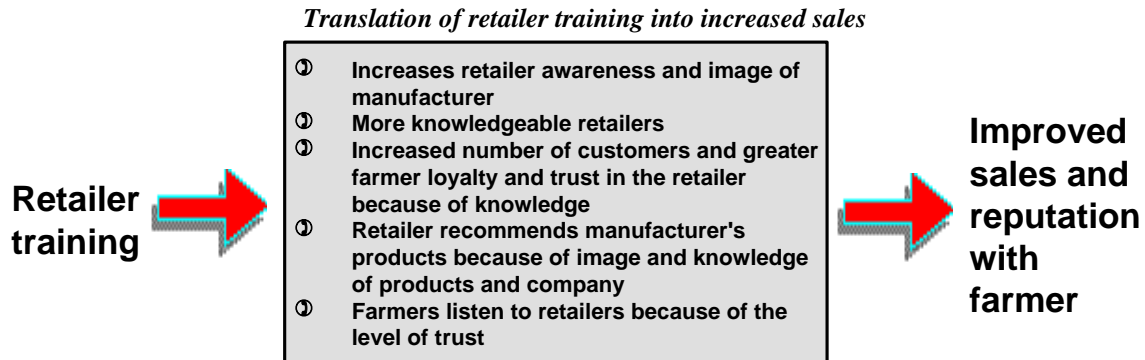
First, it is important to note that not all ag input manufacturers are created equal in the world of precision agriculture. The commodity nature of the fertilizer industry and the recent financial struggles of many fertilizer companies will almost automatically preclude them from participating in the precision agriculture market. Additionally, fertilizer companies have less to gain from relationship building with their farmer customers, as most farmers view fertilizer as more of a commodity than a branded product to which they can have a preference and feeling of loyalty.

On the other hand, ag chemical (pesticide) companies and seed companies have more to gain from the precision agriculture movement. Precision agriculture offers these players a chance to build and strengthen relationships with farmers and retailers. However, even in the pesticide and seed industries where the opportunities in precision agriculture are clear, some small players may simply lack the resources to play any substantial role in the precision agriculture market.

Ag input manufacturers (ag chemical and seed companies for this discussion) essentially have two audiences that must be addressed and considered in strategic decisions regarding precision agriculture: retailers and farmers. Without moving drastically away from their core competencies, most ag input manufacturers will not be able to become major players in the precision agriculture technology industry. The computer technology, electronics technology and heavy customer interaction required of precision agriculture companies simply do not fit with the main business of ag input manufacturers.

However, that is not to say that there is no room for ag input companies in the precision agriculture movement. Quite the contrary. Ag input manufacturers have the necessary resources to use the precision agriculture movement to strengthen their relationships with their current customers and to attract new customers.

Providing knowledge offers an opportunity for ag input companies to play a role on the precision agriculture stage, while providing the company with the benefit of better customer relations without overzealously committing resources to peripheral business objectives. Providing knowledge to both retailers and indirectly and directly to farmers offers ag input companies a way to familiarize customers with products, improve corporate image and improve customer service.



The temptation certainly exists for ag input companies to become more involved in precision agriculture through product development. However, investing resources in developing ever-changing precision agriculture technology is risky and unlikely to benefit the core business. Resources will have to be diverted for such a scheme and profit is far from guaranteed.

Having said that, the precision agriculture opportunities for ag input manufacturers may seem limited. However, considering the small investment required to educate and train retailer and farmer customers on precision agriculture principles, techniques and benefits, the potential rewards through relationship building and optimizing input usage far outweigh any costs.

Strategies for success

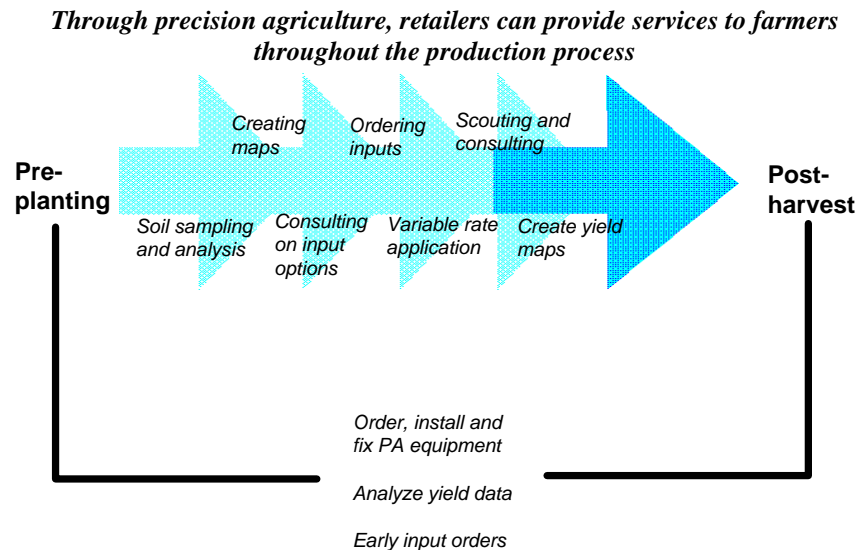
- Educate and train retailers, in particular, and also farmers about precision agriculture and agronomic practices. The major opportunity for ag input manufacturers is in utilizing the complexity of the precision agriculture market and farming today in general to build better relationships with their customers (both farmers and ag input retailers).
- Design seminars, websites, magazines and newsletters and hotlines to help educate customers and forge better relationships. These tools can be used alone or in combination with one another, but the best choice will vary from company to company depending on resources, staff expertise and a variety of other factors.
- Help retailers communicate precision agriculture's value to farmers by sponsoring studies and providing educational tools.
- Work specifically with retailers in regions that are suited to your product line.
- Utilize your company's natural balance between technology and ag production market knowledge as an objective voice on precision agriculture.
- Encourage the use of precision agriculture through studies that identify profitable uses of precision agriculture technology and that also maximize the potential of your products by using them in the most efficient and effective manner possible.
- Do not become wooed by the prospects of precision agriculture and become overly involved in non-core business areas that will add little value to the core business and will be a drain on resources.

Ag input retailers

Ag input retailers today are some of the most trusted and involved partners in a farmer's operation, particularly in the precision agriculture-intensive Midwest. Of course, a farmer's dependence on an ag input retailer varies depending on the region, crop, and resources available to the farmer, amongst others. The unique relationship between farmer and retailer gives the retailer opportunities in precision agriculture such as providing precision agriculture services and data warehousing.

In the future, it is services, both precision agriculture related and not, that will differentiate retailers from one another. All retailers can sell the same set of products, but it is the service component that will make one retailer better or more competitive than another. In terms of precision agriculture, there is an opportunity for retailers to be involved in the farmer's precision agriculture program from soil sampling and analysis to field scouting to consulting to variable rate application. If a retailer does not have the resources to actually provide a consultant or soil sample analysis on-site, partnering with another local business will serve the same purpose, which

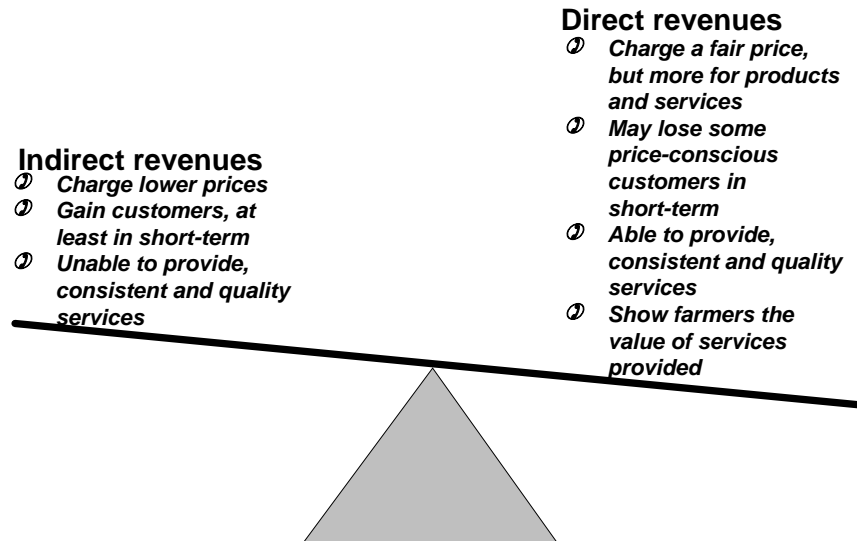
is to provide a complete service package to area farmers. The graphic below outlines some of the ways in which retailers can help farmers implement a precision agriculture strategy, although different farmers will have different service needs.



The most difficult part of the precision agriculture movement for retailers is going to be convincing the farmer of the value of the services provided. As discussed before, the value of precision agriculture has not been clearly and consistently detailed for farmers by anyone in the industry. With tight competition and low margins in the largest sector of the retailing industry, it will be essential to success to inform farmers of the value of the services provided.

Essentially, retailers have two choices in terms of a precision agriculture business strategy. They can pursue a direct revenue approach where they charge more (but a fair price) for their services, with the realization that they will probably lose some of their most price-conscious customers. The other strategy is to hope for more indirect revenues by gaining more customers, at least in the short term, by charging lower prices.

Weighing the value of indirect vs. direct revenues



As service-intensive precision agriculture becomes more prevalent and the farmer turns toward the retailer for these services, it is going to be essential that retailers convince the farmer of the value of the services that the company provides. Because many retailers have routinely given away services in the past, convincing farmers of the value of these services will be even more difficult. No doubt, the current ag economy will further complicate matters, but in the long-term, it will simply be the only way for a retailer to ensure that he will recoup the costs of expensive precision agriculture equipment and better-trained and more knowledgeable staff.

As retailers begin to play bigger roles in precision agriculture, the amount of data that they view and are to some degree responsible for will increase significantly. The handling of such data and information will undoubtedly be an issue for the future. There is really no way for most farmers to avoid giving retailers access to sensitive information about their operations. In order for retailers to provide services such as variable rate application and consulting, they are going to have to have a basis of knowledge on which to make suggestions and provide services.

Certainly, there is benefit to be gained from farmers sharing data and experiences with one another. Considering the value of such data to such things as the determination of land values, it is easy to understand why farmers may be squeamish about who knows what regarding their operation. Arguably, by stripping down the data too much to protect anonymity, the benefits of the data may be lost. At the same time, giving away details about a farm that make the farm identifiable may be the only way that a real lesson can be learned from the experiences of that farm.

Ultimately it is the opinion and attitudes of the farmers that will determine the viability of data warehousing for profit, and retailers must be prepared to handle changing farmer needs and wants. However, retailers are in a position to learn valuable lessons from the aggregate data of their farmer customers. Even more importantly, retailers are in a position to help farmers take advantage of the insights of aggregate data through recommendations without the farmer ever actually seeing the data. No other member of the crop production family has this advantage.

Strategies for success

- Provide precision agriculture services to farmers throughout the production process. If the company cannot provide the actual service, then partner with another company or laboratory that can offer services.
- Train staff to handle production problems in a precision agriculture environment. This process is not a one-time shot, but rather an ongoing process due to the ever-changing nature of the precision agriculture industry.
- Charge farmers for precision agriculture services. This will require a clear and concise message about the value of precision agriculture in general and the company's services specifically.
- Use the aggregate data of your farmer customers to provide better services and more knowledge to your customers. This can be done discreetly in a way that does not allow farmers access to data on other farmers' operations, which will prevent controversy and debate over data ownership.
- If the company's business is already focused on regions and crops that are precision-agriculture intensive, then target communications toward the farmer types that are most likely to be precision agriculture adopters.
- Give farmer customers the opportunity to communicate with the company via e-mail and the Internet.